TOWARDS A CONSTRUCTIVIST MODEL FOR

SCIENCE TEACHER EDUCATION

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SUMMARY

The study reported in this thesis is of an attempt to get some insight into two under-explored areas - the practice of a constructivist approach in science teacher education and in the teaching of science.

An overview of the Portuguese Educational System is presented with the purpose of identifying the context within which this study was conducted.

A preliminary study aimed at investigating reasons accounting for pupils' attitudes towards "physics" and "physics teaching and learning" is reported. From it, evidence is obtained supporting the view that a "cultural transmission" perspective underlies current physics teaching.

A constructivist approach to physics education is proposed as a fruitful alternative to the prevalent practice. It is argued that the approach is compatible with current philosophies of science as those of Popper, Kuhn, Lakatos and Feyerabend.

Aims for physics teaching in general education were derived within the psychological perspective of George Kelly and his constructivist view of knowledge.

Rogers' developmental model of the adoption process of an innovation was used as a framework for designing a scheme to promote change in student teacher's perspectives in the direction of constructivism and for developing teaching skills appropriate for teaching within this latter perspective.

The choice of a research methodology compatible with the assumptions underlying this study was justified by analysing the two main methodological approaches used in educational research.

The main study reported in the thesis was aimed at investigating the applicability and effectiveness of the scheme designed within three contexts: i) the course of "Physics Didactics" given by the author to thirteen student teachers in two consecutive years at the university of Aveiro (Part A); ii) the year of teaching practice of five of these student teachers (Part B); iii) the first year of professional life of three of the student teachers, (Part C).

In Part A of the main study an investigation is reported into the implementation of the four stages (awareness, interest, trial and evaluation) of the adoption process of the innovation with thirteen student teachers.
In Part B, five case studies are presented based on the implementation of the adoption stage by student teachers in their teaching practice.

The implementation of the adoption stage in the first year of professional life of three of the student teachers is presented in Part C of the main study. Despite different institutional contexts during their teaching practice and first year of professional life, the three novice teachers were able to maintain a constructivist perspective in their schools.

Difficulties encountered in the implementation of the scheme in the three contexts are reported as well as some possible ways for overcoming these difficulties.

In the last chapter of the thesis conclusions are drawn concerning the effectiveness of the scheme designed, the research methodology followed and the adoption of a constructivist approach to Science Teacher Education. Recommendations and suggestions for further research are also presented in this last chapter.
To my husband Manuel and
my children

Manuel Maria
Diogo Miguel
Sónia
Pedro Maria
Filipe Nuno
and
Tiago Maria

... they know why!
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CHAPTER 1

AN OVERVIEW OF THE PORTUGUESE EDUCATIONAL SYSTEM

1.1 Introduction

The study reported in this thesis was conducted within the Portuguese Educational context, the focus being on Physics Teacher Education.

Education as a human activity takes place within a societal and cultural setting and it is this setting which determines or at least influences the aims and organization of education in the various societies. As pointed out by Kempa (1983) this in turn will be reflected in the way in which teachers are trained. One consequence of this is that teacher training needs and practices in different countries cannot be meaningfully compared unless clarity is first established about the cultural and educational circumstances prevalent in each country.

The above consideration calls for an overview of the present educational system in Portugal. In section 1.2 a description of the general education system is given with the physics general education being presented in greater detail.

Section 1.3 focuses on current trends in the teacher training system in Portugal. An emphasis is placed on the Physics and Chemistry teacher training degree run at the University of Aveiro where the main part of the study was conducted.

1.2 General Education

With the purpose of getting the reader acquainted with the educational context in which this study was conducted, I shall give an overview in this section of the present educational system in Portugal.

At present the educational system is divided into three stages: basic, secondary and higher education. Figure 1.1, overleaf, shows a schematic view of the Portuguese Educational System. State pre-primary education is almost nonexistent. Basic, compulsory education comprises the primary (first to fourth grade) and preparatory (fifth and sixth grades). Secondary education has two cycles: unified (seventh, eighth and ninth grades) and complementary (tenth, eleventh
Figure 1.1 - Flow Chart of the Portuguese Educational System
and twelfth grades).

All pupils have the same curricula in all subjects until the end of the ninth grade, exception made for a vocational component which is introduced at the last year of the unified stage and which corresponds to 20 per cent of class time. Some vocational options are: practical chemistry, health, sports, practical electricity, economics, art and design. A vocational component also exists during the tenth and eleventh grades at a more intensified and advanced level. In these two grades pupils may choose one from among five broad areas: humanities, visual arts, social economics, natural sciences and technologies. In each area various branches can be chosen. For example in the natural sciences the following branches are possible: farming studies, food industry, fisheries, chemistry, health and sports. In each vocational branch the time devoted to it is approximately 30% of the total time, the remaining being devoted to common studies like Portuguese, foreign languages, philosophy, mathematics, etc. Students can only do physics in the natural sciences and technologies areas.

The twelfth year or twelfth grade, offers two alternatives; one is vocational; the other is preparation for higher education (universities, polytechnics and artistic institutes). At present the vocational alternative is offered only on an experimental basis in very few schools.

In order to get access to the next grade each pupil needs to achieve a certain level of attainment which is assessed throughout the academic year. The assessment in each subject is based on continuous evaluation as well as through performance on some tests designed by the teachers in charge of the different subjects. If a pupil does not achieve the minimum level s/he will repeat the grade. A student in this situation is called 'a repeater' in our system. There is a limit of three years for being a repeater in each grade. All classes are of mixed ability and, due to repeaters, there can be pupils with quite different ages in one class.

At the twelfth grade students have to do only three courses chosen according to their future interests.

Focussing more specifically on what concerns physics education it can be noted that in the curriculum at the primary level very few notions are introduced. They are related to air (its existence), water (physical states of water) and sun (as an energy source).

In the curriculum at the unified level there is a specific course called "Natural Science" whose syllabus contains topics like the corpuscular nature of the matter, changes in body's properties by energy transfer, and machines. These
subjects are given at the fifth grade. In the sixth grade "Natural Science" deals with Earth and Man only. At the first year of the secondary level (7th grade) there is a course also called "Natural Science", the syllabus of which is related to biology. Only at the 8th grade is a combined course of "Physics and Chemistry" introduced. In the 9th grade a second course of "Physics and Chemistry" exists and these two courses provide all the preparation in the two subjects for those pupils who do not follow the areas of natural sciences, technologies or visual arts. Those who follow one of these three areas have, in the 10th and 11th grades, a course of "Physics and Chemistry" in each year.

At the 12th grade the combined course "Physics and Chemistry" is split into two courses: "Physics" and "Chemistry".

The current physics curriculum, published by the Portuguese Ministry of Education is nothing else but a list of topics to be taught with an indication of the approximate number of class periods that are expected to be spent to cover each specific topic of the subject matter. The aims of the physics teaching are not established and there are no guiding principles for physics education.

Each class period in the secondary school in Portugal lasts for 50 minutes. Eight and ninth grades are assigned three physics and chemistry class periods weekly and the 10th and 11th grades four class periods weekly. The number of pupils per class varies between 24 and 34.

Appendix 1 presents the syllabus of the physics component of the combined course of "Physics and Chemistry" for the 8th and 9th grades. These are the grades involved in this study.

1.3 Teacher Education

1.3.1 Trends in Teacher Education in Portugal

The present teacher training system in Portugal is characterized by some diversity, permitting the training of teachers outside universities, as in the case of primary school teachers, as well as within where there is an integrated preparation of academic and professional studies (this applies to the preparatory and secondary school teachers). There is also a scheme through which teachers first obtain a university degree and then acquire a professional certificate through one year of teaching practice in schools controlled by the Ministry of Education (for preparatory and secondary school teachers only).

In 1978 a committee was appointed to study the several existing pat-
terns of teacher education. In their report the committee made an analysis of the situation, discussed the new teachers' profiles and made proposals for the education of pre-primary, basic and secondary school teachers (Gabinete de Estudos e Planeamento, 1978). Inservice education was also considered. In the context of the report basic education includes only six forms; numbers one to six.

According to the report teacher training, as practised at the time, presented some shortcomings. The academic standards of the pre-primary and primary school teachers were not adequate. The training patterns for teachers at the preparatory and secondary school level lacked adequate psychopedagogical and, quite often, academic training and the teachers were usually prepared to teach only one or two subjects. The non-existence of structures to prepare teachers for the vocational subjects, and the rarity of official inservice activities, were also stressed.

The staff situation in the country was also depicted in the report. It was stressed that Portugal lacked pre-primary teachers and institutions where they could be trained. On the other hand there was a surplus of primary school teachers. At the preparatory and secondary school levels the situation was bad as many teachers had not got tenure. To make things worse, teachers with tenure tended to concentrate in urban and suburban areas leaving the other parts of the country in an under-privileged situation. In general teachers showed resistance to curriculum innovations. This was likely to be due to the specialization characteristic of preservice education, the almost non-existence of inservice structures and the lack of extrinsic appraisal and incentive provided either by the school or by the management hierarchy.

Since 1978, the time of the report, to the beginning of the study reported in this thesis, (1983), no significant change took place in the situation.

The same report also enunciates the main principles on which teacher training should be based. It proposes that all teachers should be educated at the same higher education level and, if possible, in connection with other educational courses and centres. Their education should include three components; general, academic and psychopedagogical. The last one should include the practical component, i.e., teaching practice. As a complement to professional education, a one-year induction period should follow. General and academic components should comprise between 60 and 70 per cent of the total education and the professional component 30 to 40 per cent. Teaching and learning activities in the teacher education programs should be related to clearly defined objectives and evaluation should also be in connection with the proposed objectives. Whilst learning, student teachers
should be provided with learning experiences similar to those of their pupils. In this respect, student teachers should give reflective thought to their experiences of both learning and teaching. Teacher training programs should also be flexible in order to give the students the opportunity to redirect their course of study. Preservice and inservice education should be planned in relation to each other.

The report seemed to favour the integrated courses, though the committee made it clear that alternative patterns could also be successfully practised, namely the one in which the professional component comes after an university degree. The ideas presented in the report are already common practice in some countries, namely Canada, England, Sweden and the U.S.A. (Silva et. al., 1981).

1.3.2 The Physics and Chemistry Teacher Training degree run at the University of Aveiro

Until 1970 there was a four years degree in "Physics plus Chemistry" which was the same in all the universities in Portugal. In order to acquire a professional certificate graduates should do some additional courses in the area of psychopedagogy and a two-year induction period, the teaching practice, in schools controlled by the Ministry. Since 1970 the "Physics plus Chemistry" degree split into two independent five years degrees, one in Physics and the other in Chemistry with different curricula in different universities. In both these degrees there is a so called "education branch" corresponding to the last two years and having courses in educational subject matter and teaching practice in the fifth year. The teaching practice consists of each student teacher having full responsibility for a number of school classes under the direction of a secondary school teacher and two or three university teachers.

The University of Aveiro, one of the new universities created in 1973, has provided integrated degrees for preparatory and secondary school teacher preparation since 1975. One of them is the degree for physics and chemistry secondary teacher preparation which has been going since 1976/77. This degree has some general innovative characteristics, relative to other similar Portuguese degrees. It;

i) is a five year university degree,

ii) prepares teachers for the 8th to 12th grades,

iii) integrates the academic component (including education) with the professional component,

iv) is organized in semesters of 15 weeks and in credit units,
vi) includes teaching practice in a nearby school under the co-supervision of university staff and school staff,

vii) involves the relative weights of the different components shown in Figure 1.2, overleaf.

viii) involves a "numerus clausus" of 20 students in recent years,

ix) has produced an output of 4 - 5 graduates per year.

The teaching/learning activities use the facilities of the "academic departments" and those of the "Integrated Centre for Teacher Training" (Silva et al., 1981), a university unit specially equipped for the professional training of future teachers.

During the degree the number of the class-hours per week varies between 22 and 27.

The academic component includes courses on physics such as: "Introduction to Physical Concepts", "Mechanics", "Electromagnetism", "Waves", "Introduction to Modern Physics", "Introduction to Molecular Physics", "Introduction to Statistical Physics", "Circuit Analysis", "Quantum Mechanics", "Atomic and Nuclear Physics" and "History of Physics". The same component also includes courses related to the psychopedagogical area, such as: "Introduction to Education", "Observation and Analysis of the Educational Process", "History of Education", "Contemporary Pedagogical Issues", "Educational Sociology", "School Management and Administration", "General Methods of Education" and "Evaluation".

The professional component includes courses of "Educational Technology", "Physics Didactics", "Chemistry Didactics" in the fourth year and a Seminar (that can be in physics or in chemistry) and teaching practice in the fifth year.

The course of "Physics Didactics" is a methods course whose purpose is mainly to aid the integration of knowledge acquired in the previous courses, and to launch the student teachers into teaching experiences. It focuses on the teaching of physics to secondary school pupils (age range between 14 and 17).

Being a 5th year activity, along with the teaching practice (the main activity of the last year), the "Physics Teaching Seminar" is intended to be connected with the school practice, to reinforce the student teachers' capabilities in making and using simple equipment, and to overcome the traditional deficiency of physics teachers in Portugal regarding those capabilities. The equipment constructed by the future teachers (about 50 units) covers different areas of the physics
Figure 1.2 - Curriculum Plan for the Physics and Chemistry Teacher Education Degree
secondary school syllabus. With very simple materials and unsophisticated tools, the student teachers construct sets of instruments to illustrate the main principles, laws and phenomena of physics, including: i) measurement of basic physical quantities (time, mass, force, torque, electric current, etc.); ii) forces and motion; iii) hydrostatics; iv) heat; v) electric circuits; vi) electric motors; vii) wave motion; viii) optics; ix) electronics, etc. Each student teacher makes her/his own set of equipment which s/he takes away with her/him to use in her/his first years of teaching.

The purpose of the teaching practice are: i) to provide the bridge between theory and practice in real classroom situations with the help of supervisors and peers' feedback; ii) to help student teachers to adapt their perspectives on teaching to real settings; iii) to help student teachers to construct their own instruments of assessment based on their reflections and experiences. This allows for a negotiation of criteria of assessment between student teachers and supervisors; iv) to help student teachers to reflect on their aims in teaching, on the strategies to achieve them and on the applicability of those strategies.

The teaching practice takes place in a secondary school as near as possible to the university. It comprises a one-year block of teaching in which each student teacher has full responsibility for two classes, generally one of the 8th and another of the 9th grade. They are also requested to perform some teaching units at a higher level of schooling (10th or 11th grade). Classes are frequently observed by the supervisors and peers and discussion on the emerging problems takes place immediately after class or/and in sessions arranged for that purpose. The so called "teaching practice nucleus" comprises a maximum of six student teachers and four supervisors (one cooperating school teacher and three university teachers, one from each area, physics, chemistry and education). The nucleus works as a team helping each student teacher in the development of her/his own style of teaching. The supervisors' role is seen as a continuation of instruction rather than as a vehicle for assessment.

1.4 Summary

In this Chapter an overview of the Portuguese Educational System was presented with the purpose of getting the reader acquainted with the educational context in which the study reported in this thesis was conducted.

In section 1.2 a description of the general education was presented, the focus being in the physics general education (8th to 12th grade).
Trends in Teacher Education in Portugal were considered in sub-section 1.3.1. In sub-section 1.2.3 a more detailed description of the Physics and Chemistry Teacher Training degree run at the University of Aveiro was presented as the study was conducted within that context. Emphasis was placed on the professional component relative to physics, which includes part of the 4th and the 5th year.
CHAPTER 2

THE PRELIMINARY STUDY

2.1 Introduction

It is widely recognized that pupils often find physics to be one of the most difficult subjects and do not enjoy it. Evidence of this has been provided by a large amount of research on the matter (e.g. Duckworth and Entwistle, 1974; Forrest, 1971; Forrest and Smith, 1972; Nuttall, 1974; Selmes et al., 1969; Mallick, 1967; Gaskell, 1972; Edwards and Wilson, 1958; Lowery, 1967; Soy, 1967; Pont, 1970; Ahlgren and Walberg, 1973; Stronk 1974; Clish, 1975; Ormerod, 1975a, 1981; Pell, 1977; Harvey and Edwards, 1980; Leader, 1980; Kelly, 1981). Many attempts to explain the situation have been made in various countries. In 1965, a thorough enquiry undertaken in Britain began into the flow of students of science and technology into higher education. The final report (Dainton, 1968) laid particular emphasis on the phenomena which had become known as "the swing from Science". A lessening interest in science and a disaffection with science and technology among students were some of the explanations suggested for that swing (Ormerod and Duckworth, 1975).

The view that physical sciences are suffering a fall in their attraction for pre-university students relative to other subjects has been widely canvassed both in United Kingdom and United States (Philips, 1960; Pont, 1970; Duckworth and Entwistle, 1974). Evidence from research studies indicates that chemistry and physics are among the most difficult of subjects, leading to a lessening interest by young people. Some reasons have been advanced by the different researchers. Ormerod and Duckworth (1975) nested them together in five aspects relating to:

i) the introduction of conceptually difficult matter at too early a stage;

ii) difficulty with mathematics;

iii) difficulty associated with language and vocabulary;

iv) lack of time or overloading of the syllabus;

v) the fact that science education has been shaped by people with an unconscious elitist perspective.
In Portugal there have been no published studies of pupils' attitudes to science and particularly to physics. Nevertheless there is evidence supporting the view that, although there is an increase of interest in the study of biology and chemistry since 1974, the reverse has been happening in physics.

The pupils' image of physics has become that of an uninteresting, useless and dull subject. This evidence comes from different sources. One can consider the comments made by pupils, and the public in general, when, in informal talks, they are asked to give their opinions on the subject of physics. Another arises when the students enter the 12th grade. As already mentioned in Chapter 1, section 1.2, during this year there are only three courses, mathematics being compulsory, for those who choose scientific areas. In the other two, the students may opt between physics, chemistry, geography, descriptive geometry, philosophy, etc.. And it is here that other evidence of pupils' image of physics emerges. The great majority of students 'run away' from physics although some intend study for degrees like "Electronic Engineering", "Physics", "Physics and Chemistry Teacher Training", in which physics is an important component. This phenomenon can be explained by the fact that the admission to universities is conditioned by "numerus clausus" which limits the number of students admitted to each degree, the criterion of admission being the students' marks. Usually the marks in physics are lower than in the other subjects and this can be seen as a reason for the 'running away' from physics. On the other hand, these lower marks in physics, per se, result from students' attitudes toward physics.

Another source of evidence of this attitude comes from the entrance marks in the different degrees at the different universities of the country. To be admitted to universities students apply for a maximum of twelve degrees ordered by their preference. This implies that the courses whose marks are lower are the less attractive to students. As an example, in the academic year 81 - 82 (the year previous to the starting of this study) the degrees with lowest entrance marks were "Physics" and "Physics and Chemistry Teacher Training" degrees in all the universities of the country (Araujo, 1982). A similar situation occurred in subsequent years which is, in my view, an indirect but significant measure of pupils' attitude to physics.

When evidence from pupils shows that they find physics both dull and difficult, one can perceive that there is something wrong somewhere in physics teaching. Suggestions have been made in other countries for improving pupils' image of physics, such as reducing the content, placing more or prior emphasis on qualitative as opposed to mathematical treatments, including more applied physics, etc.. These are sound enough suggestions although some already put into
practice have failed to achieve the aims proposed. For instance, Choppin, (1974) found, from measurements made in 1970, that pupils liked Nuffield O-level physics less than the traditional course.

There is a large body of research showing that the teacher's attitudes to her/his subject matter are strongly communicated to their pupils (e.g. Bixler, 1958; Behnke, 1959; Belt, 1959; Greenblatt, 1962; Taylor, 1965; Schirmer, 1968; Ransay and Howe, 1969; Mitchell, 1972; Yeoh, 1973; Christiansen, 1974; Ormerod, 1975b; Lawrenz, 1975; Keys and Osmerod, 1976; Bottomley, 1979). In the physics teaching and learning process, as well as in other subjects, there is a kind of cycle involving all the individuals in the process. If we do not get teachers interested and aware of the real problems involved in physics teaching, if we do not get teachers with enjoyment in physics and the ability to inspire and stimulate their pupils to enjoy it too, the cycle will never be broken. By "enjoyment" is meant "giving pleasure or keen satisfaction".

It is my assumption that it is at the university (where teachers are prepared) that the cycle should be broken. It is at the university that we need to try out solutions which could contribute for the improvement of physics' image at the secondary school level. And this is fundamental because any shortcoming in physics education at that level will be bound to be reflected and perhaps magnified at later stages.

2.2 The purpose of the preliminary study

I agree with those who share the view that the attitude of pupils towards their subjects of study, their perception of their schools and the teaching they receive in them cannot be ignored in any worthwhile study of reasons why pupils behave as they do. But I also believed that the perceptions, ideas and beliefs of the other elements involved in the process of teaching and learning - the teachers - are also important and cannot be ignored in that study.

Having in mind the above considerations, a preliminary study was designed and conducted by me. The study aimed at identifying some relevant problems related to the physics teaching and learning process in an attempt to generate "working hypotheses" in Geer's sense (1969) upon which to focus the main study, using them as guidelines to observe and act in particular situations in the field, trying to overcome those problems. As Lutz and Ramsey (1974) point out, these working hypotheses are generated partly out of prior knowledge of the system being studied, partly only after some initial observations have been made in the field and partly from conceptual and theoretical positions held by the researcher.
2.3 The research method

The purpose of the preliminary study stated in section 2.3 conveys, per se, my adherence to the naturalistic field study approach what Denzin (1971), refers to as

".. the researcher's studied commitment to actively enter the world of the native people and to render those worlds understandable"

As Spector (1984) stresses, some aspects of this qualitative research have the potential of providing guidance to change-agents in designing effective strategies to bring about desired changes in science education. The method of collecting and simultaneously analysing data to develop "grounded theory", which is central to qualitative research, is described by Glaser and Strauss (1967) and been labeled a 'discursive approach to qualitative research' (Smith, 1982). In this method the data gathered during the study directs the design of each step of the study as it evolves. The categories, themes and subsequent hypotheses that emerge are "grounded" (have their initial foundation) in the data themselves. This process is used for hypothesis generation rather than hypothesis testing.

Taking ethnographic descriptions and intensive interviews as a point of departure I looked for data first and out of data developed working hypotheses to explain the phenomena under investigation. In Chapter 5 a detailed analysis of the two paradigms used in educational research will be presented to support my adherence to the naturalistic or ethnographic field study approach.

Believing that human action and experience are context dependent and can only be understood within a particular context I could not rely on findings obtained in other contexts, in other countries, with other constraints and other cultures.

2.4 Participants

As already stressed in section 2.2, in order to understand the reasons underlying pupils' attitudes towards physics teaching and learning, I found it important to consider the perspectives of the different categories of individuals involved in it. Thus I considered seven categories listed as follows:

1.- pupils (10 - 13 years old) prior to physics teaching;
2.- pupils (14 - 18 years old) being taught physics;
3.- school leavers or students taking humanities degrees;
4.- student teachers (at the university);
5.- experienced teachers (at the secondary schools);
6.- teachers educators (at the university);
7.- physicists (at the university).

The first category of individuals, although not directly involved in the process, was chosen because, indirectly, they were already developing their expectations, their attitudes constructed through experience, contact with others and through informal teaching.

The second category gave the perspectives of the learner. What were their feelings, what were their attitudes, their ideas about physics learning?

The third category was taken into account because of the information that it could provide on what was left from the learning of physics after some years have passed.

The student teachers chosen were students enrolled in "Physics and Chemistry Teacher Training" degrees (at the new universities) or students of the last years of the "Physics" degree (Education Branch, at the classical universities). They were chosen because they could give the learner's perspective as well as the perspective of a person already concerned with teaching problems.

The fifth category gave the perspective of the teacher bound to the real situation of the school and its population.

By teacher educators is meant teachers who are in charge of courses like "Physics Teaching Methods", "Physics Didactics", "Special Didactics", given to student teachers at the different universities involved in teacher training programs.

The last category represents the physicists who are teaching physics at university level to student teachers i.e. future teachers. It was considered that their perspectives on the process could make a good contribution to the detection of some of the problems involved. As Trotter (1980) points out, whatever solutions may be suggested to improve pupils' image of physics they cannot disguise the fact that the most important need is for teachers with enthusiasm for physics and with the ability to communicate that to their pupils. Whether or not we get such teachers depends very much on the way physics is taught at universities. According to Trotter (1980) it is one thing to advocate enjoyment as an important factor in physics teaching at secondary school level but it may be quite another matter at the universities where the teaching has to be geared to getting students up to high standard of professional competence in physics.
The number of individuals interviewed was:

1.- children prior to physics teaching 9;
2.- students under physics teaching 22;
3.- school leavers or students taking humanities degrees 15;
4.- student teachers 22;
5.- secondary school teachers 11;
6.- physics educators 4;
7.- physicists 9;

Interviewees were selected randomly from students and teachers who were available. By this I mean that, for instance, most of the interviewees belonging to categories 1, 2, 3, and 5 were from Aveiro, although there were some from other parts of the country.

Categories 4, 6 and 7 were mostly interviewed in their own universities. I always took care to conduct the interview in a private place, in an informal way and tried to generate a kind of conversation in which the respondent felt at ease.

Without exception, the individuals interviewed were all very collaborative. It was most gratifying to see that, after the end of the interview, when the taperecorder was switched off, people continued to talk and talk. This showed that the kind of problems being tackled concerned all the individuals and how much they enjoyed talking about them.

2.5 The design of the interview schedule

Due to the nature of the investigation I adopted a semi-structured interview schedule that allows people to express themselves at some length but has sufficient structure to prevent aimless rambling. I had a written note of topic questions to be raised during the interview but the order and the precise wording were not pre-determined. The questions were of the open-ended format, designed to allow a free response from the individual. In it a topic is raised but the interviewer does not provide or suggest any structure for the reply to the question. This question format is commonly used when one is particularly interested in peoples' perceptions, beliefs, opinions and motivations and when their own formulation of their replies are important, which was the case in this study.
The topics raised during the interviews were obviously dependent on the category of the interviewees. Thus, for the first category, the questions were: "What do you think physics is about?"; "What do you expect to do in physics?"; "What are your feelings about the idea that you are going to learn physics?". For the second category the questions were: "What do you think physics is about?"; "Before you started learning physics do you remember what did you expect to learn from it?"; "Has it worked out as you expected?"; "What would you like to learn in physics and why?"; "Are you enjoying learning physics?"; "According to you, what would be the best way of learning physics and why?"; "Why do you think physics is in the curriculum of the secondary school level?"; "Is it important? Why?"; "When do you think you should start learning physics?"; "What happens in your physics classes?"; "What do you think about that?"; "Do you normally understand what your teacher is talking about?"; "Do you think that what you are learning in physics has something to do with your everyday life?"; "Do you think the learning of physics is important for our society?".

The same type of questions were raised in the interviews with the 3rd category. With student teachers other questions were added as for instance: "What are your feelings about the idea that you are going to teach physics?".

The questions raised during the interviews with either secondary school teachers, teacher educators or physicists were in some way similar: "What does physics mean to you?"; "What do you expect your students to learn from your courses?"; "What capacities do you think can be developed in your students by the fact of teaching physics to them?"; "What are your feelings about physics?"; "Do you think that what you are teaching in physics has something to do with your students' day-to-day life?"; "Do you think students normally understand what you are talking about?"; "Do you think your course will help student teachers in their careers?"; "Why do you think physics is in the curriculum at the secondary school level?"; "Do you think the way physics has been taught at the university to student teachers is the best way of doing it?"; "Do you think that the teaching and learning of physics is important to our society?".

2.6 Analysis of the protocols

All the tapes were transcribed verbatim in Portuguese and then translated into English. Although sometimes it was not easy to translate the transcripts because there is Portuguese jargon used by the students that is difficult to put into English, I tried to be as accurate as possible and not to distort the information conveyed by the interviewees.
From the first interviews (with children prior to physics teaching) one fact emerged that made me change the type of questions asked them. Generally children at this stage do not have any idea of what physics is about. Although there is, in the curriculum of the primary and preparatory stage, the subject of \"Natural Science\" in which the syllabus contains some basic notions of physics, children see science as dealing with the Earth and living beings only and they try to explain Nature solely in a biological sense.

Some extracts of the interviews conducted with children can illustrate this point.

"I - What do you think science is about?

$S_1$ - ... er ... I think in science we study everything that is .. Earth .. everything that is produced in land .. the human body ... everything .."

(11 years old girl; 6th grade)

"I - (the same question)

$S_2$ - ... Natural Science? .. it studies everything that exists in nature .. men .. animals ...

(10 years old boy; 5th grade)

"I - (the same question)

$S_3$ - ... in sciences? .. the constitution of animals .. the different types of animals .. how they reproduce themselves .. how they are organized .. everything related to nature ..

(12 years old boy; 7th grade)

One of my intentions was to get an idea about what children at this stage would like to learn in physics, what their expectations were about it. But, as generally they do not know what physics is about, they can refer to what they would like to learn in science by relating the question to biology. This can be shown, once more, through the extracts of the interviews:

"I - What else would you like to learn in science?

$S_1$ - ... animals .. how they live .. their names .. everything

(12 years old boy; 7th grade)

"I - (the same question)

$S_2$ - ... to study animals .. er ... to watch through a microscope .. to observe animals and plants .."

(11 years old boy; 6th grade)

These answers reveal that, although there are some physics notions in the syllabus of the primary and preparatory level, the emphasis was put on the biological area
of Science and the physical aspects were not even approached. Only two children mentioned something different:

"S₁ - what I would like to learn in science? .. well ... space ..
I - what kind of things would you like to learn about space?
S₁ - .. uhm .. that .. I don't know (laughs) .. about things related to space ... things we see in TV .. the spaceships .. I would like to know .. what happens in space .."

(10 years old boy; 5th grade)

"S₂ - ...I would like .. to learn something about space .. how it is up there".

(11 years old girl; 6th grade)

Although children at this stage, prior to physics teaching, have no idea of what physics is about and do not generally have any expectations about what they are going to learn in physics, because of their contact with older students or adults, they start to construct an image of physics which reflects the latter's view. Some evidence of this can be seen from some extracts of the interviews.

"I - Have you ever heard about physics?
S₁ - yes .. my parents .. and a physics teacher who lives with us .. sometimes .. she talks about physics..
I - and have you any ideas of physics is about?
S₁ - ... er ..er ... I don't know .. maybe .. pretty much the same as we learn in sciences .. but more sophisticated ..
I - what do you mean by that?
S₁ -..I don't know .. more complicated .. more abstract .."

(12 years old boy; 7th grade)

"I - do you know what physics is about?
S₂ - .. well I have some ideas about it .. because I have a sister older than me .. and .. so I know what she is studying .. specially in physics .. a lot of laws .. she ought to know them .. it is something that she has to cram ... more cramming than understanding ... and I know some names that appear in books ..."

(12 years old girl; 7th grade)

"I - Do you know what physics is about?
S₂ - .. I suppose it is .. a bit complicated .. but .. actually .. I haven't a very real idea .. I mean .. my cousin who is ahead of me .. he is studying more advanced things .. I've got the feeling that what we do in physics is .. more formulas than experiments .. more deductions and things of that kind .."

(11 years old boy; 6th grade)
At the preparatory level, children are taught how to make reports but often the purposes of the experiments are vaguely perceived by pupils and sometimes the conclusions drawn are not correct. Many pupils seem to have no clear ideas about what they are investigating nor any understanding of the real purpose of the investigation. Teachers are very concerned with teaching 'the' rules for making reports. Too much emphasis is placed on 'the scientific method', meaning by that 'the method of writing up science'. Swift (1983) found a similar situation in a study involving English children.

Some extracts from 3 interviews illustrate this situation.

"I - .. look .. do you do experiments in your science classes?

S1 - yes sometimes

I - what kind of experiments?

S1 - experiments .. with tubes .. with fire .. experiments which produce foam .. steam .. we make experiments like these ..

I - and do you understand those experiments?

S1 - ... sometimes I do .. others I don't .. actually .. I find them very complicated (laughs)

I - why very complicated?

S1 - .. because sometimes I don't understand why it doesn't work like I thought and I think that the way I thought should be the right one ... but .... it doesn't work in that way ... (laughs)

(11 years old girl; 6th grade)

"I - what happens in your science classes?

S2 - .. well first we correct our homework .. then we do an exercise from an exercise book we have .. or ... we learned already how to make a report .. and learn new things ..

I - .. yes .. and have you already done some experiments?

S2 - no .. no .. I think .... we did one only ... yes that was just one .."

(10 years old boy; 5th grade)

"I - What happens in your science classes?

S3 - .. well .. what's done well? .. the teacher even teaches well .. there are some pupils who .. sometimes make too much noise .... but .. not all the time .. and we do some experiments.

I - .. do you remember some experiments that you have done this year?

S3 - ...this year ... yes I remember ... how lungs operate.

I - how did you do that experiment?
S₃ - "we had a tube with two branches .. two balloons fastened .. then a bottle without the bottom .. and a toy balloon half cut applied at the bottom of the bottle .. then a cork with two ways out and ..then we pulled out the balloon from the base .. and the balloon shrunk inside ... then we left the balloon and the balloons opened inside ..

I - why did it happen like that?

S₃ - when a person pushed upwards .. as more space was occupied inside the bottles .. the balloons shrunk ..... because ..... because ..... they could shrunk ...

I - and then .. when you pulled it out what happened and why?

S₃ - "... if we pulled it out .... er ... there was a pressure .. I think it is ... there was pressure .. and then the balloons filled themselves .."

(11 years old boy; 6th grade)

Although children prior to physics teaching, normally, do not know what they will learn in physics, their attitudes toward the idea of starting the study of physics is very positive. They approach their first formal physics teaching with high expectations and a great interest to learn new things. They enjoy the idea of starting to learn a new subject, because they are curious and interested to learn new things. As children, they are inherently curious and in the physics teaching ways have to be found to capitalise fully on this. Evidence of this is illustrated by the following extracts.

"I - what are your feelings about the fact that you are going to study physics in (...) years time?

S₁ - "my feelings .. I don't know .. I feel happy about it .. I feel happy and curious when I think I'm going to study that .."

(10 years old boy; 5th grade)

"I - (the same question)

S₂ - ".. I feel myself happy ..

I - why?

S₂ - ".. because I'm going to study a new subject .... I think I will enjoy it".

(11 years old girl; 6th grade)

"I - (the same question)

S₃ - ".. er .... I like it .. I don't know how physics is studied .. but .. well .. I'm going to know more .. more than I know now .. and I like to learn new subjects".

(11 years old boy; 6th grade)

"I - (the same question)

S₄ - "the same as when I started studying science ... as I like science ... actually it is the subject I like most .."

(12 years old boy; 7th grade)
"I - (the same question)

S₅ - .. er .. well .. I feel a wish to learn things that I don't know".

(11 years old girl; 6th grade)

The loss of interest and a certain disillusion about physics can be perceived throughout the interviews with students being taught physics. This disinterest increases from 8th to 11th grade. During observations that I have made in physics lessons in grades 8, 9, 10 and 11th, and through informal conversations with youngsters (ages 13, 14, 15 and 16), I obtain evidence which supports that emerging from the interviews. The following extracts from interviews illustrate this point.

"I - you still remember .. by any chance .. what did you expected to learn in physics before you did it?

S₁ - .. what I would like to have learned? .. I don't know .. but I think .. I don't remember very well what I did at the 8th grade .. because it was .. electricity or something like that .. I enjoyed that part .. I really enjoyed it .... but I thought that I would carry on with electricity .. but then .. when I started the 9th grade .. when that part about forces and .. levers and pulleys started .. I began to enjoy physics less .. but now at the 10th grade .... we started doing physics a month ago .. with some examples .. of reference points .. reference frames .. er ... in the start I enjoyed it .. I even enjoyed that part .... I thought I would continue to enjoy it .... but .. it looks to me .. now ..... I have a feeling that one is going to get less and less interest in physics.

I - why do you think that happens?

S₁ - .. I don't know .. maybe .. a person gets an interest in physics in the beginning .. maybe .. it arouses more interest initially .. 8th grade pupils .. for instance .. my sister .. she is now starting to do physics .. she likes it .. she still likes that .. I don't know .. but I had the same feeling when I was at the 8th grade ... that it was better than it is in the 9th and 10th grades".

(16 years old boy; 10th grade)

"I - .. but do you remember if before you have started to do physics you had some ideas about what you would learn in physics?

S₂ - .. in the beginning I supposed that it would be a bit complex but .. I really hadn't ideas .. I mean .. my cousin .. who is older than me .. told me .. what physics was about .. that it was more formulas than experiments .... there where no experiments at all .. formulas .. deductions and things like that ..

I - were those your expectations?

S₂ - yes

I - and have your expectations been realized?

S₂ - .. well .. they have been realized .. only .. not the way I would prefer .. I have a teacher .. I even like her as a person .. but .... I can't ... the teacher can't
arouse the pupils' interest in physics.

I - uhm ..

S2 - and then .. it is difficult for us to know what is being thought .. what is she talking about ... I mean .. for instance .. in the 8th grade I enjoyed physics more than now ..

I - why did you enjoy it more than now?

S2 - perhaps because it was the beginning .. I don't know ... or .. may be the subject was different .. we did it in a easy way ... now is much more complicated".

(15 years old boy; 10th grade)

"I - do you remember what you thought that you would do in physics?

S2 - ... uhm .. it was more or less .. no .. I didn't think it was so .. how shall I say it ... with so many problems (laughs)

I - what kind of problems?

S2 - (laughs) ... about simple things ... in a thing that we see as simple ... there are so many problems .. so many questions .. interrogations ... (laughs)

(14 years old girl; 9th grade)

"I - do you remember what did you expected to learn in physics before you have done it?

S3 - it was more or less what I found..

I - why do you say that?

S3 - well .. first I got a good teacher .. she did a lot of experiments .. I had lots of experiments and I enjoyed it and that was what I really was expecting ... but then .. when we started with kinematics I didn't like it very much .. it wasn't what I expected ... but it must be like that ...

I - why do you say that?

S3 - I couldn't see the practical applications of it!..

I - why?

S3 - because everything was based on maths .. we didn't see anything else ... I didn't like it.."  

(16 years old boy; 11th grade)

The same idea was conveyed through the interviews with teachers.

The following two extracts can give an illustration of this.

"T - .. students arrive here at the 11th year with a total disinterest in physics and I try hardly to arouse their interest .. but it's a fact .. they have lost it during secondary school .."

(physicist teaching at the university)
"T - ... I like to teach physics .. but let me tell you ... I hate to teach the 8th and 9th grades .. I don't feel pupils are motivated for that .. I can't increase their interest .. may be in the 8th grade ... during the study of electricity .. though it seems to me a bit early to start it ... but in that year I still feel their interest .. then they loose it .. "

(secondary school teacher)

An interesting situation develops in the period between the 8th and 11th grade. Most of the students interviewed began to show more interest and enjoyment in chemistry than in physics. This can be illustrated by some extracts of interviews.

"I - ... look ... what are your feelings about learning physics?

S1 - .. well .. I find ... the physics we are doing this year .. a bit dull and boring .. this doesn't happen with chemistry ... no ... actually I find chemistry very attractive ....

I - why do you say that?

S1 - because we learn about great discoveries .. about great scientists ... Bohr .. (laughs) and others ..

I - in chemistry?

S1 - yes

I - and what didn't you like in physics this year?

S1 - ... mechanics .. I didn't like it very much ...

I - why?

S1 - .... may be it has too much maths (laughs) ... I don't see the use of it..

I - look .. and what would you like to learn in physics?

S1 - .... in physics .... er ... if it was in chemistry (laughs) I would be able to answer that .. but in physics .... I really don't know ...

I - why?

S1 - I don't know ... I think physics is more related with maths ... isn't it? .. and ... about putting it into practice .. I don't see it .... really I don't know what the practical interest of physics is .. (laughs) .."

(15 years old boy; 10th grade, scientific area)

"I - ..is there any particular thing that you would like to learn in physics?

S2 - ... in physics ..... uhm .... I don't know .... uff! .. I think .. well ..physics never aroused interest in me .. I always enjoyed chemistry very much ..

I - why is it?

S2 - because it has got much more interest .. that's it .. physics is boring ... and
chemistry is different .. we need to understand the concepts and everything .... whilst in physics no ... we are given a lot of formulas and we must plug in the right numbers ... I mean ... that's my idea .... whilst in chemistry we need to understand things better ... all those structures ...

(15 years old girl; 10th grade, scientific area)

"I - what are your feelings about physics?

S3 - .. I mean .. I like it ... er .... but I like chemistry better than physics .. because ... you know ... I feel myself more motivated by chemistry ...

(18 years old girl; 12th grade)

"I - what are your feelings about physics?

S4 - .. er .. I ... I mean ... I like chemistry most ... everything related with chemistry gives me much more interest ... I think it has something to do with the way both subjects were taught to me ..

I - why?

S4 - .. well .. only this year I started to enjoy physics a bit more ... I couldn't stand physics at all .. because I didn't understand a word of it ... and with chemistry .. it was different ... we could see what was happening ... we did a lot of experiments .."

(17 years old girl; 12th grade)

"I - .. do you remember if before you have started learning physics ..you had any expectations in relation to what you would learn?

S5 - .. uhm ... (laughs) I can't remember very well .. I don't know .. I always liked chemistry better than physics .. I don't know .. I can't remember .. I haven't got any idea ....

I - why did you like chemistry most?

S5 - it always arouses more interest in me .. I liked that lab work .... I had in the 8th grade a teacher who showed us many experiments .. we had practical work classes and developed more interest in chemistry than in physics ..

I - did you do some experiments in physics classes?

S5 - ... some ..... but .... well physics came always at the end of the year .. so ... I did more chemistry than physics .."

(student of "Biology and Geology Teacher Training" degree)

"S6 - I didn't like physics ... perhaps due to my experience in the 8th grade where the teacher was awful ... she didn't prepare the lessons .. they were so boring ... and I got bad marks .... in the 9th grade the teacher was better and I began to enjoy it more ... and .. also my marks improved in chemistry .... but when we started to do physics my marks went down again ... I don't know why ... but I didn't like physics at all ... I enjoyed chemistry much more ... we did lab work ... oh yes ! .. a lot of it .."

(18 years old girl; 12th grade scientific area)

"I - what would you like to have learned in physics?

-25-
S7 - I don't know (laughs) .. I never thought of it .... there are things that I would ...
... oh ..but they aren't really related to physics .. it's more ... chemistry ...
I always liked chemistry better than physics .." 

I - why? can you explain that? 

S7 - .. no .. but ..I think that physics is not so interesting as chemistry ... chemistry classes were more lively ... we did experiments by ourselves .. whilst physics classes were more expositive .." 

(16 years old girl; 11th grade, humanities area) 

"Sg - .. what I liked a bit more in physics was the study of motion ... kinetics .. all the other subjects .... uff! ....awful ... I find physics much too theoretical .. for instance .. I like chemistry better than physics .. because in chemistry we did lab work ... and that help us to understand better ... one sees first .. and only after seeing we could draw some conclusions .... this didn't happen in physics ... oh no ! ... the teacher talked .. talked ... I really didn't do any experiments .." 

(18 years old girl; 12th grade, scientific area) 

I asked teachers opinions about this situation. From their point of view there are some reasons for this. As already mentioned in sub-section 1.3.2, since 1970 the "Physics plus Chemistry" degree was split into two independent five years degrees, one in Physics and the other in Chemistry, with different curricula in different universities. After 1975 an integrated "Physics and Chemistry Teacher Training" five years degree started in four new universities, but the number of teachers with this degree is still very small. The number of teachers with chemistry background is bigger than the one with physics background. This is a reflection of the situation found among students - the general preference for chemistry. Both types of teachers have to teach physics and chemistry at the secondary schools. Obviously the teachers with a chemistry degree are better prepared to teach chemistry and feel more enthusiasm for chemistry than for physics. As is widely accepted, teachers' attitudes are communicated to pupils. When teaching physics and chemistry courses to the secondary students their tendency is to drag chemistry out and to teach less physics. Another reason, affecting all the teachers, even the older teachers with degrees in "Physics plus Chemistry", was expressed by teachers during the interviews. Extracts from some interviews give an account of it. 

"I - ... but normally the majority of the teachers don't cover all the physics curricula .. this happens mainly with physics .. we detect that at the university ... 

T - well .. the curricula of the 9th grade doesn't seem .. to me .. difficult to accomplish .. what actually happens is that .. normally persons don't like to teach physics .. and for this reason they drag out chemistry ..
I - but why?

T - it's a kind of defense .. you see .. chemistry has changed quite a lot in recent years .. and the teachers were prepared for a new chemistry .. a different chemistry .. because when we were students .. we used to cram chemistry .. nowadays we try to explain .. to give a certain orientation .... it changed and .. teachers usually feel themselves motivated to study .. to do experiments ... to try new things ... different things ..... and this doesn't happen with physics..

I - .. so do you think that it has something to do with the way teachers have been prepared?

T - yes .. and also ... chemists have tried to bring teachers up to date .. you know .. new books .. even the Portuguese Chemical Society is always sending us new things ... new ideas to experiment .. different types of tests .. I don't know .. lots of things that pull teachers up .. and .... this doesn't happen with physics..

I - and what about lab work?

T - .. you see .. for instance we do much less in physics than in chemistry .. much much less ... there is apparatus .. but it is always the same .. it hasn't changed .. most of it is damaged and is put aside .. nobody bothers to have it mended .."

(secondary school teacher)

"I - .. it has been showed that .. in general .. students prefer chemistry to physics ... can you give any reasons for this?

P - .. well I think .... the problem is that in our country ... chemistry has more industrial application than physics .. and in the economical situation we are ....

I - .. but I mean .. at the secondary school level ..

P - .. yes at the secondary school level ..... usually students find physics more difficult than chemistry .... well .. I think .. it is .. more difficult .. much more difficult .... to teach physics reasonably well .... precisely because chemistry .. at the secondary level .. is still taught at a burette level .. er .. it must be .. I'm not criticizing it .... but if it was proposed to teach chemistry hard quantum mechanics to students .. the problem would be the same as in physics .."

(physicist teaching at university)

According to the above statements, it seems that students' attitudes towards physics and chemistry are a reflection of the way both subjects have been taught. While in chemistry a great emphasis has been made on experiments, physics has been taught theoretically. Another physicist from a university commenting on this issue said:

"P - I think that the problem is this .. it's easier to do inexpensively .. quick and obvious experiments showing what chemistry is about ... but in physics .. well physics as a fundamental subject .. because in the end physics is the basis of chemistry ... er ... many times physics deals with concepts ... which are more difficult to explain through trivial experiments ... I think that it's much easier to set up a very trivial experiment in chemistry than in physics .. and much cheaper too ... and that's very important .."
It is very interesting to identify the different perspectives held on physics by the different groups that came out when the question "What do you think physics is about" was answered. As far as the first category is concerned - children prior to physics teaching - , as was already pointed out, most of the children interviewed do not have any idea of what physics is about. However some children have ideas about physics, we could call them children's perceptions about the subject of physics, acquired through their interaction with older students or adults. It may be a contribution to students' attitude towards physics. It has been persuasively argued that the more teachers know about and appreciate the alternative conceptions that children bring to classrooms, the better they will be able to provide effective learning experiences for their pupils to modify the conceptions (Sutton, 1980; Gilbert et al., 1982a). It is my belief that the same argument can be used in relation to the concept of physics that children have constructed prior to physics teaching. It would help if, before starting their courses, teachers tried to find out what physics means to their pupils.

When asked "What does physics mean to you?" some interviewees gave a stereotype definition of physics, while others gave their own views. The following quotations give examples of answers of the different categories of individuals.

- "Physics ... is the science of what is evident ... isn't it? ... things we can see ..."
  (physicist teaching at the university)

- "Well ... for me physics means the knowledge of all matter .. the fundamental laws that rule the world where we live and that help us to understand a little .. the same world ..I mean .. in a more rational form than a simple subjective analysis .. or empiricist analysis .. that can drive us .. to superstitions .. to some less real analysis of the same world .."
  (physicist teaching at the university)

- "...uhm .. physics ... will be ..... it is a science .. basically experimental .. it's an exact science .. a science learned by experimentation .. that tries to explain a variety of phenomena of Nature .. it's concerned with phenomena of Nature .... but at the same time .. it cannot .. only be .. concerned with phenomena that are occurring ... as formerly ... but nowadays it must also be concerned ... to explain and develop ... or .... new concepts that are important to the development of technology .."
  (physicist teaching at the university)

- "...Well .. let's say .. my idea of physics is .... an attempt to interpret the world around us .."
  (secondary school teacher)

- "a world of very interesting things ... that I would like to know much more (laughs) .."
  (secondary school teacher)
"Physics? (laughs) what does it mean? ... physics? ... well ... for me physics ..... it is ... not only the science of measurements that we teach to our children ... but a science ... which seeks to explain ... the world ... and seeks to discover ... we enter into technology ... but that aims at interpreting the world ... and make the world more useful to mankind ... I don't know ..... this doesn't have any philosophy (laughs) ... but it's my own philosophy ... actually this is what I think .."

(secondary school teacher)

"What is physics?! ... what would it be ... well firstly ... it is a subject I have been teaching (laughs) ... but apart from that ... maybe it is ... even a little more extensive than the one which is taught ... let's see ... an interpretation of phenomena of nature ... well ... generally speaking ... I don't know (laughs) ... maybe I'm wrong ... but I consider it like this ... because ... in nearly everything ... there are always aspects that can focus ... let's say ... a restrict field of physics in nearly everything ...."

(secondary school teacher)

"oh! ... that's a question ... a bit ... I mean ... as a person with a degree in chemistry as I have! .... I like physics ... you know ... but ... I don't know ...... I think .... in fact it is a question! ... I mean for me ... what is physics? .... well it is obvious that it is ..... it is a science where we can get ... in fact ... the explanation for many phenomena that happen around us ... as well as in chemistry .... but ... I mean ... I can't find a more concrete answer .."

(secondary school teacher)

"... Physics ... I don't know .... let's say ... in a certain way .... phenomena ..... it describes them ... observation .... observation ... it reminds me all these things ... the scientific method ... well .... at this moment ... I can't say anymore .."

(secondary school teacher)

"... Well ... that question is really a little difficult ... I never thought of it ... what does physics mean to me ... er ... it gets me embarrassed .... the question ... I never thought of it ... I always liked to study physics .. I liked and I like to teach physics very much ... I don't know .... for me physics means ...... it is an explanation of facts of nature ... and really ... I find it extraordinary ... extraordinary ... to find out ... a scientific reason for all facts of nature ... I find ..... for me it means ... to give an explanation ... to interpret nature ...."

(secondary school teacher)

"It is ... it is a bit difficult to tell you what physics is about ... even because ... well ... I think ... everything is a bit of physics ...(laughs) ... life ... everything ... everthing can be physics phenomena if we look at them in that way ... everything is physics .."

(secondary school teacher)

"I have tried to answer that question many times ... and I still can't find an answer ... because ... when a kid asks me what physics is about ... I never know what to say ... because there is that idea about physics being a set of mathematical expressions and boring things detested by kids ... and for me it is difficult ...it is something marvellous ... that basically explain all our life ... I always can find physics in everyday situations .... it explains why I walk ... why I play with a ball .... these common things .."

(student teacher; 4th year physics degree, education branch)
"..I find it very cute ... very cute ... I like it ... I like physics better than chemistry ... I think that it is something touchable ... well ... perhaps one doesn't see as much as in chemistry ... but one can see real things ... a ball falling down on an inclined plan ... and all those things ..."

(student teacher; 4th year Physics and Chemistry degree)

"... er ... a science that plays with abstract things ... it's a bit like that ... why? ... maybe in consequence of the way it was taught to me at the secondary school ... things remained ... a bit fluid ... I mean I really didn't feel them ... I didn't assimilate them and ... perhaps it was one thing that took me away from physics .."

(student teacher; 3rd year Biology and Geology degree)

".. for me physics means exactly ... to remember classes ... some of them were funny ... but not as much because of the subject...(laughs) ... because of the circumstances that were brought up ... because ... you see ... there was a certain disinterest ... not generalized of course ... but there was a certain disinterest ... I don't know ... may be due to the way physics was taught ... there wasn't any relation with everyday life ..."

(student; 3rd year, History degree)

"sincerely I have never thought about it ... I mean I have a kind of idea ... but a concrete definition ... I need to think hard (laughs) ... I don't know ... maybe a set of ... let's say ... factors that ... in fact ... now .......... that caught me unprepared ...... (laughs) ... a bit unprepared ... that one ... about what physics is about ... (laughs) .."

(school leaver working in a factory)

"Physics is a kind of practical application of Maths ...(laughs) ... isn't it? ... but sure ... it is ..."

(16 years old girl; 11th year, humanities area)

"Look ... (laughs) that ... I really never thought of it ... I never thought of what really it means ... I think that it is a bit abstract ... I did physics until last year ... but not too much ... so ... I can't tell ... but I gave a look at the books of my colleagues in the 12th grade ... and I found it too abstract ... with all those Schrödinger equations ... all that kind of stuff ... uff! ..."

(18 years old girl; 12th grade, science area without physics)

Comparing the different views on what physics is about, there can be seen, from teachers to students, an increasing disenchantment in the way people talk about it. Maybe one reason for this can be found when answers to the next question, "What happen in your physics classes ", are analysed. It should be pointed out here that although the majority of the secondary school students interviewed were attending schools at Aveiro, some were from other places in the country. However the sample of the student teachers had people from all over the country and it can give a general overview of what was happening in physics teaching in Portugal.
The students' views about the way their physics classes were run can be illustrated through some extracts of the interviews.

"I - What happened in your physics classes at 8th and 9th grade?

S1 - I mean in the 8th grade for instance we studied electrostatics and electric current. I liked. I mean at that moment I found it funny. We rubbed plastic and glass bars but then electric current. I didn't like it so much... generally the experiments never worked out... and I didn't get ideas about those things... you know... I couldn't abstract enough in order to understand that. I found that it wasn't for us to understand... in the 9th grade... as far as I remember... we didn't do any experiments... the experimental part was always done by the teacher... because we couldn't waste time... during the 10th... 11th... and 12th grades we didn't have any experimental part... classes were boring... really boring..." 

(17 years old girl; 12th grade, scientific area)

"I - (the same question)

S2 - Generally... we had a theoretical lesson first... and then we did a small experiment to show us that it was true... I mean... it was always like this... first we learned the theory and then we did some experiments to elucidate it..."

(17 years old boy; 12th grade, scientific area)

"I - (the same question)

S3 - well... they run well... the teacher was talking... and we were trying to understand... as much as possible... trying to relate what we were doing with day-to-day life... we did some experiments in the 8th grade... just a few... but in the 9th... I think we did nothing...

I - do you remember what did you learn in the 9th grade?

S3 - no... (laughs)... I haven't the slightest idea...

(17 years old girl; 12th grade, scientific area)

"I - (the same question)

S4 - in the 8th grade... the teacher was able to raise some interest... in the 9th... it was a mess... nobody cared... now at the 11th... the teacher talks... talks... he goes to the blackboard... he draws graphs... and the class... is almost asleep (laughs)... 

I - did you do any experiments?

S4 - in the 8th grade we did some... in electrostatics... to verify Ohm's law... we did that...

I - and in the 9th and 10th?

S4 - nothing... nothing at all...

(15 years old boy; 10th grade, technology area)

"I - (the same question)

S5 - oh... that's difficult... it depends on the teacher...
"I - what do you mean by that?

S₅ - for instance .. the teacher I have this year ... uff! ... well I think in physics classes one should be always debate .. discuss problems .. try to find out solutions .. but my teacher .. this year .. and last year too ..(laughs) .. I have had bad luck with physics teachers .. you see .. classes are quiet .. too quiet .. they aren't as I think .. and I would like .. physics classes should be .. classes which aroused interest .. because .. I find the subject interesting .."

(15 years old girl; 10th grade, scientific area)

"I - (the same question)

S₆ - well .. we had a book .. and the teacher explained more or less what was in the book .. on the blackboard ..... and we learned ... and that's all ..

I - did you do any experiments?

S₆ - no .. never .. because (laughs) ..sometimes in physics is necessary to use mechanical models .. isn't it? .. but .. no .. we did nothing .. well only those trivial things in electrostatics .."

(16 years old boy; 11th grade, technology area)

"I - (the same question)

S₇ - it's difficult to say .. but at the 8th .. we did some experiments .. about attraction and repulsion .. but very easy ones .. very trivial .. the matter was very simple .. not interesting .. but sometimes .. some concepts that we couldn't assimilate were introduced .. at the 8th .. we did optics .. I can't remember anything else ... I found it more interesting ..

I - how did the classes go?

S₇ - uhm .. mainly based on definitions .. and also .. they had many drawings on the blackboard ..

I - didn't you do any experiments in optics?

S₇ - .. no ..

I - why did you say they were more interesting?

S₇ - .. I don't know .. (laughs) .. perhaps because it was a new subject .. a completely new one .. whilst .. at the 8th grade .. those experiments .... to attract small pieces of paper .. they were so .. bah! .. we used to do those things before ..

I - and what about 10th and 11th grades?

S₇ - at the 10th we studied the motion laws .. I felt ..... a lack of a maths base .. in order to understand a lot of things .. when we were given formulas .. we were told ..'ah .. this can be proved by integration .. by limits' .. well .. that meant nothing for me .. either I should know it already .. or those things shouldn't be taught .."

(16 years old boy; 11th grade, technology area)

"I - (the same question)

S₈ - .. what happens? .. nothing happens .. (laughs) ..

I - but what are your feelings about those classes?
Sg - I only enjoyed them .. for the first one or two years ..

I - why?

Sg - .. because everything was based on experiments .. we could see .. we discussed problems .. and we could see that .... but in the other years ... we are told and we ought to accept without seeing it ... uhm .. what's wrong? .. uhm .. the teacher is always talking .. talking .. and then he writes on the black-board something .. but we .. by ourselves .. we don't draw any conclusions .. we are told everything by teachers .."

(16 years old boy; 11th grade, technology area)

"I - what happened and .. what happens in your physics classes?

Sg - ..at secondary level .. well .. I think .. well I must tell you that the lab .... I went there only once or twice .. as far as I remember .. I went there to see .. the electrolysis of water .. and another time .. to see .. something related to pressure ..I think .. uhm .. the Torricelli's experiment ..

I - did you say you went there to see?

Sg - ..yes .. I went there to see .. I never did an experiment ..er .. at the secondary school ... in chemistry yes .. we worked at the lab more often .... in physics no .. the teacher talked about the subject of the lessons .. and at the end some problems were dictated .. one pupil went to the blackboard to solve it ... and that's all... it was always the same ..

I - and here at the university?

Sg -here at the university .. it's a bit different .. I mean .. there are classes where teachers are always expounding .. where one can go out if one wants ... then we have lab classes where we ought to go .. at least to a certain number .. and it is in there that we meet the difficulties ... I felt them .. when things that I had never touched .. were put in front of me .. to perform some experiments was required.. at least to feel at ease with certain lab equipment .. and I didn't .."

(student teacher; 4th year, Physics degree, education branch)

"I - (the same question)

S10 - .. how did it go? .. well they weren't different from other subjects .. they were normal .. the matter was exposited by the teacher .. classes were merely expositive .. sometimes there was a demonstration ... I never went to a physics lab until the 10th grade ... I went there onlt to do some weighing ... I realized now that it was rather bad .. uhm .. when I came to the university in the first year .. I had a course .. Experimental Physics .. we started with electricity .. and the teacher said to me just this .. 'set up that circuit' ... and I stood there terrified .. because I knew resistors ..'on paper' .. and batteries and everything ... but I had never seen a resistor in my life .. and I think this is awful .. how can a pupil enjoy physics in that way? .. because I think physics is applicable to everyday situations .. why don't show us this in classrooms? ...

(student teacher; 4th year, Physics degree, education branch)

"I - (the same question)
The teacher talked, we heard, sometimes we went to the lab, and it was an awful mess.

I - why?

S11 - (laughs) because as we went there just a few times, well, we were children, you see, fussy, and in those classes at lab, we were more at ease, and we took advantages of it, and of course, sometimes burns occurred and things like that.

I - burns?

S11 - yes, well, those were chemistry classes, in physics usually, we only saw experiments.

(student teacher; 4th year, Physics degree, education branch)

S12 - what happened in physics classes? well usually, theory completely disconnected from practice, I mean, we even had lab equipment, but simply, as it didn't belong to the curriculum, and maybe we were not very interested in doing practical, I don't know, maybe if we had shown interest and asked teachers about it, maybe they would collaborate more than they usually did. I have the impression that sometimes if we show interest, teachers would do more experiments.

(student teacher; 1st year Physics and Chemistry degree)

I - (the same question)

S13 - (laughs) what happened? theory, only theory. physics was only theory, nothing else. I never did experiments, teachers talked, they exposit a lesson. some problems were solved, there was no practical, that was a thing, one of the faults I can mention.

I - why do you say that's a fault?

S13 - because for me physics is for me everything that is physics phenomena, I must see them, I must see the reality. I mean, at least the fundamental. I must do things, as we do here at the university, do lab work. I think it helps a lot to visualize problems, it helps to set up problems, it's not only cramming, we sometimes can spend a lot of time trying to cram a thing theoretically, and sometimes it doesn't go, whilst, if we do it, if we see it, it would be quite easy, it helps a lot.

(student teacher; 1st year Physics and Chemistry degree)

I - (the same question)

S14 - the teacher talked, and we heard, only.

I - did you do any experimental part?

S14 - no, we never had experimental classes. I mean, before entering university, only here I have had an experimental part in all the courses.

I - and what were your feelings about your physics classes at the secondary school?

S14 - oh, the classes were boring, dull, (laughs) it was only the teacher who did the talking and we had to cram all that for tests, and nothing else.
S14 - "I think students should be more monitored during the work. You know, there is a misadjustment between what is the subject of theoretical classes and the subject about which the experiments are done. In most cases we are doing an experiment based on topics not yet studied. And because of this maybe the student is not able to understand the work. As hard as he tries, and if he was more helped by the tutorial, probably he would understand quicker and even it would be easier to understand the work and write the report."

(student teacher; 1st year Physics and Chemistry degree)

S15 - "Well, they were more an exposition of knowledge. You see, the teacher arrived there, said what she had to say, and nothing else. I had never been in a lab. I still, when I came here last year, I'm looking at that box over there. The Newton box. Well before I came here I had the idea that a Newton was a heavy thing. And when you took that box to the classroom and I felt it, I was quite surprised. Because I didn't know that the Newton was so light. I was told that one Newton was 9.8 kg or the other way round, but I was always confused. What the way was the right one? Because it was only words. I never felt it. I think theoretical things and things we forget easily, we learn them, they stick on our head, but they go away soon. When one does, I see this in Mechanics. I didn't know how to represent the forces acting on a body when it was on an inclined plane. I didn't understand... only this year, when I was doing the experiment I understood and I learned how to represent the forces."

(student teacher; 1st year Physics and Chemistry degree)
I don't know how to say it in few words, but specially at experimental level. I feel I haven't got. I don't feel at ease in a physics lab... and at practical classes... sometimes I felt a lack of link between what we were doing and what we were lectured...

(student teacher; 5th year Physics and Chemistry degree)

The central finding from all these statements, and from much more that can be picked out from other interviews, was that physics is taught in a classical, traditional, way. Students are presented with formal situations in which they listen, watch, take notes, but are otherwise passive. When experiment work is used, most of the time it is simple demonstrations in which the students' role continues to be a passive one, watching or... sleeping. In my professional activity as supervisor of the teaching practice of the 5th year student teachers within the Physics and Chemistry degree I observed a variety of physics lessons. As a result of these observations I am able to support the students' views about physics classes. The disinterest shown by pupils to this type of lessons is distressing. Even when they are engaged in a group activity doing lab work they are faced with instructions to be followed and, although they looked active, their minds are passive and they do what they are commanded to do. How can they be interested in physics when they are taught by this methodology? If there was any ideology underlying the approach that physics teaching in our schools has, it would be one of cultural transmission. The major objectives of this school of thought are literary and numeracy skills, not physics skills. The philosophical perspective is that absolute truth can be accumulated bit by bit, subject by subject. Knowledge is repetition and objectives and can be measured by culturally shared test procedures. Students work just for tests and exams. They have not been taught for thinking and understanding. Even worse, after being under physics instruction for some years they develop some attitudes that can be of great harm to future citizens. After a micro-teaching activity in a course of Physics Didactics that I was in charge of at the university, I had an opportunity to talk with a very bright 11th grade student about the way students normally deal with formulas in physics. It happened that the topic proposed for the activity was the concept of electric field. The student teacher, in the teaching simulation, had tried, without apparent success, to ensure that the physical meaning of Coulomb's law was understood by each of the six students. I was in the role of a non-participant observer. By the end of the activity I asked that particular student if he had understood what the expression really meant. His answer was:
"... well. I don't know what it really means ... but ... to tell the truth ... I have been realizing ... since I've been studying physics that it isn't important to understand those equations ... it's a waste of time to try to understand them ... what is needed is to cram them ... because if we know them by heart ... we can plug in the numbers and solve problems in tests and exams ... and this is what really matters ... isn't it? ... so I don't care ... if I don't understand some of them ... I mean ... some of them ... because there are others that I'm really interested in understanding."

This kind of students' attitude towards the mathematical expression of physics laws is fostered by the approach to teaching and assessment of learning used in schools. Physics teaching and assessment are primarily content-oriented. This may be related partly to the tradition in physics teaching, partly to the lack of teachers' reflection on the aims of physics education and partly to the philosophy underlying their teaching. It is probably easier to organize a content-oriented lesson and a content-oriented test than to provide situations in which each student can develop specific skills, and to construct specific instruments to assess them. I believe that the way physics is taught at the secondary school level reflects the way physics teachers are educated. On the other hand, this reflects the aims of physics teaching for that level of schooling. This was another important issue that it was my purpose to investigate by injecting during the interview the question - "Why do you think physics is in the curriculum of the secondary school?"

Some extracts from interviews can give insight into students' and teachers' ideas about this issue.

(Extracts from interviews)

"I - Why do you think physics is in the curriculum of the 8th and 9th grade? ... what are the aims that are supposed to be achieved through the teaching of physics in these grades? ... as you know ... a large percentage of pupils then finish their scientific studies and ..."

P - with that? ... with that syllabus? ... I think it is a bit difficult ... to answer that ... because ... I even find ... that at this level ... I may be wrong ... but ... I don't know if ... it should be at this level ... they are taught ... for example electricity before mechanics ... I think that wrong ... because ... you see ... electricity has an obscure cause ... and mechanics hasn't ... in mechanics ... motion ... it can be seen ...

I - are you acquainted with the syllabus of the primary and preparatory school level?

P - ... no ...

I - and with the 8th and 9th grades?

P - ... no ... I'm only acquainted with the syllabus of the 10th and 11th grades ... but anyway ... when they arrive at the university we think that they know
... after having heard it so many times! ... and they don't ... often they
don't ... well it's true ... students have a great tendency ... I use to give
this example ... they know what a battery is in chemistry ... but they don't
know it in physics ... I mean ... things come up ... in compartments ... er
... the lack of mental agility ... instead of being developed at those ages
... I'm convinced that it has been wasted ... I mean ... students have been
losing critical skills progressively ... and ... they arrive here at the university
... more and more immature ... and it shouldn't be ..."

(physicist teaching at the university)

"I - (the same question)

T - ... well ... because it's one of the most important sciences ... isn't it? ... besides
... every science is ... in the secondary school curriculum ... why not physics?
... it is a science reaching a large field within man's world ...

I - but do you think the way physics has been taught ... makes it possible to accom-
plish the aim of physics teaching at the secondary school level?

T - to me ... it doesn't ... and one of the reasons is the syllabus itself ... it doesn't
motivate ... it doesn't make the bridge between physics that is being taught
and real life ... it is too disconnected from everyday life ... very very much ...
... besides all the curriculum ... and the textbooks ... scarcely touch those things
... books to which kids have access ... and on the other hand ... schools are
not provided with suitable conditions ... as teachers put it ... or make an excuse
about schools' conditions ... and ... really physics isn't taught as an experimental
science ... it is taught as a theoretical science ... rhetoric ... then ... if actually
all those objectives ... all those students' capacities that should be developed
through physics teaching ... physics being an experimental science ... they
aren't ... in any way ... because they don't undertake experiments ..... they
don't work in groups ... they don't make inquiry work ... they don't do study
visits ... er ... I don't know ... they don't design experiments ... they don't devise
anything ... I mean ... they haven't any incentive from teachers ... or from schools
... which could provide incentive for them to make things ... to get interest
in discovering by themselves ... because ... and I can tell you ... I have data
about this ... around 87% ... 89% of the teachers and students don't do any
experiments ... and they would like to do ... so ...

(physicist teaching at the university)

"I - (the same question)

P - well ... to my mind ... physics and maths are the two great pillars of ... a person's
development ... let's say of the person's intellectual development ... I suppose
that the aim for including physics at the secondary school level would be
that development ... even more to develop the person's mental structures
than to give information which ... of course will arise as a consequence.

I - do you think that the way physics has been taught and what has been taught
... allows the achievement of those aims?

P - ... look ... no ... frankly I think they don't ... I suppose there should be a great
restructuring of the curriculum ... it looks to me ... that the curriculum isn't
very attractive ... and the conditions in which classes are held ... really they
are very bad ... and the students ... I suppose ... in general ... of course here
it is difficult to make generalizations ... I know there are teachers who are
able to arouse interest in their students ... there are schools where things
work out well ... but I also know ... may be the greatest part of the curriculum
don't arouse the students' interest ... but I don't know how to explain why
I have the impression that it needs a much deeper .. a much longer observation .. but I have the feeling .. that just after the 8th grade .. students turn off physics .. because they don't like it ..

I - and at the university level?

P - .. (laughs) .. look .. we must confess that not always .. a great component is missed here at the university .. the experimental part .. we have here one thing .. perhaps it is an excuse .. but it's partly true .. we don't have equipment which could extend the lab work as much as we would like .. and .. we shelter ourselves behind theoretical classes .. too much theoretical work .. the criticism that I have to make of my own classes .. is that they are too theoretical .. to tell the truth I would like to have possibilities .. time and materials to make my classes more lively .. and I'm an experimentalist .. think what will be like when it is a theoretical physicist who is teaching .."

(physicist teaching at the university)

"I - (the same question)

P - well I don't know well what the aims were of those who elaborated the curriculum .. but I think it would be a fault if students .. didn't study physics .. at least during the 8th and 9th grades .. besides .. it is the only opportunity for them to deal with physical problems .. which I think should be linked with everyday problems .. thus after those two years of physics studies .. they could better understand the world around them .. to interpret it .."

(physics educator teaching at the university)

"I - (the same question)

T - I think that's exactly in order to give to students .. a knowledge of the world where they live .. and therefore .. make them understand their surroundings .."

(secondary school teacher)

"I - (the same question)

T - .. well actually physics provides general culture .. I mean .. it gives the explanation .. to a child's questions .. it helps a mother .. to fulfill the child's curiosity .. I feel sometimes with my daughter .. she asks me some questions .. I only can answer to her through physics .. and I realize that one mother who wouldn't know something about physics couldn't answer .."

.. (secondary school teacher)

"I - (the same question)

T - .. because I think that physics is so linked with life .. all these phenomena .. they really ought to know .. we ought to show to the kids .. they need to have in some subject some knowledge about these things ..and it must be in physics .. it's part of the general culture ..

I - ..uhm .. and do you think it has been achieved?

T - .. no .. I have the feeling that it hasn't..

I - why do you say so?

T - .. I don't know .. I have this feeling .. because I have the idea that when
they leave school ... pupils to whom I have talked ... they leave school ... they
don't have these ideas ... even because .. normally many of the important
things aren't taught .. they don't belong to the curriculum .. so .. we don't
have time to teach them ... and only two years .. it isn't enough .. sometimes
they have different teachers ... there is no link ... everything is disconnected ...

"I - (the same question)

T - here .. there is an important issue .. that is .. if we think about the physics
curriculum as it is now .. it looks as it has little to do .. let's say .. with general
culture .. it seems to me that presently it doesn't contribute much .. because ..
really there are many everyday phenomena .. the pupils aren't given an
explanation for them .. I'm convinced that students leave the secondary educa-
tion .. not understanding many things .. things that I think are fundamental
.. basic .. I don't know .. perhaps the development of science .. maybe today
it is more important to the pupil to know how an electronic watch works
.. than why a boat floats .. (laughs) .. but what happens is that he is not able
to explain both ...

"I - (the same question)

T - .. ah .. how could it be possible to understand the world .. to live happy without
knowing physics? (laughs) .. look .. everything we touch is physics ..isn't it?
so it ought to be in the curriculum .. you watch yourself in a mirror .. it
is optics .. you wash your face (laughs) .. everything is physics .. besides
.. the intellectual development .. I think it develops creativity .. I think it
is fundamental .."

"I - (the same question)

S - because I think it is fundamental that an individual that is being formed ..must
achieve a minimum of knowlegde of physics .. perhaps my perspective about
physics .. that's something applicable to everyday life .. because .. if we
think a bit .. we will find physics in almost everything we do .. so I think
it would be a great fault .. if a person doesn't have the least idea of what
physics is about .."

I - look.. do you think the way physics has been taught .. allows that?
S - "it depends on the teacher and on the teacher's interest ... on the teacher's capacity of catching pupils' attention ... I think pupils should be motivated in the beginning ... in the first years ... because ... I find physics a fascinating subject ... but normally people don't find that ... they don't have any idea of what it is about."

(18 years old girl; 12th grade with physics)

"I - (the same question)"

S - "I think ... the aim ... must be ... for us to get some general notions ... in order that later we can study them in depth ... but it seems to me that it isn't accomplished completely."

I - why?

S - at least ... I couldn't understand well ... electric current when it was taught to me at the 8th grade ... I couldn't see why electrons went that way ... I mean I really couldn't understand that ... nevertheless ... I think it should be important ... if one ... in real life knows a minimum ... it's general culture ... but I think ... in the way physics has been studied at the 8th and 9th grades ... we don't get it."

(18 years old girl; 12th grade with physics)

"I - (the same question)"

S - "... maybe it helps us to understand better ... certain things ... certain phenomena that occur in everyday life."

I - you said ... maybe ... what does it mean? ... does it happen or no?

S - "... I think so ... in TV ... in some cultural programs etc. ..."

(15 years old boy; 10th grade, scientific area)

"I -(the same question)"

S - "... I mean ... it hasn't a great interest for the ones who enter humanities degrees ... though I think it would do them some good if they had at the 8th and 9th grade an experimental physics course ... more experimental than other thing ... I think it's good for motivation ... for showing people what physics is about ... as a general culture."

(15 years old boy; 10th grade; technology area)

"I - (the same question)"

S - "it must be important ... if it's there (laughs) ... uhm ... I think it is important ... not too important ... (laughs) ... but I don't know ... but it is important for us to understand better ... our surroundings ... certain concepts ... energy ... I liked what I studied last year ... and I got a different idea ... different from the one I had before ... well I think it has some importance ... although ... it doesn't bring any practical results."

(15 years old girl; 10th grade, scientific area)

"I - (the same question)"

S - "... perhaps as a general culture ... but I think it isn't achieved ... well ... that aim ... they haven't been able to reach it ... if that was the aim ... it isn't reached"
"I - (the same question)
S - on one hand physics studies phenomena everyday life phenomena well some others (laughs) aren't from everyday life isn't it so? (laughs) and on the other hand there is a lot of problems around physics problems that are going to be tackled later. I was always told that physics is important for civil engineering I don't know up to what point but I have been told that .."

(15 years old boy; 10th grade, technology area)

The above transcribed extracts from interviews with teachers reflect the views of most of the teachers interviewed. According to teachers, physics is in the curriculum of the secondary school because:

i) it gives general culture

ii) it helps people to understand the world around them

iii) as a result of the interaction with physics content students achieve intellectual development, meaning by that cognitive development.

All these opinions about the role of physics at this stage of schooling show a major emphasis in the acquisition of physics content, understanding of everyday phenomena and general culture. Only few teachers mentioned, without great conviction, the development of process skills such as hypothesizing, systematic observation, objective evaluation of evidence, curiosity, self-confidence and the like.

Students in the early years of university and at secondary schools are not very sure about physics' role as a subject of study, maybe as general culture, or a basic necessity for later studies. They conveyed the idea that physics should perhaps help them to understand everyday phenomena, but in general their experience did not support that view.

The answers to the question "Do you think that what you are learning in physics has something to do with your everyday life?" give an account of those experiences.

(Extracts from interviews)

"S1 - yes it has something to do with everyday life only it should have much more. I mean sometimes the teacher brings to the classroom some instruments many things that we don't use in everyday life .."
I - could you give an example?

S₁ - ... uhm ... uhm ... the radiometer ... we don't see a radiometer in everyday life .. there must be other things from everyday life that can show us the same phenomenon .. things more common .. more usual .." 

(14 years old girl; 9th grade)

"S₂ - yes .. because .. well physics is .. a science .. practical .. then it is a thing that must be put into practice in everyday life ..

I - and according to you that way it has been taught helps you to do that?

S₂ - ... yes .... I think so ...

I - why?

S₂ -.. because the way it has been taught .. enables us to understand .. and if we understand .. we put it into practice .."

(15 years old boy; 10th grade)

"S₃ - .. well I think it has nothing to do with my life as a person .. as a student .. it seems it has ... hasn't it? ..

I - how do you perceived your life? ..

S₃ -.. well .. as a person .. as I cope with other problems that come into our houses through TV .. newspapers .. etc .. I don't know up to what point physics can help .. for instance .. a distinction that we made this year between .. displacement and distance traveled ... in everyday language .. that is the same thing .. isn't it? ... and thus for normal life that doesn't seem to me of great interest .. only for talking about specific subjects .."

(15 years old boy; 10th grade, scientific area)

"S₄ - .. actually .. I think .. what we have been studying .. and the way we have been taught has nothing to do with our lives yet .. because .. we actually .. as students ... are limited to being receptors many times .. we must only learn only .. because we don't have an activity where we could put it into practice .... anyway after a class .. we are supposed to come out different .. we come out always with something else .. but concretely .. I don't know .."

(17 years old boy; 11th grade, technology area)

"S₅ - practically no ..

I - why?

S₅ -because .. what we learn in classrooms .. has nothing to do with outside ... for instance .. in normal life it hasn't a great application or utility to know that bodies with the same charge repel each other .. or bodies with different charges attract each other ... it doesn't happen in normal life .. things like ... laws of reflection ... well ... uhm ... maybe that has more ..but.. I'm not very sure about that ..

I - when you see yourself in a mirror ..

S₅ -(laughs) .. yes .. when I look myself at a mirror and when I'm in a car and look through the rearview mirror .. maybe ..(laughs) only that ..
but during your classes the relation between what was being given and everyday life wasn't shown?

S5 - .. no ... I don't thing so .. no .. no .."

(16 years old boy; 11th grade technology area)

"S6 - ... directly ... it hasn't really ... I don't feel it has any interest for everyday life ... I go to classes .. the teacher explain what she has to explain .. but ... at this moment ... perhaps it will be useful later on .. in day-to-day life ... but .. at this moment I can't see a great relation .."

(15 years old girl; 10th grade, Scientific area)

"S7 - .. I mean .. it has some relation ... but it would be necessary to have a greater experimental part ... I have often noticed in my group .. that they are working .. but they don't know what they are doing .. they don't know what the teacher is talking about .. they haven't an idea of what motion is .. nothing .. the teacher shouldn't talk so much about functions and variables .. 'this is a function of that .. this varies with that' .. I think they would understand better if they knew what they were talking about .. instead of working with formulas only .."

(15 years old boy; 10th grade, technology area)

"S8 - no ... this year no .. at least practical applications no ...

I - and at the other years?

S8 - .. somethings ...

I - as for example?

S8 - work ... force .. it has something to do with real life hasn't it? .. for instance ... force .. for instance .. levers .. the way they work .. I could relate to real life .. with some things that I know ... winches .. etc. .. I mean I could relate .."

(15 years old boy; 10th grade, scientific area)

"S9 - at secondary school level? .. uhm .. no .. for me .. physics was something .... I could see applications of only very few things .. it was a thing I studied .. I found it funny .. but .. it hasn't a great application in practice ..

I - and the physics you studied at the university?

S9 - .. oh .. that was still more abstract .. it still has less practical applications ...

I discovered in university the applications of what I learned at the secondary school ... now ... the matters I learned at the university .. I wasn't able to find out the applications .. I learned many things ... many formulas .. lots of maths .. but rarely things for which I could see the applications in everyday life .."

(student teacher; Physics degree, education branch)

"S10 - no .. no ... although I had perhaps discovered that relation by myself or from other persons .. but not in the classroom .. I think that relation wasn't shown to us at all..

I - and here at the university?

S10 - ..oh .. even less ... here .. as I use to say .. they don't live in the reality
persons are essentially theoretical. I feel this and the direct application that things can have aren't shown. That's what I think."

(student teacher; Physics degree, education branch)

"S_{11} - physics... I don't know... some... yes... electricity... but there are things... no... at least I didn't see the links with everyday life."

(student teacher; Physics degree, education branch)

"S_{12} - I have the feeling that what we were learning was too unlinked to everyday life...

I - why was that?

S_{12} - I haven't the slightest idea... at this moment I don't know..."

(student teacher; 1st year, Physics and Chemistry degree)

"S_{13} - I think so... I mean... sometimes... one doesn't dream how things really happen... but to my mind... the attention of pupils should be raised... maybe the objectives aren't reached very easily... teaching is more... theory... I think teachers should call students' attention to everyday phenomena... thus they would assimilate ideas in a better way...

I - and at the university?

S_{13} - well here... I can see the link better... because... I do lab work... really I find it very good... the lab work... we can see the relation between theory and practice..."

(student teacher; 2nd year Physics and Chemistry degree)

"S_{14} - not all the time... and for me that is fundamental... it is the daily application... thus a person gets more interest... if this isn't so... one thinks... 'what am I doing here?'... I mean... why do I need this?...

(student teacher; 1st year Physics and Chemistry degree)

"S_{15} - that maybe not... and here it is... it's always the same problem... the way physics has been taught... I don't know... I find it has nothing to do with my life... sometimes we say... 'why are we studying this?'... we never make an application of it...

(student teacher; 1st year Physics and Chemistry degree)

The general impression gained through the protocol analysis concerning this issue was that, at the secondary school level, physics is taught in a way not linked with day-to-day life. Students can not see the point of studying it. For teachers the understanding and interpretation of the world is one of the most frequently mentioned aims for physics teaching at the secondary school. According to the students and teachers these aims are not reached. Physics is taught separately
from the realm of human activity. The finding brought out in this topic deserves a deep reflexion on the use of physics content. Some secondary students are able to maintain a certain interest in physics in the belief that at a later date what they are learning will make sense, or be useful for later studies. However, perhaps the majority of pupils expect more immediate intellectual satisfaction. They are not prepared to wait years before theoretical ideas presented in physics classes can be related to their daily experience. Most of these students will finish their physics education after the 9th grade. Such students need to be able to make sense of the physics ideas presented to them in a more immediate way. From the protocol analysis of the interviews with school leavers or students taking Humanities degrees at the university, even what physics is about is almost completely forgotten in less than two years after finishing physics education. An illustration of this group's attitudes toward physics is provided by some extracts of the protocols of some interviews.

"I - when did you finish doing physics?

S1 - nearly six years ago

I - for how long did you study physics?

S1 - I did physics for three years .. I think..

I - do you remember what did you learn form it?

S1 - no .. because ... perhaps it was a fault of those who taught physics to me ... teachers .. there wasn't any preparation .. I imagine they were excellent physicists .. only I didn't notice that (laughs) .. and then they couldn't arouse my interest in the subject .. thus .. everything I did in physics .. remained only sufficient .. (laughs) .. less than that .. to pass exams .. so .. it really didn't remain .. I haven't a real idea about physics .. it remains as some notions only .. (laughs) .. overall the sensation about was needed to pass the test and nothing else .. I mean .. unfortunately .. because I recognized now that to know something about physics is of the greatest interest .. the problem is that I ..don't know nothing at all .. (laughs) .."

(21 years old boy; 3rd year at the university, History degree)

"I - when did you finish doing physics?

S2 - three years ago

I - for how long did you study physics?

S2 - three years .. in the 8th and twice in the 9th grade .. I failed the first 9th ..(laughs)

I - during the period you did physics did you learn what you would like to learn in physics?

S2 - .. I mean .. for me physics .. I haven't a definite idea about physics..

I - before starting to study it?
S₂ - yes .. physics appeared to me as something new .. and I found it .. I don't know ... only as a knowledge of general culture .. do you understand? .. it didn't appeal to me .. in fact .. I never was in love (laughs) with physics and I will never be .. and for me that was something ... uhm ... er .. if I hadn't had the subject .. it would be the same ..

I - look .. when someone speaks about physics .. what does physics mean to you?

S₂ - sincerely I never thought about it ..

I - don't you have any idea of what physics is about?

S₂ - .. I mean .. I need to think hard ... I don't know .. maybe ..... physics ..... I don't know ... various factors .... let me see if I can think ...... in fact .... this now .... it got me unprepared (laughs) .... it got me unprepared ... that ... what physics is about ...

I - look do you remember if you did any experiments in physics?

S₂ - .. in physics? ... let me see .... in chemistry I still remember but ... physics ..... I can't remember .... I don't know .. I'm thinking about ... something ..... it was like ... but I'm not remembering very well what it was ... I think it was something made of wood .. and then it had some little thing made of iron and .... a ball .. that's it ... an iron ball ... I think that is physics .. isn't it ? (laughs) .. I can't remember .. I must think ..

I - but do you remember what was for?

S₂ - .. no ... no .. I can't remember .. I'm not seeing .. that ... I have a vague idea about physics .. it is physics isn't it?..

(21 years old boy; working in a factory)

"I - when did you finish doing physics?

S₃ - in the 9th grade .. so .. four years ago ..

I - for how long did you study physics?

S₃ - I think it was only one or two years .. I can't remember very well ..

I - in the 8th and 9th grades?

S₃ - yes ..yes it was during two years

I - what does physics mean to you?

S₃ - .. I don't know .. when I studied it I didn't enjoy it very much .. now at this moment I find that it must be interesting .. and I think physics is a science that is going to have a great impact on the future .. but .. concretely for me ... I never thought of it..

I -uhm .. during the period in which you did physics did you learn what you expected to learn?

S₃ - well ... I didn't expect many things ... thus I think I learned what I expected .. because I started it without knowing what it would be about ... I expected a new thing .. well and in a new subject everything I learned was more than I was expecting ..

I - and what would you like to have learned in physics that you haven't?
S₃ - .. I don't know .. perhaps .. things .. just a bit more concrete .. because .. for instance now I think .. I know nothing about physics .. if they gave us a more concrete view of what physics was about ... what's its interest is ..maybe it would have helped .."

(18 years old girl; 1st year of university, Languages Teacher Training degree)

The same ideas were conveyed by the students who were taking classes in physics. At this stage, as they already knew what physics was about, some of them could remember some of the things they thought they would like to learn in physics before they started learning it, but often they only remembered what they were studying at the moment. What they had studied in previous years was only vaguely remembered. This was reflected in conversations about what else they would like to learn in physics.

(Extracts from four interviews)

"I - Do you remember what you did last year in physics?
S₁ - .. no ... I can't remember (laughs) .."

(16 years old boy; 11th grade)

"I - do you still remember what happened in your physics classes in the 8th grade?
S₂ - .. I think .. we studied the Periodic Table
I - .. in physics?
S₂ - uhm .. in physics ..... in physics .... maybe ... uhm ... dynamics ..
I - uhm..
S₂ - .. I don't know .. I don't know if it was that .. I can't remember ..
I - and at the 9th?
S₂ - .. in physics ..... we did .... well I'm remembering what we did in chemistry but in physics .. I can't remember very well .... really I can't remember
I - and last year at the 10th grade?
S₂ - last year .... we did .... last year we did ...... in physics ...er ... er ... we did dynamics ... I think ... I can't remember .. something related to motion .... I think it was only that .. I can't remember that .."

(16 years old boy; 11th grade)

"I - .. those things you had already done in physics .. what do you think about them?
S₃ - ... well they are ideas that I learned .. and they are useful to any understand ...er .. and .. I mean .. I'm sorry .. because what I learned .. when I learned ... it wasn't based on practical applications .. it was too much theoretical ... thus .. we forgot that much more easily .. sometimes many important things ... we can't even remember .."

(16 years old boy; 11th grade)
"I - .. what else would you like to learn in physics?

S4 - (laughs) .. no I haven't never thought about that .. I mean .. we do the subject and we haven't time to think deeply about what more we would like to learn ..

I - why do you think that happens?

S4 - you know .. we go to classes .. the teacher gives the subject and we learn ... we aren't .. how should I say it? .. now part of physics is electronics and in that part I would like to have learned more .. I mean .. we never learned about it .. the only thing we learned was a bit of electricity .."

(16 years old boy; 11th grade)

If one of the aims of physics teaching in general education is to help pupils to develop a theoretical understanding which enables them to interpret and make sense of everyday experiences, then an urgent reassessment of the physics curriculum, as well as teachers' strategies for teaching, are needed. It means selecting illustrative phenomena not simply because of the support they give to a theoretical idea, but because they are of practical use and of everyday interest in their own right. It also means bringing the theoretical ideas within the compass of pupils' understanding.

This last point is deeply intertwined with another finding from the protocol analysis. It related to students' understanding of what is being said by teachers. Many research studies in recent years have shown that students often bring to the classroom explanatory patterns of intuitive physics that represent a common and self-consistent set of concepts that, although sometimes different of the scientific ones, can persist beyond all instruction. Substantial evidence from a wide variety of sources (e.g. Driver, 1973; Leboutet-Barrel, 1976; Viennot, 1979; Gilbert, 1977; Driver and Easley, 1978; Nussbaum and Novick, 1981; Anderson and Kärrqvist, 1981; Gilbert et al., 1982a; Clement, 1982; Gilbert et al., 1982b; Shipstone, 1984; Driver et al., 1985) shows that pupils, on the basis of their everyday experiences of the world, hold their beliefs and expectations very strongly. Before formal teaching, children have already acquired meanings for many words commonly used in science lessons which are referred to by Driver and Easley (1978) as 'alternative interpretations'. They are an important part of children's culture and they have a large significance for subsequent learning. Consequently it is extremely important that teachers are aware of "children's science" as termed by Gilbert et al. (1982a). Through observations carried out by me in secondary school lessons I encountered some of these students' patterns and I could appreciate the difficulty teachers have in handling them. For example, in a lesson in which pupils and teacher were discussing the forces exerted by two men on two equal cars placed at different positions on an inclined plan, one of the pupils was arguing her views strongly
by saying:

"... gosh .. I can't believe that .. it's obvious that the man in the upper position is using a bigger force than the man in the lower position .. it's evident ... I can't see why you are telling us that the forces are the same .... the inclination is bigger at the upper position ... the man has to face a bigger resistance than the other at the bottom ..... I will never believe that ...

The teacher was astonished. She could not understand where the problem was. For her it was obvious that the man in the upper position was exerting the same force as the other man. They discussed and argued about it but, by the end of the lesson, both views remained the same. For both their points of view continued to be 'obvious'.

At the Meeting of the Portuguese Physical Society held in Coimbra in 1982, I presented a study on the concept of force held by students in the 9th, 10th and 11th grades and 1st year of university (science and humanities areas). The study was based on the application to that population, of a questionnaire developed by Watts and Zylbersztajn (1981). The results of this study are summarized in Appendix 4. Even more alarming than the results themselves was the teachers' reaction to the communication. There were about three hundred teachers. It looked as if, for the first time, they were being confronted with this problem. After the communication I heard teachers' comments like the following: "What on earth are we doing?", "What does that really mean?", "How can it happen?", "I never thought that would be possible!", "What have we been doing?". It was apparent that most of teachers were unaware of the gap between "children's science" and "teachers' science".

In order to get a better insight into this issue, I injected during the interviews reported in this thesis the question "Do you think that your students normally understand what you are talking about?". Some extracts from the interviews can give an account of the teachers' views about this problem.

(Extracts from interviews)

"I - .. do you think that your students normally understand what you are talking about?

T - .. er ... well I think they don't ... I think there are several things they don't understand ... certain things and some pupils ..

I - and why do you think that happens?

T - .. because I realized .. after tests and things like .. that .. probably I wasn't very clear ... I didn't use the best strategy .. I realized that the strategy I
used wasn't the best one ... because it wasn't complete .. or because I didn't speak very well ... or ... well ... there is my component .. but there is also the students' component .. they have very closed minds .. they are limited .. they came here with a deficient preparation .. to my mind ... these are the two main reasons .."

(physics educator teaching at the university)

"I - (the same question)

P - .. I feel ... many times .. I feel strongly the difficulties that they are feeling ... in fact I realize .... for instance that what was extremely simple to the students some years ago .. nowadays is very difficult for them to understand ... yes ... they have difficulties sometimes ... you see ... things weren't assimilated very well .. I notice this in tests ... and I notice also another thing .. they don't realize that what they are writing isn't what they are thinking ... I think so ... students .. normally have difficulty in understanding what we are conveying .. above all they show a great difficulty in following the course ... and I consider myself a slow teacher .. I mean I don't usually go to fast ... but .. the pace is completely different from secondary school .. they cannot cope with that .."

(physics teacher teaching at the university)

"I - (the same question)

P - oh .. yes .. sometimes they bring some ideas already acquired .. wrong ideas which they can't get rid off .. or it takes time ... but .. after some time they lose them .. but it is difficult .."

(physics teacher teaching at the university)

"I - (the same question)

T - sometimes .. some of them don't understand or .. they interpret wrongly ... but in general .. I think they understand .. but then .. they don't know how to study or .. I don't know ... there is really some fault somewhere ... there isn't exactly a link .. well I also think that it is ... or .. overall .. this happens because they don't have .. I find ... I mean .. they don't know how to read .. and then something they have .. notes .. or books .. they don't know how to read them .. then they don't know how to answer written questions .. and when we ask them orally .. they say .. 'oh! .. that I knew' .. when we talk to them ... that's different .."

(secondary school teacher)

"I - (the same question)

T - ... it happens .. for instance .. concretely in tests I realize that our students have a great difficulty in interpreting questions .. this happens very often .. during tests they use to come to me and say that they aren't understanding what I want with the question .. I read it and they say 'O.K. I already understand!' .. I mean .. I read it making pauses and emphases .. and that was just enough for them to understand what I wanted .. this is one of the aspects .. the difficulty they have with our language .. in the interpretation of questions .. during classes ..... maybe someone in not understanding .. but generally I think they understand ... at least they say they are understanding what has been said .."

(secondary school teacher)
"I - (the same question)"

T - that's inevitable ... it has happened ... I don't remember any case now ... but it happens ..

I - why do you think that happens?

T - well .. sometimes when that happens ..... it can be because pupils aren't paying attention ... but the language .. let's say ... for instance .. words that are completely clear to us ... for some pupils have different meanings .. therefore .. concepts which involve certain terms .. aren't the same .. and that has an influence .... there isn't any doubt that happens ..

I - can you remember any particular case?

T - ...... er ..... I can't remember any one now ... but if I remember I will tell you .."  

(secondary school teacher)

"I - (the same question)"

T - ..well .. I care .. as all teachers do ... that what I intend to transmit is understood by students ... but many times they stick to some ideas which don't let them understand .. they are stuck to them and they don't reason in a clear way .. and teachers .. sometimes make that mistake .. they think that the subject is understood well by students .. as a function of their own reaction and not as a function of students' reaction .. because the teacher found that lesson was good .. for him .... for him everything is so evident that it seems obvious that the students should understand it in the same way .. and I'm convinced that not all the time that happens .."  

(secondary school teacher)

"I - (the same question)"

T - ... sometimes ..... really one can detect ... a slip .. the speech doesn't reach the pupil in a correct way .. and then one thinks .. yes ... but really most of the times there isn't that feedback from pupils to teacher .. and the teacher isn't aware of that ... you see .. classes are too large .."  

(secondary school teacher)

"I - (the same question)"

T - .. in general ... I try to be understood ... but sometimes I feel that they don't understand .. certain kind of concepts ... I think they are understanding but .... well I feel myself frustated when I ask some questions ... and I got the idea that they are understanding ... but then .. when I ask for an application .. I realize that they didn't understand ... you see .. at the end they didn't understand .. they only memorize .."  

(secondary school teacher)

The above extracts summarize the main reasons given by teachers for students' incomprehension. According to the majority of them the students' lack of understanding is due to: (a) lack of clarity of teacher speech; (b) the use of a bad strategy by the teacher; (c) pupils' closed minds; (d) pupils' lack of basics;
(e) pupils' lack of study; (f) pupils' disinterest in learning; (g) pupils' ideas that must be displaced; (h) pupils who do not want to understand; (i) pupils who do not pay attention; (j) pupils who do not know how to read properly.

The assumption underlying these arguments is that the learner's blank mind can be filled with teachers' science (Gilbert et al. 1982a). Teachers aren't aware of students' views prior to teaching and their implications for the teaching/learning process. However some of the interviewees mentioned the fact that they have found that sometimes, pupils have conceptual views that are difficult to replace. Nevertheless these findings seemed to have no implications at all for their teaching strategies. Either because pupils' ideas or meanings for words are not recognized as being sufficiently strong that could persist or interact with teaching, or because teachers who recognize this have not enough time to explore them and build up learning experiences taking those ideas into account. Even more, though some teachers recognize pupils' views they are not acquainted with the techniques of identifying and exploring them.

During my observations in classroom situations I came across another source of pupils' difficulty in learning physics. This difficulty concerns the problem of symbols. How far can a pupil understand the symbols that are used so much in physics teaching? This question arose after the observation of some situations which emerged in classes where the concept of force was being taught. In one situation one pupil was asked to draw, on the blackboard, the weight of a body in two situations: when it was in the air during its free fall and when it was standing on the earth. In the first situation the pupil showed no difficulty in drawing the vector correctly, but he could not draw it when the body was on the earth. The teacher asked him insistently to draw the body's weight in that situation. He draw some vectors around the body, as shown on the picture bellow:

![Diagram](image)

The teacher asked him: "why can't you do in situation 2 the same that you did in 1?". The pupil kept silent but looked very confused. His brain could not allow him to point the vector into the earth. He acted as if he was considering the vector symbol as a real arrow. The situation was not resolved and the pupil was ordered to sit down and another took his place on the board. I continued to look at him and could see that he did not pay attention to what was going on at the board, showing no signs of interest in the resolution of the problem.
The same difficulty emerged in another class where one pupil was asked why a book on a table did not fall down. The pupil made the following drawing:

and explained that the book would not fall down because it was nailed on the table. He was transforming the vector into a 'hail' form.

A very common situation happens when pupils are asked to represent, for instance, the force exerted by a man on a body pulled by him with a string.

They usually draw the vector so that the extremity reaches the man's hand. I have noticed that teachers are not aware of the meaning of these drawings. They shorten the vectors themselves or ask pupils to do it without any further investigation. None of the teachers interviewed made any reference to the understanding of symbols by pupils. I think this would deserve a deeper investigation.

Students are not aware of their own views before teaching because, probably, they have not had opportunities of confronting them with teachers' views. They have been acting as receptors. This can be elicited by some extracts of interviews.

(Extracts of interviews with students)

"I - Do you... normally... understand what your teacher is talking about?

S1 -... er... it depends... but some times I don't...

I - why is that?

S1 -... I don't know... maybe... a lack of a basic notions... er... it's a bit difficult to understand the things that teachers talk about..

I - and do you think teachers are aware of that?

S1 -... I think... sometimes they are... because... for instance... there are certain things... which are obvious for us... and they keep explaining them in a more detailed form but others in which we have more difficulty... these are given in a rush... at least it has been happening a lot of times... and sometimes... it upsets us... because... we are listening and listening... wasting time... and there are other things which are more difficult... at least they aren't so evident and they are taught... in a rush..."

(17 years old girl; 12th grade, scientific area)

"I - (the same question)
S₂ - well I try to understand .. (laughs) .. I mean normally .. I understand .."
(17 years old girl; 12th grade, scientific area)

"I  - (the same question)

S₃ - .. at the moment ..... sometimes yes .. sometimes no ... only later on ..
I  - why do you think this happens?
S₃ -.. perhaps the subject is more difficult ... also sometimes I'm not paying
attention (laughs) .."
(16 years old boy; 10th grade, scientific area)

"I  - (the same question)

S₄ -.. normally .. I understand .. usually the teacher .. after explaining a thing
... thinks that we didn't understand and .. in trying to explain it better ..
things become more complicated ... usually that is the worst of it .. by the
end .. nobody understand anything .."
(15 years old boy; 10th grade, technology area)

"I  - (the same question)

S₅ - I understand ... what she is talking about .. only sometimes .. it is she who
makes things more confused (laughs) .. but that is a teacher's fault .. not
mine .. I understand .. usually .."
(15 years old girl; 10th grade, scientific area)

"I  - (the same question)

S₆ - ... I mean .. I understand .. but .. if I ask her to clarify some doubts .. I think
she doesn't know how to explain it to me .. and I get more confused .. and
I loose interest .."
(15 years old girl; 10th grade, scientific area)

"I  - (the same question)

S₇ - yes .. I understand .. I'm already .. how can I say it? .. I'm .. more or less
mechanized for learning easily..
I  - what do you mean by this?
S₇ -.. well .. the teacher writes a formula and one tries to understand it .. many
times I don't understand .. but .. I mean .. it stays more or less memorized
.. without understanding .."
(16 years old boy; 11th grade, technology area)

"I  - (the same question)

S₈ - I mean .. if I like the subject .. I understand what has been said .. because
.. for me that is fundamental .. for instance .. in the 8th grade I liked physics
better than now .. I understood at that time .. but now .. I'm not so interested
.. I don't pay attention during classes and I don't understand .... at the 9th
.. and even now ..the teacher is talking about one thing .. and I'm understanding
another ... only some time later I realized that .."
(15 years old boy; 10th grade, technology area)
"I - (the same question)

Sg - ... sometimes I understand .. but .. when I don't understand I don't try to talk with the teacher .. because she starts to mix everything up... or .. it seems that she doesn't know how to explain things ..."

(14 years old girl; 9th grade)

"I - (the same question)

S10 - yes .. normally I understand .. only sometimes ... when things get too complicate with lots of demonstrations of formulas .. with too much maths .. (laughs) .. "

(16 years old boy; 11th grade, technology area)

"I - (the same question)

S11 - .. yes I understand ... usually I understand .. physics isn't too difficult .."

(15 years old boy; 10th grade, scientific area)

With some students, mainly those giving answers like the last one, I could not resist asking them a last question about situations such as "are there any forces on a ball on its way up after leaving your hand?". Usually the answer was "yes .. there is a force upwards that makes the ball go up". As I expected it is not easy for students to perceive this gap between their own' and their teachers' views. In the way assessment has been undertaken, it is also difficult for teachers to detect this problem.

It is interesting to examine some of the perceptions students have of the best way of learning physics. That was my purpose when I introduced, during the interviews, the question "According to you, what would the best way of learning physics?". There is a great similarity among these perceptions as can be shown through some extracts of interviews.

"I - According to you, what should be the best way of learning physics?

S1 - I think .. we should have more general notions from the beginning .. we should have more practice .. better conditions .. the apparatus should be in order ... I mean we should learn .. seeing that really things happen in the way we are told ... if not ... a doubt is left .. would it be like that? ...

(17 years old girl; 12th grade, scientific area)

"I - (the same question)

S2 - I think the person's participation is very important .. but .. you see .. at the time .. the topics must catch a person's attention .. subjects must foster interest .. because we like to participate but .. the subject must arouse some interest .. it must be relevant .. students should be stimulate to participate .. instead of classes where teachers pour out their knowledge ...they should
... I don't know ... but I think .. they should stimulate debates .. discussions .. and maybe we would draw some conclusion by ourselves .. I think it would be more interesting .. at least .. sometimes good discussions arise in classes that give us new perspectives .."

(17 years old girl; 12th grade, scientific area)

"I - (the same question)

$S_3$ - I think it should be based on experimental investigations .. one looses interest if things aren't seen .. I mean .. if one sees .. and that was my own experience in the 8th grade ... one likes more .. because .. er ... one finds it funny .. to see how things can be applied .."

(18 years old girl; 12th grade, scientific area)

"I - (the same question)

$S_4$ - .. er .. to my mind .. at least at the secondary school level .. every teacher should be more concerned with the experimental part .. as you know .. we have almost nothing now .."

(17 years old girl; 12th grade, scientific area)

"I - (the same question)

$S_5$ - I would like most ... if it would have more practice .. because I think what students like most is the experimental work and no theory .. I think that experimental work has a great influence on students' interest toward physics .."

(18 years old boy; 12th grade, scientific area)

"I - (the same question)

$S_6$ - .. maybe ... related to everyday phenomena .. because when we are .. only talking about physics .. at least it happened to me ... I have a tendency to separate it from things that happen in everyday life .. and if those things .. were taught in a way that we could see the relations ..... I think it would be more effective .."

(15 years old boy; 10th grade, scientific area)

"I - (the same question)

$S_7$ - I don't know .. it should have an experimental component .. because .. as you know we have nothing ..

I - why do you think that an experimental component is important?

$S_7$ - ..well if we are learning about physics phenomena ... physics phenomena aren't to be learned in a class with talk and chalk ... for instance .. now .. the teacher started talking about uniform circular motion and nobody is thinking what it really means .. and she draws graphs on the board ... and nobody understand them ..

I - so .. you think that the experimental work has an important role in physics teaching ..

$S_7$ - oh yes .. indeed I think so .."

(15 years old boy; 10th grade, technology area)
"I - (the same question)

Sg - well .. teachers ought to communicate with students .. let's say .. bring up questions .. debates .. and they should try to guide a sort of debate .. I think it would arouse more interest .. as well as to show us how things work .. like doing experimental work ..

I - didn't you have that experience?

Sg - oh! no .. no ..

I - so how have classes been held?

Sg - like normal classes (laughs) ..

I - what do you mean by normal classes?

Sg - .. classes where the teachers explain .. put some drawings on the board .. now my teacher has given us some paper and pencil problems ... I even enjoy that .. but nothing else .. nothing to arouse enthusiasm .."

(15 years old girl; 10th grade, scientific area)

"I - (the same question)

Sg - .. it would be better if we have more contact with the problems .. through experimental work .. yes .. to have a concrete problem .. from day-to-day life .. and we .. by ourselves .. draw the conclusions .. of course helped by teachers .. but to me .. experimental method arouses much more attention .. much more interest .."

(15 years old girl; 10th grade, scientific area)

"I - (the same question)

S10 - .. oh ... that's .. I don't know (laughs) .. it should be more based on practice .. perhaps ...

I - why?

S10 - .. well really they are some limitations .. for instance there aren't environments without friction here on the earth and things alike .. but .. mainly when motion is the topic .. it starts to be very vague .. I don't see anything in practice .. everything is too theoretical .. I never see a car moving with rectilinear motion .."

(16 years old boy; 11th grade, technology area)

"I - (the same question)

S11 - .. I think we should do more experiments .. not so much prose because physics is for us to see what is happening .. to see phenomena and that isn't done by talking .. talking .. it should be based on experiments .."

(14 years old boy; 9th grade)

"I - (the same question)

S12 - well .. first .. the students shouldn't be taught .. I mean .. they should be taught to learn by themselves .. and secondly .. physics learning should be based on experiments .. because physics is an experimental science .. and this year we haven't done many experiments .. actually we hadn't done any .."

(16 years old boy; 11th grade)
"I - (the same question)

S_{13} - I don't know .. I think through experiments .. it would be more interesting ..

I - why?

S_{13} - I think it would motivate more .. the students' attention is called upon more .. it's something they can see instead of something that is only in books and that .. can be or can't be .. isn't it ? .. in principle it is true but .. we can't really be sure if we don't have the opportunity to confirm it .."

(15 years old boy; 10\textsuperscript{th} grade)

"I - (the same question)

S_{14} - .. I don't know .. but I think .. teachers .. the most part of them .. I don't know .. but they should feel what they are talking about .. instead of looking at books .. they should feel what they are saying and then .. they should be helped by experiments .. it makes us understand the subject better .."

(16 years old boy; 10\textsuperscript{th} grade)

"I - (the same question)

S_{15} - .. based on experiments

I - why?

S_{15} - one understands much better .. because a person can SEE .. can see things happening in reality .. one understand better than .. even because things stay in a person's head .. one remembers them much better .."

(15 years old boy; 10\textsuperscript{th} grade)

"I - (the same question)

S_{16} - .. I mean the best way .. maybe .. if much more applications should take place .. more practicals .. really the experimental part done in schools is too small .. perhaps because syllabuses are overloaded and .. almost always .. it is .. er .. let's say .. teachers aren't really interested in doing lab work .. to me if practical was compulsory .. more students would learn and understand physics better .."

(16 years old boy; 11\textsuperscript{th} grade, scientific area)

"I - (the same question)

S_{17} - perhaps .. first a theoretical part .. and then after a certain topic .. an experimental part ..

I - uhmm .. why? .. is it important?

S_{17} - .. because being like that .. we could draw conclusions about the agreement between theory and practice .. and (laughs) we would believe in theory .. because .... very often theory .. looks .. let's say .. a bit untrue (laughs) .."

(16 years old boy; 11\textsuperscript{th} grade, scientific area)

"I - (the same question)
S18 - physics is an experimental science isn't it? .. so .. the learning of physics should be based on experiments .. and not based on talking and drawing .."

(16 years old boy; 11th grade, technology area)

"I - (the same question)

S19 - .. I just think that it should have more experiments .. not so much prose .. because physics is for us to see phenomena .. and that isn't always talking .. it should be practical also .."

(14 years old girl; 9th grade)

"I - (the same question)

S20 - .. I don't know .. I think through experiments it would be more interesting .. much more interesting ..

I - why?

S20 - I think it motivates students much more .. it catches more their attention .. it is something they can see instead of something that comes in books and which can be true or not ... well it should be .. (laughs) but we can't confirm that truth .."

(15 years old boy; 10th grade, scientific area)

"I - (the same question)

S21 - .. I don't know .. but I think teachers should feel what they are talking about instead of looking at books .. they should feel enjoyment for physics .. and they should be helped through practical work .. and students would enjoy the classes too .. we would like to go to classes for their own sake .. it shouldn't be like going to classes .."

(16 years old boy; 10th grade, scientific area)

"I - (the same question)

S22 - with practice .. a lot of practice ..

I - why?

S22 - because so we can see .. if physics studies some phenomena of nature .. they are things that can be demonstrated practically .. instead of being so theoretical .. one can see .. and I think it has much more interest if we draw conclusions for ourselves .."

(15 years old boy; 11th grade, technology area)

The students' views emerging from these extracts are representative of all the other interviews as well as the views of other students to whom I have talked after class observations. The central idea is related to experimental work, but it's role it is not well defined. They do not either have the maturity or the experience to understand the real purpose in doing experimental activities. They referred frequently to 'see things', because in most cases all the experiments they have involves watching demonstrations, used to illustrate and confirm 'accepted'
principles. Laboratory work should be an important feature of physics teaching. Yet teachers may not be making the most of this important resource. All student teachers and teachers interviewed seemed to believe that the best way to teach physics is based on experiments. The latter expressed their reasons why it is not done. Some extracts of interviews can illustrate their views on this issue.

(Extracts of interviews with student teachers in the last year of the university and with practicing teachers)

"I - What according to you should be the best way of teaching physics?
S.T.1 - well .. I think students should start working by themselves .. well .. when it is possible .. because not always .. materials are available .. neither material nor time .. well .. but I think teachers must .. as often as it is possible .. give students what we didn't get .. I mean .. the link with things we see everyday .. because we talk here at the university about motivation .. we are taught about the importance of motivating pupils ..."

(student teacher; 4th year of Physics degree, educational branch)

"I -(the same question)
S.T.2 - the best way to teach physics is through experiments .. of course it must have theory .. and after experiments they must draw conclusions it's obvious .... but I think experimentation in physics it's fundamental .. I even think that physics without experiments .. leads kids to detest physics .."

(student teacher; 4th year of Physics degree, education branch)

"I -(the same question)
S.T.3 -..it's a bit difficult to answer that question .. (laughs) can't it be chemistry instead of physics?
I -do you have ideas about the best way of teaching chemistry?
S.T.3 -yes .. because chemistry is more based on experiments than physics ..(laughs)
I -why?
S.T.3 -because all through my schooling I always did more experiments in chemistry .. in physics I only did something related to electric current .. but otherwise .. it was more reading .. the teacher explained a few things .. well studying physics in this way .. uhm ... it's not very interesting .. I think it was for this reason why I didn't enjoy it very much .. although I'm in a Physics and Chemistry degree! .."

(student teacher; 4th year of Physics and Chemistry degree)

"I -(the same question)
S.T.4 - in the lab .. because I think it's easier for kids of 13 or 14 or even 15 years old .. who are in a concrete phase of thinking .. to learn a concept which he sees .. which can be verified in front of him .. than to listen and listen and listen ...

(student teacher; 4th year of Physics and Chemistry degree)
"I - (the same question) 

S.T. 5 - well I think overall .. students must be motivated .. I mean .. they must feel the necessity to explaining phenomena .. to know why things happen .. so first .. motivation .. and then they must be confronted with a problem ..which they are going to try to solve through experiments and to try to draw conclusions .."

(student teacher; 5th year Physics and Chemistry degree)

"I - related to experimental work .. for instance is it possible at 10th and 11th grade to do experimental work? 

T - absolutely impossible .. 

I - why? 

T - many circumstances .. we don't even have proper classrooms for doing it .. er .. because .. labs .. are occupied by other classes .. classes of other subjects .. and .. it would be necessary to have .. technicians who are badly needed in schools .. and also .. for doing experiments .. the syllabus should be reduced .. to me .. physics should start to be taught earlier .. at the 7th grade .. 

I - .. when for example you are teaching kinetics or dynamics .. without experimental activities .. how do students react? 

T - .. well .. er .. they .. of course we give them a description of possible experiments .. I mean .. with pictures .. slides .. but .. it's true .. something is missed .. the student should handle .."

(secondary school teacher; teaching the 12th grade)

"I - look .. now as you mentioned the experimental work .. how do students react to it? 

T - .. well .. they always enjoy it .. they participate .. but it needs a good preparation .. sometimes even with everything planned .. things don't run very well .. there are always problems .. due the size of the class .. thirty pupils .. six groups of five students .. as you see it is too many people .. and the rooms aren't large enough .. well all these things can ruin any practical class (laughs) .. but anyway .. it is always worth trying .. if there is time and material available .."

(secondary school teacher)

"T - ..you know .. in physics I notice a fault in the experimental component .. 

I - why? 

T - because .. there is no experimental component in physics teaching .. look .. I don't know why .. for instance .. until the 9th grade .. even with very poor conditions we try to do experimental activities .. I think that is fundamental .. teaching physics at that stage without experimental component is absurd .. at 10th and 11th grade .. some years ago there were experimental classes .. they belonged in the curriculum .. nowadays those classes are abolished .. so .. as you see .. with the syllabus which we ought to accomplish overloaded .. and .. all these fluctuations in school timetable .. we don't have any chance
to do practical work.. I would love it if the curriculum could be changed... contents... everything... in order that students could undertake their own experiments... to draw their conclusions... unfortunately our teaching isn't that way... and students are only filled up with teachers' talking..."

(secondary school teacher)

"T - I think... teachers are constrained too much by the curriculum... they are in a way obliged to follow a very very straight line and ought to cover all the syllabus... it's impossible... to do inquiry in the lab... it's impossible..."

(secondary school teacher)

"T - actually I think... well we change... change our opinions... don't we?... (laughs)... but I start thinking that physics teaching from the end of the last century to the beginning of this... have had a great mathematization... which had the highest degree with Maxwell... where effectively the mathematical mind invaded physics and... in consequence... physics changed to an extremely formal science... and I think in a great majority of teachers there is a continuity of this... it's easier... starting from principles... making some deductions... and get to the end... and write what was intended to demonstrate... in physics it's easier to teach in that way... in a deductive way... to get the mathematical expressions and... I think it's easier for students too... because they know that they will get there if they do everything right... they don't understand anything in physics... but in order to learn the subject... to pass exams... it's the only thing necessary... that's true... you know it... there are certain topics... for instance optics... geometrical optics... unfortunately... may be I'm not exagerating... in 95% of the cases what teachers teach is geometry and they don't teach optics at all... as far as I know at the university... physics is taught in a way inherited from the end of the last century and... there is no doubt of that... that doesn't attract anyone... and we have fewer and fewer people motivated and with enthusiasm for physics..."

(physicist teaching at the university)

"I - What according to you would be the best way to teach physics?

T -... well... the best way would be... in a good laboratory...with possibilities... for instance... with audio-visual aids... good slides... bringing to classrooms phenomena that students can observe in their day-to-day life... and then trying to explain them... and in order to that... to use the experimental part... the laboratory... but very well equipped... that would be... ideal... because really that is utopia..."

I -... why do you say it's utopia?

T -... oh... first... with the number of pupils in each class we have... with the schools we have... with the labs we have... that is impossible...

I - from all those factors which one do you think is the most important?

T -... the teachers... that's the truth... because even without materials... without anything we can catch students' attention... what we need is teachers who really care..."

(secondary school teacher)
"T - well ... physics is basically an experimental science .. it's an exact science .. so it must be learned through experiments .. experiments that should be undertaken by students themselves in labs .. certain kinds of experiments .. to illustrate and confirm phenomena and principles .. which they learn theoretically .. they must get the idea that all the other ones they study and .. which aren't illustrated .. have also an experimental evidence .. it would be an aim to achieve .. the enjoyment of lab work .. they should link physics phenomena to everyday phenomena .. these experimental classes should be held in laboratories .. being preceded by a lecture .. where students should have the theoretical concepts .. and then in the lab .. they should be left alone .. they should have all the equipment on benches ... but the objectives of the work should be learned beforehand .. what they want to verify .. what they want to demonstrate .. where they want to get .. etc. .. and they should try to do the work without help .."

(physicist teaching at the university)

The strong emphasis on lab-work done by students that emerged from the protocol analysis as the best way of learning physics isn't a new finding. Since the beginning of this century it has been accepted in many countries as an essential element in physics teaching. All the teachers interviewed made an appraisal of the role of practical work in secondary schools and universities. But, in spite of this, lab work or experimental activities have not been used in the approach to the teaching of physics in our schools. When I am referring to lab work I refer to any work involving experiments in laboratories. By experimental activities I am referring to experiments done in any classroom where students are involved in hands-on activities. As can be elicited from the interviews, for most teachers and students, experiments can only be undertaken in 'proper classrooms', i.e. laboratories. However, they see as an aim of experiments to be an understanding of everyday phenomena. Nevertheless everyday phenomena do not happen in laboratories. It should be more efficient if students undertake their own investigations under normal class conditions.

It is interesting to note that, once more, the perspectives held, either by teachers or students, are content-oriented. The role of experiments is viewed as an illustration of principles, confirmation of laws or explanations of everyday phenomena. Neither of the teachers or students interviewed referred to the development of skills, attitudes and habits inherent to the processes of science. In an attempt to investigate what were teachers' views about this issue I injected, during the interviews, the question "What capacities do you think can be developed in your students by teaching them physics?". Many teachers did not give a direct answer, showing an uncertainty about what those capacities involve.
"I - Which capacities do you think can be developed in your students when taking your course?

P - .. well I try .. to show that things are driven by observation ... and to develop physics comprehension .... without formulas .. but I find a great difficulty .. students are very uninterested .. they don't want to learn physics .."

(physicist teaching at the university)

"I - (the same question)

T - .. well .. on one hand .. the capacity of ... of looking at ... or preparing their lessons .. sometimes subjects which weren't covered during the course ..... er .... they should be able to teach them .. to know where they should go when they are teaching .. to achieve the capacity for changing the strategy if necessary .. to explain in a different way so their pupils can assimilate well the subjects being taught .."

(physics educator teaching at the university)

"I - (the same question)

P - first .. critical mind .. one thinks that it is totally absent .. then a certain capacity of initiative .. inclusively in the practical aspect of being able to do small demonstrations in classes without being stuck to a textbook ..... capacity for devising ... er ... a simple experiment without being always appealing to abstract notions .. a certain creativity .. and a certain .... but this as something to do with their basic knowledge in physics .. a certain capacity of developing a suitable answer for pupils at different levels .. this and other difficulties I have identified in student teachers in teaching practice ... the lack of capacity to give to an apparently simple pupils' question an answer different from the one they learned at the university ... I mean .. they could have learned a concept mathematically very well defined .. but .. in a class situation .. they can't give a simple answer .. er ... I suppose a teacher gone out from the university shoul be able to do that .."

(physics educator teaching at the university)

"I - (the same question)

T - ... er .. observation ... critical mind .. to know how to link a certain number of facts with the knowledge they are achieving .. I don't know .. interest by certain topics .. certain areas .. certain things from day-to-day life ...

(secondary school teacher)

"I - (the same question)

P - .. well .. I think .. er .. there is a very important aspect ..on one hand .. they ought to feel that physics is culture .. I mean .. it's their profession .. but it is also part of their culture .. there is .. that I would expect .. that I would like my students ... er ... let's say .. it is a good tool I would like they achieve .. er .. the capacity of assimilating innovation in the scientific field .. let's say .. to a certain degree a student must be given the capacity of assimilating innovation ... because as teachers they will be confronted with situations
... the pupils who read the newspaper .. the child who says .. 'but ... explain to me .. for instance .. what caused the disaster of the nuclear reactor .. in America! .. the teacher has to be able ... to have tools .. er .. to create their own knowledge .. it looks very important to me .."

(physicist teaching at the university)

"I - (the same question)

T - .. in fact what I expect they learn in physics ... it is ... they must get ideas that physics is an experimental science ... and that they have to perform ... certain kinds of experiments .. which they learn theoretically ... so .. I expect they get enjoyment from laboratory experiments .. to get a knowledge of how to explain .. to link physics phenomena with everyday phenomena .."

(secondary school teacher)

"I - (the same question)

T - .. well .. more reflection on .. the capacity of .. application of knowledge .. all those problems .."

(secondary school teacher)

These extracts are representative of all the other teachers' ideas about this issue. In general, teachers see the role of practical work in secondary school, or even at the university, as a means to extend pupils' knowledge of phenomena, to illustrate and confirm principles. In a word, they are concerned with experimental work as content-oriented teaching. They did not mention experimental activities as opportunities to encourage individual initiative and imagination, to develop skills of accurate observations, measurement, hypothesizing logical arguments, self-confidence and alike. All these skills are relevant to everyone in any profession. It is my belief that it more important for school leavers, or for students who carry on with their studies in non-scientific areas, to have acquired these skills than to accumulate information that are most likely to be forgotten sometime later. Only three or four teachers mentioned capacities of observation and critical mindedness. I have had opportunities to observe some episodes in classroom which show that some teachers were uncertain about what those skills involve. I will describe one episode that illustrates this point. In a class where pupils were dealing with experiments related to the topic 'substance, elements and mixtures' the pupils working in groups were provided with worksheets with instructions written by the teacher. On the worksheets, after the instructions, there were blank spaces for pupils to write the results of their observations. Each group had a specific task to carry out. The task of one of the groups was to fill up a glass of water and add some sugar in. All the instructions were written on the sheet. After that,
the pupils were asked to fill in the blanks, writing down what they had observed. After several days I had the opportunity to read the worksheet of that particular group. It was written there that: 'What we observed: the sugar molecules occupied the spaces between the water molecules'. I asked one of the girls of the group if they really observed what they wrote. The girl's answer was: '.. well the teacher told us to write it down .. because .. really what we really saw was that the sugar disappeared .. but if the teacher said so .. it must be true'. Other example of this behaviour in relation to observation occurred in a class where the teacher was showing a very old and really nice museum piece, a steam machine. After inserting the alcohol lamp in the machine, the teacher warned the pupils to observe what was happening. She said: "Observe the steam coming up .. and the wheel is turning round .... as you can observe the chemical energy is changing into mechanical energy". I was observing the class and what surprised me most was, besides the teacher's idea about 'observation', the lack of curiosity and lack of critical-mindedness showed by the pupils. They did not show any signs of curiosity about what was happening. They laughed when they saw the wheel running and when they heard the whistle ... but nothing else. I could perceive that the teacher was very proud of herself because she was 'using experiments in her classes'. Although not produced by protocol analysis, these episodes are mentioned because they give support to the evidence from the interviews.

The role of experiments isn't seen as a means to foster the development of process skills, attitudes and habits, partly intellectual and partly attitudinal, that would be needed for any citizen.

The problem of the teacher's role in the development of students' attitudes toward physics arose in nearly all the interviews. The students' views about this point adds evidence to the research findings showing the implications of their attitudes toward the subject produced by teachers' behaviours, attitudes, perspectives, enthusiasm and interest in physics. Some extracts of interviewees can illustrate this point.

(Extracts from six interviews)

"I - What happens in your classes? .. what's done well .. what's done badly? ...

S₁ - ..well they don't go very well ...

I - why?

S₁ - the lessons given by the teacher are dull and .. after two hours of class .. at the end we are completely fed up .. waiting anxiously to get out ..
I - and this year?

S1 - this year and last year .. it's the same .. we have had the same teacher in both years ..

I - what do you feel about your teacher then?

S1 - .. the lessons are boring (laughs) .. we had .. she had a baby in the third term .. so she was substituted by other teacher .. a teacher who has taught for a long time at our school and he gave us lessons which are very different from the ones given by the first teacher ... he never let us sleep during classes (laughs) .. you know .. the first teacher .. she is teaching us again this year .. she does deductions and calculations at the board .. only .. without asking questions .. and she does all the computation .. till the end of the lesson .. we write everything down ... but as most of the students don't do that .. they get bored and they finish by doing nothing ..

I - and what about the other teacher? what where his lessons like?

S1 - the other teacher .. he did more ... he did mathematics computations also .. but he let us to do the deductions alone .. he only gave us topics and the formulas were deduced by us and .. he asked questions all the time .. we couldn't loose our attention (laughs) ..

I - he made dialogue ..

S1 - oh yes .. always .. and this teacher .. this year .. is more like ... she talks and talks .. we take notes .. and then the lesson finishes (laughs) .."

(16 years old boy; 11th grade)

"I - (the same question)

S2 - .. well at the 9th grade .. few things went well because the teacher wasn't a good teacher (laughs) .. at least she hadn't a great vocation for teaching .. she may know the subject .. but she didn't know how to teach ... and .. we did some work which had no interest at all ... this year we started physics just a month ago .. we had chemistry first ... and it has been theory only .. I think the subject is a bit difficult .. it's about motion .. perhaps the teacher doesn't teach very well .. I don't know .."

(15 years old boy; 10th grade)

"I - do you understand what your teacher is talking about?

S3 - .. it depends very much on the teachers ... their personality and the way they view the subject .. our teacher now .. she doesn't view the subject in the right way .. the subject itself .. how should I say it .. she hasn't that flexibility needed to make students understand and have a critical view of the subject .. she can't explain by herself .. she is always stuck on books and on what is in the books ... she doesn't give practical examples .. she usually doesn't think .. she says .. 'look I'm going to give you an example' .. and she gives an example that is in the book .. it looks as she is trying to force things ..

I - .. look and do you think she notices that?

S3 - to notice that? .. that she doesn't give good lessons?

I - to notice that you aren't understanding what she wants you to do

S3 - .. I think she understands ... because .. my group is usually very participative
and at physics classes there is like .. a breakdown ... people talk to each other .. there is more noise at the physics classes than at any other ... I don't know .. and this is also seen by the results of the tests ... we should know the subject better if the lessons were different ..

I - uhm .. then you notice that there is a lack of interest in your colleagues in the subject?

S₃ - .. I think so .. but she .. I don't know .. she doesn't inspire confidence .."

(16 years old boy; 11th grade)

"I - (the same question)

S₄ - .. it depends on the teachers .. normally .. normally what is done wrong depends on the fact that there are few experiments .. and then it depends to some extent on the teacher also .. teachers who talk too much .. and don't let pupils do the talking .. it happened last year .. one doesn't understand things well in that way ... this year we are having more dialogue and then one understands better .."

(15 years old boy; 10th grade)

"I - (the same question)

S₅ - .. I think .. the teacher sometimes .. when she explains .. she says .. what she had already said and one stays at the same point ..

I - and normally do you understand .. what she is talking about?

S₅ - sometimes I understand ... others I don't .. and it's no use to ask the teacher .. I don't try to do that because she starts to complicate things much more .. she doesn't know how to explain in other way ..

(14 years old; 9th grade)

"I - (the same question)

S₆ - .. is that .. is the teacher .. he is always talking .. talking and then he writes in the blackboard something but we don't .... I mean you don't .. by ourselves .. I don't draw any conclusion .. any conclusion .. it's him who says everything to us ..

(16 years old boy; 11th grade)

When student teachers were asked about their feelings about the fact that they are going to teach physics, their answers showed how they view the role of the teacher. Some extracts of interviews address this point.

(Extracts from interviews with student teachers)

"I - look what do you feel about the fact that in one year's time you are going to teach?

S.T.₁ - on one hand I feel .... a bit frightened .. I don't know .. thinking of my professional life .. I'm afraid to face it .. I'm very much afraid of not being able to handle classes .. I'm afraid of being a bad teacher .. because I have been in some way a victim of bad teachers .. victim of persons without

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great knowledge ... sometimes wrong information .. was transmitted ..... many times they convey wrong ideas .. that one internalizes .. and then a long time was needed to get rid of them .... and it was very difficult to get rid of them ... I'm afraid to convey to my pupils the experience that I had with my teachers ..... on the other hand .. I think it will be O.K. ... because really I like physics and chemistry .. and ... well I'm not sorry .. on the contrary .. because physics and chemistry are the disciplines ... more ... how can I say it .. one can go to the lab to play with kids .. because that's the thing they like most .. what they don't like is maths (laughs) .."

(student teacher; 4th year of Teacher Training Physics and Chemistry degree)

"I - (the same question)

S.T.2 - .. er .. I think .. well it's overall a thing I would like .. to teach physics .. and .. aboveall not to do what certain teachers did to me .. I would like to teach in a proper way .. to make pupils understand .. to be motivated .. as I was in my 11th grade .. where I liked physics much more .. because I had a teacher who was able to arouse our interest .. she motivated her pupils..

(student teacher; 2nd year of Teacher Training Physics and Chemistry)

"I - (the same question)

S.T.3 - .. I .. I don't know what I'm feeling ... a very boring thing ... I feel I know nothing .. sometimes a very simple question that we should really know how to answer .. I don't know .. I think .. if a person is attending an university course .. I think he must know something more than the one who isn't .. and sometimes it does not happen .. and this is something that makes me think about this problem .. if one wants to explain to others and sometimes one isn't able to see other way of explaining .. unless the way it comes in books .. a kind of repetition .. I find it .. the worst thing of all .. sincerely I have been thinking .. if I'm going to do as many teachers use to do at schools and at this university .. I think I would kill myself .. because really I see that .. only repetition ... oh .. it doesn't interest anyone and mainly with kids .. if things don't say something to them .. they turn off .. and the school is getting a very distorted image .."

(student teacher; 2nd year of Teacher Training Physics and Chemistry degree)

"I - (the same question)

S.T.4 - .. well .. there are some topics in physics that I like and others I don't .. and so .. I'm afraid that when I teach kids .. I will convey these feelings ... I think it would be important to find that method ..(laughs) .. that is the worst .. nobody is going to find it ... no one knows what students really prefer .. and that is the most difficult thing .. to find the method that makes them interested in physics .."

(student teacher; 2nd year of Teacher Training Physics and Chemistry degree)

"I - (the same question)

S.T.5 - well .. I like the course .. but .. the problem is .. I'm going to feel .. a little .. er .. when I will face students .. uff! .. will I know physics enough
to teach these people .... well the problem is not a lack of theoretical knowledge ... I notice that school teachers always know a lot .. one can see that some years later .. but what they don't know is how to explain to kids .. and that is my fear .."

(student teacher; 2nd year of Teacher Training Physics and Chemistry degree)

"I - (the same question)

S.T. - .. uhm .. I feel ... I'm very frightened ...

I - why?

S.T. - .. because the physics I would like to teach isn't the one I was taught .. and the way I would like to teach ... it isn't also the way I used to be taught .. I have to jump this gap .. between the way I was taught .. between my experience as a student and what I intend to be as a teacher .. I'm afraid that without noticing it I will start doing what I have criticized in my teachers .. not being able to communicate to my pupils in the way I would like to communicate with them .. falling into a routine .. and not caring about their interests .."

(student teacher; 4th year of Teacher Training Physics and Chemistry degree)

"I - (the same question)

S.T. - .. a great apprehension .. a great fear (laughs) .. precisely because my expectations when I started to learn physics weren't realized .. teachers weren't able to fulfil my anxiety .. my curiosity .. and I'm afraid of not being able to realize .. for instance my students' expectations .. and not managing to be the teacher I wish to be .."

(student teacher; 4th year of Teacher Training Physics and Chemistry degree)

These last extracts show some of the concerns future teachers feel about starting teaching. Almost all the interviewees point out the fear they feel about not being able to communicate with pupils, of not getting them motivated, of not being understood by pupils, having difficulty in making their knowledge clear. One student teacher summed this up saying:

S.T. - what I really want .. when I start teaching is trying to do my best .. although I'm a bit frightened .. because I feel that there are some faults in my preparation either scientific or psychological .. I'm afraid of not being able to transfer the knowledge I have ... too theoretical .. to knowledge that can be understood by kids .. to cope with problems of discipline in classes .. not getting a good relationship with my pupils .. well I really don't know .. but anyway I'm happy to start teaching physics .."

Once more the answers to this question show that student teachers concerns are content-oriented, following the same patterns conveyed by teachers. As pointed out before, a content-oriented education is unable to lead students
to achieve such purposes as citizenship, social responsibility and self-support. Unless content is used as a means to develop scientific attitudes such as "open-mindedness", "honesty in recording data", "being tolerant with others' views", "capacity of inquiry", "capacity of judgement" and the like, physics teaching runs the risk of being a waste of time. Evidence of this emerged from interviews with school leavers and students attending humanities degrees.

It is interesting to examine some of the perspectives that teachers and students have on the importance to society of physics teaching and learning. To have an overview of those perspectives I introduced a question about this issue. Subsequently I asked the interviewees if the way physics has been taught in our schools reflects their views. The reactions to these questions are best illustrated by some extracts of interviews.

"I - do you think teaching and learning physics is important to the society where we live?

P - of course .. I think so .. physics is effectively a science that is the basis of all modern technology .. besides it enriches the culture of those who don't go to universities .. it helps to see the world in other way .. it contributes to the evolution of society ..

I - do you think the way physics has been taught in our schools contribute to that evolution?

P - .. uhm .. I mean .. er .. I think it always contributes .. of course it isn't the best way to do it .. it isn't really .. we have already talked about this .. but .. something will contribute .. not in the best way .. I see .. for instance .. at teachers level .. I don't know .. I have many doubts .. because if we agree that teachers have an important role in the progress of society .. I will say no! .. more and more students leave university knowing less and less physics .. they arrive at schools .. without the necessary preparation .. there is in fact a deficient scientific basis .. I think it needs a big change .."

(physics educator teaching at the university)

"I - (the same question)

P - I would say .. in the same way .. that in the last century nobody was cultivated without knowing humanities .... nowadays everyone should have some physics culture .... unfortunately .. as we already saw .. at the secondary school level this hasn't been achieved .."

(physicist teaching at the university)

"I - (the same question)

P - oh! .. of course ..

I - why?

P - .. er .. well .. how can I explain that .. I think .. for the evolution of a society .. it must have a concrete idea of what is .. fundamental .. of what is necessary .. of what is indispensable .. etc. .. and there are a lot of things directly linked to physics .. for instance .. even technological development .. well I know it is technology .. but at the end .. for common people .. there is something
that happens .. that makes life more easy and this is linked to physics .. well .. and if people don't have any physics knowledge .. they live in a world that they don't understand ..

I - do you think the way physics is taught in our country contributes to that?

P - no! .. no .. because .. well it's .. as I said before .. physics is taught too far away from reality .. everything is presented much too theoretically .. away from reality .. and to me .. at the secondary school level .. things should be linked to reality .."

(physicist teaching at the university)

"I - (the same question)

P - oh yes! .. indeed it is .. I think it is fundamental .. not only physics teaching but any teaching .. I think teaching is fundamental .. I think that there is one thing that everyone needs .. it's culture .. and knowledge .. and physics is so important as a professional activity .. as an aspect of a person's culture ..

I - looking at the way physics has been taught at university level do you think it contributes for the evolution of the society?

P - ... well I think ... er ... the problem isn't in physics teaching .. but it is a problem of professional activity .. I mean .. a person who likes his profession should teach it .. he has everything for motivating his students .. however .. there is .. a great problem in our country .. teaching is an underemployment .. as they didn't find other job .. they enter the teaching profession .. but really they aren't too interested in this profession .. they see it as a way for avoiding unemployment .. and that is .. according to me .. one of the greatest problems of teaching .."

(physicist teaching at the university)

"I - (the same question)

P - well .. maybe physics teaching is important .... what is the importance of physics teaching? .. er .. the secondary school teachers teach physics to the men of tomorrow .. er .. it is important that they successfully convey deep knowledge to their students .. and the students must get a basis to help them in their careers or to help them to understand the world .. as I mentioned .. there was a giant jump in the development of technology .. and nowadays anyone will like to know .. for instance .. why that object flies .. why it goes to space and how did it happen .. how computers work .. all that science that is now growing up in our day results from the development of physics .. not only .. but mainly of physics .. so I think it is important to teach physics .. not only to future secondary school teachers .. but to tomorrow's men .. the other aspect .. the importance of learning .. it's not only as a career aspect but as a human formation .. I think that teacher should be good professionals and that they really should teach well either at the secondary or university level .."

(physicist teaching at the university)

"I - (the same question)

T - all the development we can get in future is on the hands of these kids that we teach .. and to me .. I think physics has a great contribution to make to that ..

I - do you think that the way physics has been taught in our schools is going to
help in anyway the society where we live?

T - that .. that .. I don't know .. I was thinking in a general way .. but the way it has been studied .. well .. that .. I don't know .. I don't know .. perhaps not as much as we would expect .. I don't know .. maybe I'm being pessimistic .. but .. I don't know .. if this doesn't change! ..."

(secondary school teacher)

"I - (the same question)

T - without any doubt .. it has a great interest to society..

I - and do you think the way it has been done is ..

T - well .. now .... if .... as it is now .. er ... it should be modified .. but at least .. I mean .. it is better if it exists as it is now .. than nothing ... because if the alternative is to take it off .. at least it is in the curriculum .. I see that we started to study it at our 7th grade .. now it is started only at the 8th .. some day .. it must be questionable if it should be or not at the curriculum .. and it may even happen to be taken off .. and with that I don't agree .."

(secondary school teacher)

"I - (the same question)

S - I think so..

I - why?

S - ... er .. I think so because at the end almost everything .. let's say .. the great problems always have a physics basis .. going to the Moon .. electronics .. computers .. etc. .. they all have a physical principle at the basis .. and I think if one wants to have some deeper knowledge of what is happening and not only .. to push buttons .. you know what I mean .. it's inevitable to study physics..

I - .. so you think that the way it has been taught in our country contributes to that?

S - .. no ... many students get such an aversion to physics .. they don't want to hear about physics anymore .. and then as adults .. they will have difficulties .... it is hard to get rid of that aversion .. and for that reason .. some people who could be good in the field of physics are lost for ever..

(secondary school teacher; 4th year Teacher Training Physics and Chemistry degree)

"I - (the same question)

S - I think so .. to me everybody must know it .. it's part of everyone's culture .. everyone must have some knowledge about physics .. it's useful to everyday life..

I - do you think that the way physics has been taught has something to do with that?

S - .. no .... I don't think so because .. it's the same reason again .. physics has been taught based on theory and it should have more practical .. so one could get more interest and enthusiasm for it .. because I'm sure that those students who finished their learning at the 9th grade .. now they remember nothing
... nothing at all of what they studied in physics .."
(17 years old girl; 12th grade, scientific area)

I could carry on writing down extracts of interviews concerning this point, but the views conveyed by them are similar to the ones written above. All the interviewees recognized the importance for society of the learning and teaching of physics. However all of them agreed that the way physics has been taught in our schools does not contribute much to the evolution of society. All the reasons mentioned were very similar to each other. Physics is important to society because it helps people to understand the world around them, to get a better understanding of how things happen, to develop areas like electronics and space control, etc. and physics education in Portugal is far from achieving that.

2.7 Findings emerging from the preliminary study

Throughout the protocol analysis I looked for the different groups' perspectives held on physics and the teaching process. The purpose was to obtain potentially significant comments enabling possible sources of difficulties to be identified. As a result of this analysis, some crucial problems involved in the process were uncovered. The findings of this preliminary study can be nested into the following categories.

1. Prior to physics teaching children may have preconceived ideas about what is physics and these ideas do have implications for teaching and learning

Although, in general, children at this stage have no directly developed ideas of what physics is about and consequently they have no expectations about what they are going to learn in the subject, most of them, due to their interaction with older students and adults, construct their own views prior to teaching. These views can have some contribution to their attitudes towards physics. Teachers should be aware of these children's views and their implications for teaching.

2. There is, in general, a growing disinterest in physics throughout the period of pupils' schooling

Children are inherently curious, and though some of them may have preconceptions about physics, as pointed out before, they have an enthusiasm towards a new subject. The findings on this issue show that in physics teaching
ways have to be found to capitalise fully on this. A decreasing enthusiasm and interest shown by students throughout their schooling is elicited from interviews and it can be seen as a reflection of the way physics has been taught.

Research studies in different countries show similar findings. Cooley (1964) who, in the United States has monitored the interest in science of pupils of various ages, found that this was at a peak at 13 plus after which it fell slowly. The biggest drop of all occurred in the two successive years when the would-be scientists actually start to study chemistry and physics viz. grades 11 and 12. Also in the United States, Learner (1971) and Bridgeham (1972) stress the increasing disinterest in sciences particularly in physics in grades 10 to 12. The latter erected a model which proposed that disappointingly low grades in the study of each successive science: biology, chemistry and physics in grades 10 to 12, deterred the students from taking up the science in the next grade. In a study conducted in England, Harvey and Edwards (1980) point out that the evidence emerged from their study suggests that children in their first year of comprehensive school education in physics did not display any increase in their interest in this subject during the academic year. In a study conducted with a sample of high school teachers in Western Australian, Schibeci (1981) points out that all teachers interviewd believed that students attitudes to science deteriorated during high-school years. It is interesting to note the way in which one teacher in this study summarized the views of his colleagues:

"Oh yes, I think they are keen to do anything at year 8. God only knows what we do to them between year 9 and year 10!"

Hadden and Johnstone (1982, 1983a, 1983b) report, in a longitudinal research project involving Scottish pupils, that evidence of the deterioration of attitudes to science increased from the primary school to the secondary school. Although they note that the changes of attitudes are easier to detect than factors which can account for them, they see the effectiveness of the teachers as one of the more dominant factors in determining those changes. Also Schibeci (1984), in an update survey about attitudes to Science, points out that those appear to decline as school students move to higher grades.

Nevertheless, evidence emerged from my interviews which shows that student teachers in the final years of the Physics degree, (education branch), or Teacher Training Physics and Chemistry degree possess, in general, a great interest and enthusiasm for physics. But they feel very insecure about ways to convey these feelings to their future pupils.
3. Different perspectives are held on the concept of 'physics' by different categories of individuals

What physics means to the individuals in the different groups can convey an idea of how the image of physics is being transferred from teachers to students. From the analysis of the protocols it is interesting to verify that generally physics means a great deal to teachers. Some show enthusiasm and appraisal of the subject. Notwithstanding, students hold very dull and very unenthusiastic perspectives on physics. Physics teachers are not able to convey their own views about the subject to their students.

4. There is a big gap between what people think are the aims of physics teaching at secondary school level and what actually is achieved

According to the individuals in the different categories interviewed, physics at secondary school level should help students to understand the world around them, to interpret everyday phenomena, to provide general culture and to promote intellectual development. Also, according to them, what is actually achieved is far from this. Physics is taught in such a way that students can not see the links with day-to-day life, and some time after finishing their physics education they forget the little they have 'learned'.

In the past few years, research concerned with the learning of science has increasingly used a theoretical framework derived from Ausubel's theory. The key idea of this theory is that of "meaningful learning". Ausubel (1968) suggests that learning will only be meaningful when the new idea or concept which is to be learned can be consciously related to relevant concepts and ideas which have been acquired previously. When new knowledge cannot be linked into the existent cognitive structure, rote learning or simple memorization results. The memorized material will carry no meaning for the learner and will not contribute to understanding or to problem solving ability. As Stones (1968) points out

"For us to decide whether or not learning has taken place, the change in behaviour resulting from it must be relatively permanent". (p.2)

Learning which cannot be related to existing cognitive structure is often referred to as rote learning and rote learning (at least in physics) does not last for long. Evidence to support all these statements was elicited from the protocol analysis. Students cannot learn meaningfully if what is taught is not integrated into their existing cognitive structures, which for physics at the secondary school level has
a lot to do with students' experience with everyday phenomena. A great effort should be made to devise ways for teaching student teachers to acquire skills in order that their teaching be meaningful to their future pupils.

5. Within all the variations in schools (class size, curriculum, materials etc.), the most important factor governing pupils' attitudes toward physics is the teacher.

The findings concerning the role of the teacher in students' attitude toward physics is, as expected, in accordance to a large body of research in this field (e.g. Bixler, 1958; Behnke, 1959; Belt, 1959; Greenblatt, 1962; Taylor, 1965; Ramsay and Howe, 1969; Yeoh, 1973; Lawrenz, 1975; Ormerod, 1975a, 1975b; Keys and Ormerod, 1976; Bottomley, 1979; Schibeci, 1981)

Within all the variables in schools (class size, curriculum, materials, etc.), the most important factor governing pupils' attitude toward physics is the teacher. These findings have serious implications for the preparation of teachers including especially on how physics is taught at universities and for those involved with teacher training.

6. According to both teachers and pupils the experimental component of physics teaching is fundamental to its learning

In almost all the topics approached in the interviews, the words experiment, lab work, investigations, demonstrations and the like, were frequently used. According to teachers' and pupils' views the experimental component of physics teaching is fundamental to its learning. Nevertheless, either the purposes of experimentation in physics teaching is vaguely perceived by teachers and students or there is an uncertainty as to what kinds of skill are involved. Experimental work in classrooms or in labs, when done, has not been used to best effect. According to students, the best way to learn physics is through doing it. The same opinion is passed by teachers but they reply that it is too difficult to put it into practice. However these reasons given are not convincing, as can be elicited from the extracts of the interviews.

7. Students are not taught for understanding

Students are taught not to think, but to pass exams. Worst of all, they acquire attitudes for their adult lives that are the opposite of those that should
be developed during their schooling. To deal with this problem involves a great change in the way learning is assessed. This is another area deserving an in-depth investigation.

8. Teachers must confront the juxtaposed opposites: "Lessons are too easy and experiments are too trivial ... or lessons are too difficult, too mathematized and too abstract."

There is a profound inbalance in the way content is presented to students. Some students and teachers are fortunately aware of this! My own observations in classrooms support this finding which emerged from the interviews. The lack of aims in the official curriculum and the sticking to textbooks available could be reasons for that. However, the main reason seems to be teachers' lack of knowledge and interest in theories of teaching/learning and of the psychological and conceptual development of their students.

9. Alternative conceptions and symbols are important in physics language and everyday language

One source of difficulties in learning physics seems to be the symbols used in formal teaching. For example the symbol of a vector quantity - an arrow - is very difficult for pupils. When, for example, representing a force applied by a person to somebody, they show a great reluctance to draw it because "it crosses the man". Other symbols like field lines, representations of electric charges and atoms, even curves (for instance potential curves relative to rectilinear motion) can cause great difficulties in the understanding of the phenomena involved if teachers are not aware of the pupils' meaning for the symbols used.

Another source of difficulties in the learning of physics is an issue which was not given due consideration either by teachers or by physics educators during teacher preparation. Much research in science education, and more specifically in physics education, has emphasized the role of students' personal experiences in their construction of knowledge. Broad evidence from research work shows that children, youngsters and even adults bring to classes meanings for words and explanatory patterns of "intuitive physics" that represent a common and self-consistent set of concepts (e.g. Tiberghien et al., 1977; Erickson, 1977; Viennot, 1979, 1979; Johnstone and Mughol, 1978; Helm, 1978; Driver and Easley, 1978; Stead and Osborne, 1979; Fredette and Lochhead, 1980; Trowbridge and McDermott, 1980; Gilbert and Osborne, 1980a; Erickson, 1980; Anderson and Kärrqvist, 1981;
Watts and Zylbersztajn, 1981; Shipstone, 1982; Solomon, 1982; Séré, 1982; Clement, 1982; Watts, 1982, 1983; Gilbert et al., 1982b; Engel, 1982; Brook et al., 1983; Ivowi, 1984). These explanatory patterns or alternatives conceptions and meanings for words are strongly held and are very resistant to change, persisting after several years of formal teaching. These findings are widespread among research workers. But what is the situation among teachers? From this exploratory study it seems that teachers either at the secondary school or university level are almost completely unaware of this problem and its implications for teaching. Even when teachers are aware of the problem they feel uneasy in coping with it.

10. The importance of teaching and learning physics to society is recognized by all

All the interviewees recognized the importance of teaching and learning physics to the evolution of society. However they were unanimous in their opinion about the irrelevance of physics as it is taught in our schools. This contradiction also calls for further studies.

11. According to the majority of students and teachers, chemistry is a more interesting, enthusiastic, attractive and easy subject than physics

A broad range of evidence supports this statement. The main reason pointed out is related to the different methods used in teaching both subjects. While chemistry teaching is primarily based on experiments, physics is taught mainly in an expositive way. The lack of concern for educational issues on the part of physicists is other reason that is pointed out. This is a point of deep reflection for physicists. These findings should be carefully examined at universities involved with physics teacher training degrees.

12. Physics classes are held in a traditional way and are primarily content-oriented

The current physics curriculum of the secondary school level is nothing else but a list of topics to be covered. The aims of physics teaching are not established and there are no guiding principles for physics education. This could bring some advantages to the teaching and learning process, giving teachers some flexibility to use their own perspectives on physics education and to use learning and teaching theory more suitable to their personality and to the students they
have to teach. If this was the case, what is needed on the part of the teachers is a deep reflection on the different theories of education, the philosophies underlying those theories and a strong awareness of the teaching and learning problems. In general, according to my findings, this does not happen and classes develop in students the idea that physics consists of theories, learning physics is learning theories and that these theories are the content of physics. The teacher's job is to transmit information directly. The student's job is to be a good, quiet and passive receptor and s/he will be rewarded for that. What happens in physics classrooms is a concern that all required topics are covered during the school period, which does not happen in the majority of cases. Students do not like physics classes, they get bored, become disinterested in physics and teachers are unable to cope with this situation.

Physics classes are primarily content-oriented and teachers are less concerned to develop specific skills than to transmit knowledge. Nevertheless, as it could be elicited from the interviews with school leavers or students who finished their science education at the 9th grade, some years (even some months) later they cannot remember any of the topics studied nor even what physics is about.

13. Student teachers have severe concerns about starting to teach

The main concern felt by student teachers about starting teaching is related to the fear of not being able to communicate with pupils, of not getting them motivated, of not being understood by pupils, of having difficulty in making their knowledge clear, of not being able to transmit knowledge.

Although a dissatisfaction with the way they were taught was apparent throughout the student teachers' conversation, their concerns reveal that in relation to their future job they hold the same perspective on teaching as was held by their own teachers.

2.8 Summary

In this Chapter, an exploratory study aimed at investigating the reasons underlying students' attitudes towards physics, their causes and implications for teaching and learning, was reported.

In-depth interviews were conducted with individuals belonging to seven categories of persons involved in the process, namely: pupils prior to physics teaching, pupils being taught physics, school leavers or students taking humanities de-
degrees, student teachers, experienced secondary school teachers, teacher educators and physicists teaching at the university.

In the analysis of the protocols an attempt was made to record observed regularities and organize them into empirical generalizations with the purpose of generating "working hypotheses" upon which to focus the main study.

The findings emerged from the preliminary study seemed to support the view that a "cultural transmission" perspective has prevailed physics teaching in Portugal.
CHAPTER 3

PLANNING THE MAIN STUDY

3.1. Rationale for change

As a result of the preliminary study some crucial problems in the teaching and learning of physics were uncovered. Although all of them, per se, would deserve an in-depth investigation because of their relevance in the improvement of physics education, there is one that appeared to be more basic and underlying all the others, being the source of the others. I am referring to the philosophy of science education which underlies the physics teaching approach that has been used in Portugal. The grounds for this statement stem from the psychological perspective of George Kelly which has had a considerable influence on my work as a science educator and consequently on the present study. One of the tenets of Kelly's theory is that an individual will invariably approach any situation in life with a personal theory of explanation. This means that s/he will have a personal set of hypotheses which are used to model and make sense of events and these may be modified in the light of their explanatory utility. Accepting this viewpoint, then, the physics teachers will have models of such things as science, scientists, scientific methods and progress, their role as teachers, their students and the nature of knowledge. These models were built under the influence of the philosophy of science held by each teacher either conscious or unconsciously. Elkana (1970) stresses that it is

"the philosophy of science which modules general attitudes which form the foundations of the various theories of science-teaching".

It is these theories which will influence the practice of science teaching and particularly in this case physics teaching.

The finding, that physics classes are held in a traditional way and are content-oriented, shows that a "cultural transmission" approach to teaching and knowledge dominates physics education. The main aim of physics teaching appears to be the transmission of "nuggets of truth". The assumption is that through a process of accumulation of such fragments, students'blank minds will be filled up with true knowledge.

Theorists of this perspective on education see the primary task of
the teacher to be the transmission of information, rules or values collected in the past. The teacher's job is then the direct instruction of such information and rules. This view was supported by Hutchins (1936) when he wrote

"Education implies teaching. Teaching implies knowledge. Knowledge is truth. The truth is everywhere the same. Hence, education should be everywhere the same" (p. 66).

Within this "cultural transmission" perspective students are faced with facts poured out by teachers and they act as passive receptors. Their "understanding" are usually assessed by means, through which, most of the time, the students' capacity of memorization or rote learning is the only one evaluated. No recognition of the personal interpretations made by students has usually been taken into account. The findings of the preliminary study show that the "knowledge" produced by this approach to teaching does not last long. The philosophical approach underlying this perspective on teaching is that truth can be accumulated bit by bit, subject by subject, for knowledge is repetitive and objective. This view of absolute truth accumulating corresponds to the basic philosophical principles of realism. For most scientific realists, as for example, John Locke, the mind of the individual at birth is assumed to be a "tabula rasa". The task of the school is seen to be the instruction in a body of knowledge whose truth had been repeatedly confirmed. The positivist, empiricist-inductivist conception of science is in sympathy with this absolutist view of truth and knowledge and thus, if teachers hold to that conception of science, the way in which students are taught will place little or no emphasis on the students own conceptions and active participation. The cultural transmission approach to teaching and learning has been supported by psychological theories of development which stress the passivity of man's mind. This emphasis is found in all types of associationism, behaviourism, stimulus-response psychology, contingency theories, etc.. As suggested by Pope and Keen (1981)

"the appropriate metaphor for the view of man put forward by cultural transmission educational ideology, is that of the machine. The machine can be anything from the wax upon which the environment makes its mark (Locke) through to the computer".

In this context the role of the environment, seen as the "input" is to transmit the information more or less directly, which will be accumulated in the "organism". The "output" is the resulting behaviour. Using the metaphor, man-the-machine, cognitive development can be seen as the result of guided learning and teaching and behaviour is the result of an association between stimulus and response.

The disenchantment and discontent with this approach to physics
teaching and learning was expressly conveyed by the persons involved in the preliminary study. The urgent need for a change of the teachers' and students' perspective on teaching and learning called for a search of alternative educational ideologies which could foster that change.

Particularly in the last two decades, progressive educators have developed programmes to encourage students to develop an active approach to learning. The psychological theories of Piaget, Bruner and Ausubel have lent support to this movement. However, some feel that the pedagogy which has resulted from this influence still does not fulfill what is desired. Postman and Weingartner (1971) stress this point when they wrote

"There is no way to help a learner to be disciplined, active and thoroughly engaged unless he perceives a problem to be a problem, or whatever is to be learned to be worth learning. It is sterile and ridiculous to attempt to release the enquiry power of students by initiating studies that hold no interest to them."

The pupil or student can be actively involved, in the physical sense of conducting a closed-ended experiment, but the learning derived from such an experience will be of limited scope if the person can see no relevant links between the activity and their personal concerns.

Many philosophers of science, like Popper, Kuhn, Lakatos and Feyerabend, reject the view of knowledge and reason as being impersonal and detached and suggest that reason is informed by passion. Popper rejects the empirical-inductivist tradition in science which held that observation preceded theory. For Popper all observations are theory laden. By adopting the non-absolutist view of scientific truth and his stance on the theory laden nature of observation, it would be expected that, in the teaching of science, emphasis would be placed upon the role of personal frameworks in scientific observations and on the need for critical examination of pre-suppositions prior to embarking on data collection. Popper (1972) suggests that growth occurs through the process of conjectures and refutations. He sees science and knowledge as progressing through systematic attempts to test our hypotheses or conjectures in order to refute them. Popper's schema of scientific method involves a continuously developing feedback process with the following stages: 1, description of the problem (usually a rebuff to existing theory or expectation); 2, proposed solution, in other words a new theory; 3, deduction of testable propositions from the new theory; 4, tests, i.e. attempted refutations by, among other things, observation and experiment; 5, preference established between competing theories. Swift et al. (1983) point out that
"Popper's view on the progress of scientific knowledge has been used as an analogy for the progress of cognitive development in individual".

And they add,

"since an aim of teaching is fostering the cognitive development of students, teachers of science might find the analogy fruitful".

This analogy implies that cognitive development would be encouraged by teaching strategies which encourage the articulation of conjectures and the submission of these ideas to critical refutation. This would seem to necessitate the active involvement of the learner as constructive rather than reactive. It is not sufficient that a body of knowledge, from a textbook or given out by the teacher, is accepted unquestioning by the student. Students must find ideas to be true for themselves and must be able to incorporate them within their own views of the world.

I would like to stress here that Popper's emphasis has been on a critical examination of theories and the growth of scientific knowledge as opposed to the psychological and sociological aspects of how scientists go about their task. This view is in opposition to the conception of "scientific attitude" which, according to Gauld (1982), has been formulated by science educators for the past 60 years as I shall discuss later.

In "The Structure of Scientific Revolutions" Kuhn (1970a) makes an attempt to delineate a new image of science, in opposition to those disseminated by the then influential logical-empiricist movement in the philosophy of science and the traditional scientific historiography. Departing from the older historiographic tradition, which presented a "development-by-accumulation" view of scientific progress, the model proposed by Kuhn depicts the evolving history of a mature science as a sequence of periods of "normal science" - periods of continuity to which the cumulative development view can be applied - interrupted by "scientific revolutions" - extraordinary episodes in which a change of professional commitments takes place. Besides periods of normal science and revolutions Kuhn also considers a preparadigm period which precedes the first period of normal science research in a field. This period is characterised by a proliferation of paradigms. As Kuhn puts it:

"during what is called, in Structure of Scientific Revolutions, the 'preparadigm period', the practitioners of a science are split into a number of competing schools, each claiming competence for the same subject matter but approaching it in quite different ways"

(Kuhn, 1978, p. 235).
Lakatos (1970) develops a theory of science that attempts to reconcile the relationship between large, general, scientific theories and their contemporary alternatives, together with all of their smaller constituent theories. This approach contrasts with Kuhn, who sees eras of science as 'normal' when a ruling paradigm exists without effective opposition. For Lakatos

"the history of science has been, and should be, a history of competing research programmes (or if you wish, 'paradigms'), but it has not been and must not become a succession of periods of normal science: the sooner competition starts the better for progress"

(Lakatos, 1970, p. 155)

He makes a distinction between "passivist" and "activist" theories of knowledge, and derides passivism as implying that "true knowledge" is nature's imprint on a perfectly inert mind. He makes a further distinction between "conservative activists" and "revolutionary activists"; the former hold

"that we born with our basic expectations; with them we turn the world into 'our world' but must then live for ever in the prison of our world"

(Lakatos, 1970)

Lakatos' work embraces revolutionary activism in the belief that conceptual frameworks can be developed and also replaced by new, better, ones.

Feyerabend begun his work by asking how observation statements should be interpreted. From an early study (1958), in which he considered the ascription of colour properties to unobserved objects, he concluded that:

"the interpretation of an observation-language is determined by the theories which we use to explain what we observe, and it changes as those theories change"

(Feyerabend, 1958)

This placed Feyerabend in the anti-positivist camp: all observations are theory-laden and hence meaning-dependent. Interpretations (meanings) of observation-language change as the theories change.

These four philosophers represent varying degrees of relativism in their epistemological stance. Their accounts of or for science represent some of the major traditions in philosophy of science. These, jointly with the Baconian tradition, have, and continue to have, significant influence within the community of philosophers of science. The four traditions developed by Popper, Kuhn, Lakatos and Feyerabend although contradicting each other in broader terms, share much about the inadequacies of the positivist, empirical inductivist conception of science. The basic version of the latter conception is often called Baconian inductivism due to the powerful contribution of Bacon's philosophy of science. In contrast with an absolutist view of truth held by Bacon, the other four philos-
ophers share a relativistic view of knowledge being the theory-ladenness of observation a cornerstone of post-orthodox philosophies of science.

It is uncontroversial to claim that science and philosophy of science interact, although the nature of this interaction can give rise to many controversies. The interaction between science and science-teaching is made through philosophy of science. As Elkana (1970) points out it is

"the philosophy of science which moulds general attitudes which form the foundations of the various theories of science-teaching".

There is nowadays a growing "invisible college" of science educators who believe that the teaching of science should acknowledge what current philosophies of science, such as the ones of Popper, Kuhn, Lakatos and Feyerabend, recognize - the role of personal construction in the development of scientific knowledge. Compatible with this view is the psychological perspective of George Kelly. In Kelly's theory of personal constructs I found an appropriate framework for implementing the change on teachers' and students' perspective of physics teaching and learning.

3.1.1. A constructivist perspective for teaching

In 1955 Kelly discarded the classical trichotomy of thought, action and feeling in order to launch an alternative theory of psychology concerned with the personal and with how total people construe themselves, other people and their world. He outlined his theory in a fundamental postulate elaborated by eleven corollaries (Kelly, 1955, Chapter 2). The theory is based on three ideas: constructive alternativism, man as a scientist and double entity choice. Constructive alternativism is the term with which Kelly identifies his philosophical position. In Kelly's words

"we can no longer rest assured that human progress may proceed step by step in an orderly fashion from the known to the unknown. Neither our senses nor our doctrines provide us with the immediate knowledge required for such a philosophy of science. What we think we know is anchored only in our own assumptions, not in the bedrock of truth itself, and the world we seek to understand remains always on the horizons of our thoughts".

Then he explains what he means by constructive alternativism:

"To grasp this principle fully is to concede that everything we believe to exist appears to us the way it does because of our present construction of it. Thus even the most obvious things in this world are wide open to reconstruction in the future."

(Kelly, 1977)
For Kelly, events are subject to

"as great a variety of construction as our wits would enable us to contrive"
(1970 a, p. 1).

He rejects an absolutist view of truth and contrasted his position with that of "accumulative fragmentalism" - the notion that knowledge is a growing collection of substantiated facts or "nuggets of truth". His philosophical position is, thus, opposed to that of the realist. Even the most highly developed scientific knowledge can be seen to be subject to human reconstruction.

There has been many analogies used in psychology. Man-the-machine, was already pointed out as the appropriate metaphor for the view of man put forward by "cultural transmission" educational ideology. Kelly's analogy was man-the-scientist. It says that the individuals deduce hypotheses, raise issues, develop methodologies, define instruments, generate data, perform experiments, induce further hypotheses and revise theories in the course of construing their personal reality. According to Kelly, each person erects for himself a representative model of world which enables him to chart a course of behaviour in relation to it. This model is subject to change over time since constructions of reality are constantly tested out and modified to allow better predictions in the future. Thus for Kelly the questioning and exploring, revising and replacing in the light of predictive failure which is symptomatic of scientific theorising, is precisely what a person does in an attempt to anticipate events. Double entity choice proclaims that when individuals do change, reconstruct reality, they choose between two entities, not an entity and a non-entity.

Kelly proposes that behind an individual's judgement, and consequent behaviour, lies an implicit theory about the realm of events within which the judgements are made (fundamental postulate). The implicit theory about the realm of events is the individual's personal construct system. The system enables the individual to see and handle situations (construction corollary). The system is particular to an individual (individuality corollary), ordered (organization corollary) and composed of double entities (dichotomy corollary). An individual develops and uses his personal construct system by choosing between alternatives (choice corollary) over a finite range (range corollary) as successive construals of events occur (experience corollary). The system can be varied (modulation corollary) and can contain incompatible sub-systems (fragmentation corollary). Individuals can have a consensus on some aspects of reality (commonality corollary), interact with another individual's system (sociality corollary).
Kelly's central position is that people are best understood in terms of the way they anticipate events. The persons' processes are revealed by discovering their personal constructs which act as "spectacles" through which they view their world. Kelly's key idea is the "construct" itself. A construct is a way in which some things are seen as being alike and, simultaneously, different from others. Each construct consists of a single bipolar distinction, e.g. moral-immoral. One, the positive pole of the construct, represents the basis of the perceived similarity, the other, the negative pole, represents the basis of contrast. A construct is unlike a logical concept in that its boundaries are personally defined on the basis of individual and personal experience. By recognizing one's own potential for changing the constructs which one holds, one is opening the door to creativity. But, as has been noted, Kelly does not deny the existence of reality. Instead he chooses to focus on the importance of coming to an understanding of a person's constructions of reality.

When applied to an educational context the Kelly's philosophy of constructive alternativism provides a framework for an adaptive educational system which assumes many ways of succeeding and multiple goals from which to choose. An educational system in which individual learning styles are important and educational research is predicated on the individual's perspective. As Pope and Keen point out

"it is Kelly's stress on the personal nature of meaning and the elevation of the person to the central focus of inquiry that aligns him with much of contemporary theorizing on education."

(Pope and Keen, 1981)

Theorists of education, e.g. Postman and Weingartner (1971) and Rogers (1969) argue that it is important to realize that significant learning will only take place if the learner perceives personal relevance in the matter being learned. What is relevant to the person is intrinsically important. For education to be a joint venture between teacher and learner it is vital that each has some awareness of the other's personal constructs. Kelly (1970 b, p. 262) recognized learning as a personal exploration and saw the teacher's role as helping

"to design and implement each child's own undertakings .... To become a fully accredited participant in the experimental enterprise she must gain some sense of what is being seen through the child's eyes."

One may well perceive teacher and student perspectives on teaching and learning as a development of personal construct systems through the experiences teachers and students have in interaction with their environment, both inside and outside of the educational establishment.
This constructivist emphasis is in opposition to the traditional teaching methods based upon the "cultural transmission" approach. It can thus be seen as an alternative to the naive empiricist-associationist theories which have dominated physics education in this country and have led to a passivist approach to scientific knowledge.

3.1.2. Aims for physics education in a constructivist perspective

From the findings of the preliminary study it appears that a complete rethinking of the aims for the teaching of physics at the secondary level (and beyond) is needed.

Very often the words "aims" and "objectives" are used synonymously, but some authors attach to them different specific meanings. Because, in the present study, the two words are used with different meanings, they will be defined here in order to avoid confusion. "Aims" (which has the same meaning as general objectives) are the broad intention of a course. "Objectives" (specific or performance objectives) are detailed specifications of the behaviour expected of students at the end of a lesson, a unit, or a course. The central importance of aims has been recognized by curriculum designers who recommend that all courses at all levels should have written statement of aims. These should be known to the teachers and to the students. The assessment must reflect the aims.

The utility of a classification of educational aims was first recognized in the 1920s as a means to facilitate communication between specialists in evaluation, as well as, between other persons involved in educational research and curriculum design. Since then, several classifications have been proposed. The most widely known was produced by Bloom et al. (1956) and Krathwohl et al. (1964). These authors consider three main domains for educational aims; the cognitive, the affective and the psychomotor. The cognitive domain deals with objectives having to do with thinking, knowing and problem solving. The affective domain includes objectives dealing with attitudes, values, interests, appreciation and social-emotional adjustment. The psychomotor domain covers objectives having to do with manual and motor skills.

There is no "correct" system of classification. The function of any system of classification is to help persons to cope with complexity. The Dewey Decimal System of classifying books is a familiar example of such a system. It is useful because it helps persons to handle very large numbers of books system-
atically and also give them, through the Dewey number, an indication as to what a book is about. At the same time the rationale of the system is criticized by many librarians; and in fact many major libraries no longer use the Dewey system and have adopted a system that enables them to do their job more efficiently.

In the same way that some librarians changed to another system when they found the Dewey system lacking in utility, so teachers and other educationalists should assess a system of aims on the basis of its utility. If it cannot meet the demands of practice, then they should look elsewhere - if necessary, develop their own.

A review of literature about classification of aims shows that there are several other classifications proposed by various authors. Frazer (1978) summarized them in a table (table II) in which four broad classifications (a, b, c and d) and their respective domains are indicated.

<table>
<thead>
<tr>
<th>Table II - Classifications of aims</th>
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<tbody>
<tr>
<td>a) Knowing</td>
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<td>b) Knowledge</td>
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<tr>
<td>c) Cognitive</td>
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<tr>
<td>d) Content</td>
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The three first classifications (a, b and c) will not be considered here because I found the last one (d) more useful for my work as I shall explain next. It is, thus, the last classification I will analyse on the light of a personal construct psychology.

In this classification "content aims" refers to specific subject matter. In a constructivist perspective one purpose of physics courses should be to help students to progress in their cognitive development, using the existing knowledge of the learner as a basis. This will help students to have the ability to recall certain facts and to understand concepts and principles. Another purpose, adopting the Kelly's model man-the-scientist, is to help the development, in students, of certain mental and practical skills which are specific to physics. However a broad and more basic purpose for a constructivist physics teaching should
be to use the contents of physics as a vehicle to help an understanding of, and a sympathy with, the methods of science. It should also help the development of scientific capacities, attitudes and skills such as (i) an ability to be accurate and rational in observation and deduction; (ii) an ability to communicate relevantly and concisely both in writing and speech; (iii) self-confidence when faced with a novel situation such as trying to solve an unfamiliar problem; (iv) an ability to perform tasks in a persistent, honest and rational way; (v) an ability to use creativity to tackle problems encountered in real life; (vi) an ability to get a consciousness of one's own mental frameworks in the interpretation of scientific phenomena; (vii) an ability to face life with an open and curious mind, etc. These, and many others, are labelled in this context as "process aims". It is a fact that we live in an increasingly complex and uncertain world marked by accelerating technological and social change. It is suggested that educational procedures developed during an era of relative stability and certainty are no longer able to provide the student with all the skills he/she needs to exist effectively in contemporary society. For such reasons Schroder, Karlins and Phares (1973) suggest that an emphasis on process aims rather than exclusively on content aims of education, is needed. Frazer (1978) notes that a trend in the last decade has been to give more emphasis to aims of the type which are labelled as "process aims". However, according to him, most of this emphasis has been in the form of words and not in the form of action in the classroom.

Although I am in favour of the classification in which aims are categorized in "content" and "process" aims, I do not see them separately. Teaching "process" and "content" cannot be separated. "Process" can only be taught via "content!" and the two reinforce each other. Adopting a constructivist approach to teaching, I could not make a distinction between the two. I believe that knowledge should be part of a person's inner experience and it is therefore emotional as well as intellectual. This point was stressed by Kelly in that, for him, the distinction usually made between cognition and affect was inappropriate.

Within this context I will scrutinize the aims for physics education at the unified level on the light of the Kelly's metaphor man-the-scientist. This metaphor was put forward by Kelly in the following way:

"A long-range view of man leads us to turn our attention towards those factors appearing to account for his progress rather than those betraying his impulses. To a large degree - though not entirely - the blue print of human progress has been given the label of 'science'. Let us, then, instead of occupying ourselves with man-the-biological-organism or man-the-lucky-guy have a look at man-the-scientist."

(Kelly, 1963)
As pointed out by Watts and Pope (1982) Kelly's model is a generous view of humanity. He refuses a picture of people as "impotent reactors", with behaviour determined by circumstances or genes and prefers a model that portrays people as active agents able to make things happen, able to construct events. He stresses that his model is for all men when he says:

"when we speak of man-the-scientist we are speaking of all mankind and not merely a particular class of men who have publicly attained the stature of 'scientists'. We are speaking of all mankind in its scientist-like aspects ...." (Kelly, 1963)

What should be considered the scientist-like aspects? Physics being a Science, what should be the aims for its teaching in a constructivist perspective? Kelly's model of person-as-scientist allows for hypotheses to be generated concerning the particular kind of scientist to be considered. Personal constructivists have been exploring the question "Man-the-Scientist, but which?" by referring to contemporary philosophy of science. For example, Kelly's personal scientist has been construed as a Kuhnian (e.g. Vander-Goot, 1981; Candy, 1982), as a Lakatosian (e.g. Watts and Pope, 1982) and as a Popperian, Kuhnian, Lakatosian and Feyerabendian respectively in Swift et al., 1983. Kelly himself was unclear about the type of scientist that typified human way. Shotter (1975) quoted by Watts and Pope (1982) says:

"Kelly's approach is difficult to characterize, for his works are littered with illuminating comments from many points of view."

Whether illuminating, or purposefully obscure, Kelly's theory provides an opportunity for us to adopt the 'invitational mood' and propose a view of man-the-scientist.

Examination of much writing about scientific capacities, attitudes and skills reveals a very mixed picture. While some writers name some attributes as, for instance, capacities, others name the same as attitudes and others still name the same as skills. As Tasker, Freyberg and Osborne point out in their report on the first phase of the Learning in Science Project (1982), in much curriculum material there seemed to be some confusion between aims or objectives relating to skills and those relating to attitudes. According to them, on thinking about these aspects of science teaching, a distinction between scientific process skills, scientific habits and attitudes to science must be made. "Skills" were considered to be those thinking processes and actions which are employed in carrying out a particular activity. "Habits" were considered to be associated with carrying out an activity in a particular way. Such habits are partly intellectual and partly attitudinal; it is one thing to know what parallax error is, for
instance; it is another to have developed the skill to avoid it; but just as important
is the habit of mind which incorporates a continuing desire to be as accurate
as circumstances require in taking measurements. Schibeci (1981), in a study
about science teachers' perceptions of affective-domain objectives, draws a
distinction between attitudes to science (such as "enjoyment of science lessons"
and "interest in science") and scientific attitudes (such as "honesty in reporting
data" and "tolerance of the views of others"). Gauld (1982) reports that, in an
analysis of 1547 aims culled from science education literature, Frazer (1978)
found that almost half of these could be categorized as aims related to the
development of scientific attitude. However, Gauld points out that

"there is a great deal of evidence that little emphasis is placed on this
aim in the classroom, apparently because methods for teaching and testing
attitudes may not be widely available rather than because of a general
dissatisfaction with the aim itself".

Within the context of Gauld article, scientific attitude is described
as "an attitude to ideas and information and to particular ways of evaluating
them, a formulation which distinguishes it from 'an attitude to science or scien-
tists' on the one hand and from 'an ability to carry out scientific procedures'
on the other". In his paper, scientific attitudes are identified with "the tendency
to be accurate, intellectually honest, open-minded, objective and to demand
reliable empirical evidence before making decisions". It is suggested that "they
may be most clearly seen in the problem solving activity of scientists". Gauld
points out that the information about the scientific attitude is often conveyed
and reinforced in educational settings by appealing to the work of scientists
in the past. He stresses that the conception of the scientific attitude which
appears in the science education literature seems to have been derived primarily
from the writings of scientists and philosophers of science before about 1960s
in the sense that it is embodied of an empiricist view of science. In his critical
reappraisal of the role of the scientific attitude as a science curriculum aim,
Gauld concludes, based on the material and arguments presented in the paper,
that the development of this attitude as it has been formulated by science educa-
tors for the past 60 years, should be eliminated as the major goals of science
education. He finishes his analysis suggesting that if the meaning of open-minded-
ness, objectivity, or scepticism and indication of how evidence is weighed were
clarified and the way in which they relate to scientific practice were more
carefully discussed in the light of the material presented "one could retain a
reformulated and more acceptable version of the scientific attitude".
I hope that the analysis of the aims for physics teaching at general education level derived from Kelly's philosophy of constructivist alternativism that I shall make in the following paragraphs will help on the clarification of the role which the development of the scientific attitude should play in science education.

In the present study a distinction is made between scientific capacities, attitudes and process skills. Scientific capacities are seen as the adequate mental power to conceive, understand and undertake scientific enterprises. A scientific capacity is for example the capability of being able to face novel situations with open-mindedness. It is also the faculty of being inquisitive towards the unknown. It is also the mental power one should have to be able to critically analyse scientific situations, statements, problems, documents, experimental results, arguments, etc. It is the talent of being creative in the scientific sense, i.e. to be able to imagine and create situations which could contribute to the understanding of scientific phenomena as well as allowing to see the same phenomena in a new perspective. Another scientific capacity is the quality of being able to conduct a scientific work in a group. This means to be able to conduct team work, being an active member of a group taking into account the view of others, being able to "negotiate" their own's instead of imposing them to others when conducting a scientific task. Still another scientific capacity is the capability of self-confidence. It is meant by this, the capability which allows one to recognize one's own possibility to embark in scientific enterprises. It is the capability of having confidence in one's own unaided power and judgment when required to undertake scientific tasks or to interpret scientific phenomena. All these attributes are considered, in the present study, scientific capacities. I see the development of these capacities as an aim for physics education compatible with a Kellian perspective on education. This I shall discuss next.

Kelly's fundamental postulate talks of a person's process being psychologically channelized by the ways in which he anticipates events. The channels are established as means to ends, a person's process

"slip into grooves which are cut out by the mechanism he adopts for realizing his objectives. Thus a person's construct system can act both as a frame and a cage". (Ryle, 1975).

The capacity of open mindedness has an important role in the demolishing of those cages. If a person is not provided with opportunities to develop this capacity or, even worse, if the society surrounding the person acts as a retarding agent for the development of this capacity, the person's construct system will be
a "cage" or a "prison" and hinder development. To comprehend science as the human enterprise that it is, our future citizens must learn from experience that our ideas of what is true may change. They must be able to revise their opinions or conclusions in the light of new evidence. One task of a science teacher (in the case a physics teacher), as seen from a constructivist viewpoint, is to provide situations which could help the development of the capacity of open-mindedness. Ways of doing this, are, for instance, by stressing the dynamic features of science, the development of situations in which children can confront their different points of view and freely argue them in peers-teacher group discussions. Teachers should lead pupils to realize that knowledge is always open to change and revision. The scientific knowledge can't be seen as the final truth but rather as a more adequate explanation for the world that is available in a certain era. Experiences that foster open-mindedness include those in which pupils are confronted with the need to revise a belief as the result of having acquired new information on the subject. I have seen many classroom situations in which instead of a development of this capacity, pupils are discouraged from the use of open-mindedness. This is, per se, contributing to the development of a closed mind.

The evolutionary view of science, and the relativity of knowledge so strongly stressed and advocated by current philosophers of science, imply that teachers, in their role of facilitators of the development of the student-as-a-scientist in Kelly's sense, should help them to develop the capacity of an open-mind. They should help them to be able to accept innovations and to get the skill of seeking new solutions for old problems.

For Kelly, the construction of reality is an active, creative, rational and pragmatic affair. To be able to embark in this construction, is of vital importance that the person possesses an inquisitive, critical and creative mind. In this constructivist perspective teachers should foster in pupils the desire for understanding when confronted with a novel situation which they cannot explain in terms of their existing knowledge. Instead of giving information, teachers should motivate pupils to get the information for themselves. A curious person asks questions, reads to find information, and readily initiates and carries out investigations. Curiosity is a desirable outcome of instruction. But, who are the most curious? Usually they are the younger children. Somehow our pupils manage to lose the spirit of inquiry with advancing age. Curiosity is learned. It can be extended or repressed in the classroom. Problematic situations in which answers and explanations are not immediately available help to stimulate
curiosity. The solutions of problems should raise new problems. The well-taught pupil will approach human behaviour and social structure and the claims of authority with the same spirit of alert scepticism that he adopts toward scientific theories. It is there that the future citizen who will not become a scientist will learn that science is not memory or magic but rather a disciplined form of human curiosity.

New ideas are not accepted in science simply because they are new or different. To be scientific also means to be critically minded. A person with this capacity looks for evidence and arguments that support other persons' assertions. He challenges authority with the questions "How do you know?" and "Why do we believe?". He is concerned about the sources of his knowledge. Haney (1969) points out that one of the greatest temptations confronting the science teacher is that of giving direct answers to pupils' questions and of offering glib explanations. Teachers need to be careful of answers that include the word "because". To foster the development of this capacity of critical mind, teachers should provide evidence to support the generalization in the lesson. Pupils should be taught to look for arguments and evidence supporting important propositions and they should be taught to provide these in their own communications. There are, during physics teaching many situations in which the critical mind of the pupils can be developed. For example pupils should always be asked to critically interpret numerical results of physics problems. The normal mode of instruction in maths involves the development of a solution strategy for a particular type of problem. Then pupils are asked to apply this solution strategy to numerical examples. These numerical examples are labelled by most texts and teachers with a description such as "Examples", "Exercises", etc., but are rarely termed "Problems". If pupils do not make any calculation's errors the solution is correct. However in physics "problems" the correct resolution, concerning the maths aspect, can lead to results incompatible with physical situations. A critical physical analysis of the numerical solution of a problem is a very good opportunity to develop the capacity of critical mindedness. Also the reading of historical and biographical accounts of investigations provides valuable situations in which this capacity can be developed in pupils.

The history of science contains stories of men and women who broke with traditions and saw nature in a new light. The creative person is sensitively open to all his experiences, sensitive to other individuals with whom a relationship is had and sensitive perhaps to most of all the feelings, reactions and emergent meanings which we discovers in. But creative development does not
have to be left to chance. To foster this creative spirit in classroom, teachers can provide experiences in which pupils have the opportunity to design their own investigations and invent and evaluate their own explanations for natural phenomena. Teachers can encourage creative behaviour by (i) treating unusual questions with respect; (ii) respecting unusual and imaginative ideas; (iii) showing students that their ideas have value; (iv) providing opportunities and credit for self-initiated learning; (v) making evaluation contingent on causes and consequences. If creativity is stifled early, it will become imitative, if it survives at all (Torrance, 1965, p. 12). As stressed by Getzels and Jackson (1958) creative thinking contributes to the acquisition of information.

Modern mass societies, and even schools and classrooms, are made up of a bewildering variety of social worlds. Commonality alone is not enough for interpersonal understanding and for the process of social interaction. Kelly's sociality corollary recognizes that the construing of individuals and groups is negotiated with those with whom they live and teach:

"To the extent that one person construes the construction processes of another, he or she may play a role in a social process involving the other person" (Kelly, 1955, p. 95).

In this perspective the development of the capacity of group working is an aim, as important as the others already considered, to be achieved through physics teaching. To foster the development of this capacity, teachers should provide situations in which it could happen. These situations can be of a wide range, for instance the critical analysis of a text, the planning and performing of an experiment, the interpretation of experimental results, etc.. The teacher's role is to go around groups, to be sure that all the groups' members participate, respect others' opinions, and that there is no one solely playing the role of leader, etc.. In my experience of 16 years of teaching sex mixed classes and six year of classroom observations as supervisor of teaching practice I gathered evidence that shows that it is usual, in mixed sex groups, for the boys to take the leadership of the group while girls take a passive role. Teachers should be aware of these situations and act accordingly.

The emphasis on the person as the meaning-maker is central to Kelly's position. He rejects the notion of a passive receiver of knowledge. I have been able to observe situations in classrooms in which a pupil act as a passive receptor because his capacity of self-confidence is not enough developed to help him to put forward his ideas to take an active participation. Sometimes this capacity is not fostered by teachers who, because they are not aware of
it, instead of helping its development, act in ways that stifle it. I believe that
the aim of helping the development of the capacity of self-confidence through
the physics teaching is compatible with a constructivist perspective on teaching.
This capacity is revealed when a person is confronted with different situations
which demand, from the same person, a direct action disclosing a well-founded
self-assurance. If to the pupil who starts to verbalize his understanding of the
physics phenomena being under observations, is denied the opportunity and the
necessary time to end his action, he will loose self-confidence instead of develop­
ing it. The teacher's 'wait-times', one of the teaching skills considered in various
studies about teacher efectiveness (e.g. Row, 1974; Esquivel, Lashier and Smith,
1978; De Ture, 1979; Shulman, 1979, and Tobin and Capie, 1983) haven't been
fully considered. In my opinion, its more important role is the enhancement
of pupils capacity of self-confidence.

Just to facilitate the way of presenting subsquent work I shall list
these scientific capacities as follows:

A. Scientific capacities

A₁ - open-mindedness
A₂ - inquisitive-mindedness
A₃ - critical-mindedness
A₄ - creative-mindedness
A₅ - team-work
A₆ - self-confidence

A scientific attitude is seen within the context of this study as a
mental position, a feeling, a behaviour or a conduct regarding scientific situations.
Carrying out a scientific activity in an accurate, precise, correct way is to
demonstrate possessing the scientific attitude of accuracy. This attitude is
also evidenced by the way people make statements or give opinions. To be intel­
lectually honest when communicating his/her findings is also to have a scientific
attitude. Intellectual honesty is concerned with the conscious act of truthfully
reporting observations. The state of mind of being congruent with one's own
scientific statements, of not being self-contradictory when tackling scientific
situations it is also considered a scientific attitude. It is the attitude of consist­
ency. The mental power to make logical scientific connections when interpreting scientific phenomena is also another scientific attitude. It is the attitude of rationality. To demonstrate this attitude towards scientific problems is to act in a nonempiricist view of science. The person who holds scientific capacities of open-mindedness and critical-mindedness faces scientific situations with an attitude of rationality. Acting or having power to act effectually when conducting scientific activities is to have an attitude of efficiency towards these activities. A person who holds capacities of critical-mindedness and self-confidence is more able to demonstrate an attitude of efficiency towards scientific enterprises than one who does not.

In a constructivist approach to physics teaching, teachers are seen as facilitators of the pupil's progress in their scientist-like aspects. The development of these five components of the scientific attitude, accuracy, honesty, consistency, rationality and efficiency is possible to achieve when teaching physics. Helping the development of the attitude of accuracy in gathering and interpreting data seems to be relatively easy to achieve and test when pupils are engaged in hands-on experiments if teachers are aware of the importance of this attitude in their future lives as citizens. As a scientist man should be impatient with vague, woolly, emotional statements of what given observations or experiences mean. It implies an attitude of accuracy when conducting experiments as well as when reporting their results. If teachers working in a constructivist perspective want to develop in their pupils the scientific attitude of honesty they should ask themselves how they reward honesty in their classrooms. When doing experiments do the pupils know the "right" answers to report regardless of their actual sense data? The value of open-ended experiences for instructional purposes is that they are more like those of the scientist at the frontier of knowledge where the answers are not yet known. Teachers should help their students to be intellectually honest in communicating their findings, seeing this task as a way of helping them to progress in their intellectual development.

Usually children show a lack of consistency between their actions and statements as well as when unfolding their discourse. They also usually show a lack of rationality and bring to the classroom some kinds of superstitions that still exist in their world outside school (and perhaps inside?). Another role of a constructivist physics teacher should be to help the development of this attitude of consistency through the teaching of physics content either when pupils are engaged in class discussion or interpreting physics phenomena.
The teachers should also be aware of the importance for the intellectual development of their students, of the attitude of efficiency. Efficiency is the attitude of the one who is productive, the one who obtains results, the one who is competent. I have observed many situations in physics lessons in which neither the teacher nor the pupils bother to complete the work they were supposed to do. To foster the development of this attitude, situations should be provided in which pupils are stimulated to get results in a fixed period of time, to use efficiently the means they have to organize and complete their work. Each task should be carried to the end even if it looks very insignificant.

For the same reasons presented early the five scientific attitudes considered above are listed as follows:

**B. Scientific attitudes**

- **B1** - accuracy
- **B2** - honesty
- **B3** - consistency
- **B4** - rationality
- **B5** - efficiency

For Kelly, man's behaviour is not driven by instincts (as in psychoanalytic theory) nor is it determined by the schedules of reinforcement and associations between stimulus and response (as in Skinnerian and behaviourist theories). According to Kelly's analogy for man, man-the-scientist and scientist-the-man are both engaged in a process of observation, interpretation, prediction and control (Pope and Keen, 1981).

Elkana (1970) makes a useful distinction between the tactics of science and the strategies of science:

"the tactics of science is the special method by which the scientist proceeds from the well-formulated question in science to the answer of solution. It is also part of the tactics of science to show to interpret the experimental result in the light of the theory which helped to formulate the questions .... The strategy of science is the choice of the fundamental problems motivated by the underlying metaphysical presumption".

The tactics of science are usually called "processes of science". Scientific process skills are the scientific abilities to use one's scientific knowledge effectively in doing science. Finley (1983) reports an investigation of the epistemologic foundations of the conception of science processes as they have been considered
during the past twenty years by researchers, curriculum designers and science educators. The results of that investigation indicated that "a commitment to inductive empiricism pervades the presently held view of science processes". In his article he concludes that when this commitment is subjected to philosophical criticism, two of its major tenets are unsupported.

"First, enquiry viewed as an inductive process is not tenable because there is no frame of reference for judging what facts should be collected or how they should be organized. In addition, there is no logical way to derive inductively new general statements from specific sets of facts. Second, the idea that all meaningful information or knowledge is derived directly from experience is also untenable. Our perceptions are in large part determined and selected according to the a priori knowledge we possess about the nature of objects and events".

One of the implications for science education of the view of science advocated by modern philosophers of science relates the teaching of scientific processes. As pointed out by Finley, the science processes are likely to be context bound. The processes will be different from discipline to discipline and different even within a discipline when different conceptual aspects of the discipline are in use. He stresses that

"if science educators are to understand better the nature of science processes, the relationship between content and process must be understood".

And he adds

"... if we continue to view processes as separated from content we run to risk of placing students in a position where it is difficult or impossible for them to learn what we expect them to learn".

The development of scientific process skills through the teaching of physics'content is compatible with a constructivist view of science education. Within this perspective, consistent with recent philosophers of science, science is seen to proceed in the light of available knowledge. Conceptual knowledge is seen to drive the science processes and not result from them. This implies that the development of the skills related to these processes can only be achieved through the construction of scientific knowledge. Thus, in a constructivist perspective, the development of this scientific process skills is also an aim for physics teaching at general education level. For the reasons already mentioned, the scientific process skills will be listed as follows:
C. Scientific process skills

C1 - observing (accurate and systematic)

C2 - formulating hypotheses (to explain observations and measures)

C3 - designing, planning and performing experiments

C4 - recording, organizing and interpreting data

C5 - manipulating (materials, measuring instruments, apparatus, etc.)

C6 - communicating

C7 - predicting

C8 - inferring

As pointed out by Pope and Gilbert (1983), knowledge in science can be seen as progressing from the personal construction of individual scientists seeking to make sense of their experiences and anticipate events, towards some consensus construing of a topic by a community of scientists. Kelly's commonality corollary allows for overlap between personal views, and therefore a partial consensus. The body of formal knowledge which we call science should be seen as constructed by, and related to, the personal commitments of those who form the scientific community. Children, even before they meet school science, are scientists, i.e. they have their personal theories and indulge in experimentation. Through their direct experiences with the physical world and informal teaching the child will have evolved a set of personal theories in order to explain events. The children's personal scientific knowledge or their alternative frameworks (Viennot, 1979; Gilbert and Osborne, 1980b and Watts, Pope and Gilbert, 1983) have strong implication in the teaching of science. Many recent research studies have shown that these frameworks are often very resistant to change and are impervious to traditional classroom science teaching (Viennot, 1979, Thomaz, 1982). One task of a teacher, as seen from a constructivist viewpoint, is developing situations for learners whereby their personal constructs can be articulated, extended or challenged by the formal constructs of the currently accepted scientific view. To accomplish this task teachers should be aware of the existence of those alternative frameworks of their pupils and devise ways to investigate them. But equally as important as this, they need to be able to help their pupils to be aware of their own personal frameworks in scientific observations. Only
then can pupils challenge their own views and change them to more scientific ones, which will help them to progress in their intellectual and cognitive development. In this perspective, I see other important aims for the teaching of physics:

**D. to help pupils to:**

- **D₁** - be aware of their personal frameworks in scientific observations
- **D₂** - progress in their intellectual development
- **D₃** - progress in their cognitive development

If teachers adopt a Kellyian approach to the teaching of physics I believe that they will help their pupils to:

- **D₄** - develop positive attitudes towards physics

and

- **D₅** - appreciate science as an activity of interest for the common person

The last two points, seen by me as two important aims for physics teaching, if achieved, would be an answer to my concerns expressed at the beginning of this study.

To facilitate writing, I shall use sometimes the word "abilities" as an umbrella to include scientific capacities, attitudes and skills.

### 3.2 The purpose of the Main Study

Over the past twenty years there have been many curriculum development projects in science in several countries. New science curricula have listed a limited number of aims or general objectives within which more specific curricular intentions (and often some of the pedagogical strategies) are spelled out for the science content to be covered.

According to Fensham (1983) the current aims of science curricula for primary and secondary education fall into five broad category concerns:

1. **Concerns for the factual and theoretical (conceptual) knowledge of science;**
(2) concerns for the process of scientific investigation and reasoning;
(3) concerns for practical (laboratory) investigations in science;
(4) concerns for attitudes towards science and attitudes associated with science;
(5) concerns for the relation of science to society.

As Fensham points out, not all science curricula with stated aims include all five categories, and the emphasis across them vary considerably. Some curricula like "Science, A Process Approach", "Patterns - An Integrated Science Project of the U.K. Schools Council" and "Intermediate Science curriculum Study" specify detailed aims in category (2), (process aims) whereas other curricula may simply refer broadly to "scientific reasoning". However, most of this emphasis has been in the form of words and not in the form of action in classroom (Frazer, 1978).

In examining curriculum development projects a tendency to shift the centre of classroom activities from the teacher to the pupils (a positive feature in itself) can be noticed. However this tendency also tends to conceptualize activity in terms of an inductive process of discovery.

As pointed out by Zylbersztajn (1983)

"It is an irony that what became to be considered a radical new approach to science teaching, was, to a large extent, based on a philosophy of science in crisis and due to be soon superseded. Thus the former inherited a weakness of the latter."

The empiricist tradition, as the one advocated by a Baconian philosophy of science, overlooks the role played by theories and world views in the interpretation of empirical data. Similarly, discovery learning approaches tended to overlook the fact that learners do approach their tasks with preconceived ideas which influence the interpretation of their observations and even their perception of the task. Zylbersztajn (1983) presented a case study in which this point is illustrated by the performances of a group of pupils doing a practical activity with lenses. Driver (1983) also presents a number of examples in which shortcomings of inductive discovery are pointed out. Discovery learning approaches failed to exert a great impact in teaching in countries where curricular reforms stress it. The shortcoming mentioned before can be seen as one of the reasons for that failure.

In recent curriculum reform movements learners have been essentially treated as "tabulae raseae", as far as a scientific world view is concerned. It
has been assumed that such a world view or understanding of science will gradually be built up by the learners from all the separate pieces of intended learning in a science course. Prior "theories", or world views, of the learners have been neglected by the proponents of the curriculum reform movement of the sixties. Fensham (1983) reports that in a survey of 20 science curricula in North America, Europe, Southeast Asia and Australia, no set of general objectives was found that acknowledge that their learners do have world views about the phenomena that were to be studied.

In science education, and, more concretely physics education, in Portugal, the current curriculum is nothing but a list of topics to be covered. No stated aims have been advanced. As could be elicited from the analysis of the protocols of interviews with teachers, their views about the aims for physics teaching are vague. Even when mentioned, physics is seen to help students: (i) to achieve general culture (most often emphasized), (ii) to understand the natural world and (iii) to develop cognitively. Even these, they all agree, are far from being achieved during school teaching.

Education has traditionally been a very conservative enterprise. Pope and Keen (1981) identify the classical academic tradition of western education as being one of "cultural transmission". Portugal being a western country is no exception, as could be inferred from the preliminary study. As already stressed at the beginning of this Chapter, from this cultural-transmitter's perspective, education is not seen as an agent for social change and teachers are cast as defenders of society. The body of knowledge transmitted by schools is not questioned and so the structure of society is assured. No critical thinking is developed in students so they act as passive receptors of the superior knowledge imparted by the authority - the teacher. This is what actually happens and this approach has proved unsatisfactory. In reality this is what students, teachers and the public in general do not want. When one of my student teachers was asked, in a first lesson of "Physics Didactics", about her meaning of "teaching", the answer given was that she only knew what "not teaching" was about. Her experience as a student under "teaching" gave her the feeling that she had been used only as a receptor. She knew that "teaching" should not be what she had had but she could not tell what "teaching" should be. Perhaps the question is not an easy one to be answered, or may be it has different answers. Actually I think it has. The answer is truly dependent on teachers'perspectives on teaching and on their views about the aims of physics taught at the different levels.
In Lutz and Ramsey's terms, "working hypotheses" are certain general heuristic maxims which are generated partly out of prior knowledge of the system being studied, partly from first observations, and partly due to conceptual and theoretical positions held by the researcher. Lutz and Ramsey (1974) point out that "it is not likely that anyone is totally free of concepts which predispose him to see certain things. If one is studying education, he will have had some degree of experience with that system".

Unlike the experimental hypothesis, which is generated prior to the experiment, the working hypothesis is generated only after some set of observations have been made in the field. The purpose of the preliminary study, as stated in section 2.2, was an attempt to generate "working hypotheses" upon which to focus the main study. As consequence of a deep reflection on findings of that study and on the psychological perspective of George Kelly, a working hypothesis was generated. In a constructivist perspective the aims of the physics teaching at the general education level should be to use the physics content as a vehicle to help the development in students of capacities, attitudes and process skills inherent to scientific enterprise. If teachers are not concerned with the achievement of these aims, physics teaching is a waste of time and, worse than that, can contribute to a great "swing from science".

As I am deeply involved in teacher education programs of physics and chemistry teaching degree run at the University of Aveiro, mainly concerned with the formation of secondary school teachers, my interests were focused on this area. The design of the main study was based on the following issues:

- Living in an era in which change is occurring so rapidly that we can no longer foresee the information that would be necessary for a student to have in order to be successful in his world, more emphasis on process aims rather than exclusively on content aims is needed;

- Considering a constructivist view of human knowledge and results derived from recent research in science education what process aims should be emphasized during physics teaching at the unified level? The answer seems clear if students should be helped to deal with change - the teaching of strategies to survival (Pope and Keen, 1981).

The teachers' role needs changing from a transmitter of knowledge to a facilitator of the development of man—the scientist, using Kelly's analogy (Kelly, 1955).
This implies developing in students capacities of open-mindedness, inquisitive-mindedness, critical-mindedness, creative-mindedness, team-work and self-confidence; attitudes of accuracy, honesty, consistency, rationality; process skills as observing, formulating hypotheses (to explain observations and measurements), design and planning experiments, recording, organizing and interpreting data, manipulating (materials, measuring instruments, apparatus, etc.) and communicating. It also implies helping pupils be aware of their personal frameworks in scientific observations, to progress in their intellectual and cognitive development in a constructivist's perspective, to acquire positive attitudes towards physics and to appreciate science as an activity of interest for the common person.

For a teacher to be able to help their students on the development of those "abilities" he/she must have them developed in himself/herself. In teacher education ways should be found to help student teachers to be aware of this issue and be able to evaluate to what extent those "abilities" are developed in themselves.

In a system where the traditional perspective on science education has a very strong impact how can a change on that perspective be achieved by student teachers who are going to embark in the process of teaching? And how can we help them to develop skills to teach physics using its content as a vehicle to develop in pupils those above mentioned "abilities"?

In an attempt to find possible answers to these questions a scheme for developing in student teachers those teaching skills was designed.

The aim of the main study was to investigate the application of this scheme within the context of the course of "Physics Didactics" given at the University of Aveiro.

3.3. Teaching skills and Preservice Teacher Education

In this section I shall state what I mean by teaching skills in the context of this study (3.3.1.) and I shall very briefly mention a number of historical factors that shaped the present patterns of Teacher Education (3.3.2.). Some
more recent training techniques that have had some impact on the training of science teachers will also be briefly mentioned (3.3.3).

3.3.1 Teaching skills

As stressed by Wragg (1984), there is less dissent about what constitutes effective teaching in discussion between people outside the profession than there is in the research and evaluation literature.

The quest for the philosopher's stone which characterized the teacher effectiveness research of the mid-1950's, appeared to be given a death blow when a number of writers such as Barr (1961) summarizing the research literature, concluded that there were teachers preferred by administrators, others liked by pupils, yet others taught in classes where there were substantial gains, but by and large these were not all the same teacher. Indeed there is no general agreement on what it is meant by "a good teacher". Good teachers do not have necessarily the same characteristics, neither do they exhibit the same behaviours. What some people consider to be good others may consider as not so good. In other words, as pointed out by Tamir (1983 a)

"the criteria for evaluating teachers' excellence or mediocrity are not very clear".

By teaching skills I mean a set of related types of teaching behaviours during teacher's interaction with pupils, which tend to facilitate the achievement of specified types of aims proposed for the teaching. This definition implies immediately a deep commitment to the meaning of "teaching" or more precisely to the aims for teaching.

Examination of much current writing about teaching skills reveals a very mixed picture. In some fields of study and practice of teaching there is frequently a lack of critical scrutiny of the objectives of the teaching skills. For instance, much work in microteaching involves student teachers practising skills such as questioning, beginning and ending lessons, varying the stimulus, reinforcement, clarifying of explanation, use of examples, and so on, while teaching small groups of children for short periods of time, frequently with the use of video-recording (Alen and Ryan, 1969, McIntyre and Duthie, 1977). The practice may be in itself of great value for the improvement of teaching skills; the main problem to be guarded against is conceiving the skills being practised as ends in themselves, barely related to each other, with no overall
theoretical rationale neither related to the aims proposed for the teaching. It is my belief that the teaching skills to be learned in any methods course for teacher preparation depend very much, I would rather say entirely, on the learner–teacher's perspective underlying teaching. If the perspective is one that emphasizes the transmission of knowledge, then skills to be learned are for instance, the skill of a clear and interesting exposition of contents, the skill of an accurate assessment of what pupils retained of what have been said, etc. On the other hand, if the perspective of teaching and learning is a constructivist one in which the emphasis is made on the development in pupils of scientific "abilities" the teaching skills to be learned are quite different, as for instance, the skill of developing in pupils critical mind, self-confidence, inquisitive mind, science processes skills and so on.

As it is well known, teaching children is a very complex task. Teaching teaching skills to student teachers is still a more complex task. One of the reasons is the age of the learners. They are already adults, generally with a well defined personality, each one having his own style of acting in life, and are much more marked by life experiences than are the children. If, when teaching children, in a constructivist perspective, teaching should take into account children's ideas and prior experiences and help them to construct their own knowledge when dealing with adults this issue rises to a higher level.

3.3.2 Preservice Science Teacher Education

In this section I shall very briefly mention a number of historical factors that have shaped the present patterns of Teacher Education before going on to consider some more recent training techniques that have had some impact on the training of science teachers.

In the eighteenth and nineteenth century training institutions were known as "normal schools", on the grounds that there was some single "norm" endorsed by society. Prussia was in a better position to face educating large number of children in the 18th century than any other country in Europe and the first normal schools were established at Halle in 1704, Berlin in 1748 and Munster in 1759. In France the "école normale" was founded in 1808 to train teachers for the "lycée". Rich (1933, p. 78) explains the term "normal" as used extensively in Europe and North America. The use of the term "normal" in connection with teachers' training is significant of an "idol" of the training college—the idea that there exists some norm or type in teaching, and the nearer the teacher
comes to that norm the better will his teaching be. It is this conception that explains the popularity of the model school, which was looked upon as the concrete embodiment of the norm so far as the school as an institution was concerned, whilst the teaching of the Master of Method was to be regarded as the norm in the technique of class teaching. The function of a training establishment was to perpetuate this stereotype, and the Master of Method was employed in the model school to ensure that each new generation of teachers was poured into the same approved mould (Rich, 1933). According to Wragg (1979) no acceptable science of teaching has emerged to replace de "normal school" concept of the 18th and 19th century. In different countries over the centuries there are several factors which have served to determine the content and pattern of teacher education programmes. For instance one of the factors can be consider the size of the country and its difficulties. In 1956, for example, the Chinese Ministry of Education estimated that over one million new teachers would be needed in the following seven years. In the 1940's the Soviet Union due the effects of World War II had to rebuild its institutions without the aid of its twenty million dead. And at the same time, denazification of teacher training had to be given high priority in Germany.

Also the social conditions of the time have had a powerful impact and influence in the pattern of training. Amongst factors currently of importance are falling enrolments in secondary schools and the rapidly changing society and the world of education, which put pressure on teacher educators to train professionals who will educate their own students in the future, for life in another and very far future.

Another very strong influence has been exerted by the great religious organisations who have frequently used their autonomy, administrative expertise and position of authority in the community to establish centres of teacher education such as Saint Luke's College, or to influence existing institutions and patterns of teaching. For instance, in Tsarist Russia under Peter the Great in the late 17th and early 18th centuries all available teachers were priests and most had been trained at theological seminaries. In Portugal, until the mid 18th century, the primary, secondary and higher educational levels were almost exclusively in the hands of religious congregations, predominantly the Jesuits. A drastic decay of the number of pupils enrolled in any of the educational levels occurred after the banishment of the Jesuits from the country in 1759. For instance, in the case of the secondary educational level, this number was only recovered in the first decades of the 20th century (Leite, 1982). This was a consequence
of the collapse of the educational system, namely in what concerns the number of qualified teachers. Later in 1834 all the religious congregations were banished. In consequence, an almost complete vanishing of schools took place, the teaching being undertaken by private teachers without any kind of tenure.

Wragg (1979) points out that when in many countries possession of a university degree has entitled its holder to teach usually without further training (this happened in Britain until 1973 and is still happening in Portugal in 1985), at Bologna University in the Middle Ages a candidate for a bachelor's degree had to have given a course of lectures to other students in order to get his degree.

Another factor of influence has been the so called "Great Educators", people who did not necessarily train teachers themselves, but whose thoughts and writings were read and interpreted by those who did. Some of those are Pestalozzi, who stressed the importance of immediacy, the object lesson and simultaneous instruction of the whole class; Froebel who emphasized play, motor forms of activity and aesthetic expression, Dewey whose activity programme broke away radically from the common recitation lesson formula; psychologists and writers on psychology such as Freud and his followers Melanie Klein and Susan Isaacs, Piaget, Ausubel and Bruner, the Gestalt school and the later behaviourists like Skinner. To these should be added the host of largely anonymous teachers whose personal example inspired novices who came into contact with them (Wragg, 1979).

In an attempt to conceptualize and confront historical antecedents of current practice Wragg (1979) presents three models of teacher training. The first one is the "primitive model" as he calls it. Accounts by anthropologists of twentieth century primitive communities in New Guinea, Borneo, South American or African or by historians depicting life in earlier times, abound with descriptions of teaching. What is usually missing, however, is formal training in teaching methodology for those who do the teaching. To know something or to possess a skill is to be in a position to teach it to others.

The second, to which he calls "classical model" describes elements of the preparation of teachers in the so-called "classical" periods of Greece, Rome and earlier still India and China. Its features include stress on the need for close personal contact with a distinguished practising teacher, some systematic analysis of the teaching/learning process and the advent of authoritative texts on teaching.
In the third model of teacher training, called by Wragg "the industrial society model", there emerge formal certification procedures. This phase of historical development is characterised by population movements to the cities and towns and increased bureaucratization of education.

According to Wragg (1979) the recent pattern of training novices in the skills of teaching has been firmly under the influence of these earlier models. Dent (1971) quoted by Wragg has gone so far as to argue that little has changed since 1814.

"What they (the colleges) did not do, even in this period of extensive and intensive change, was to alter the basic pattern of teacher education. Despite all the modernization and liberalization that have occurred over the past century and a half, the 1814 pattern has persisted. Nearly everyone says it must be changed. One hopes the change will be for the better".

Commenting on this, Wragg (1979) considers that the criticism made by Dent is over-harsh. Nevertheless some of the more recent training techniques used in teacher training programmes are still embodied by the spirit of the classical model, as I will point out later.

There are many forms of science teacher education programs, as far as the division of time between subject matter and pedagogy is concerned. The two basic models are, on the one hand, the 'end-on program' which requires prospective teachers to complete their science courses and learn a bachelor degree before commencing their teacher education program, and, on the other hand, the 'fully integrated program' in which teacher education experiences are planned for a span of several years and are integrated with the total academic program. There are certainly advantages and disadvantages to each approach but, as it is stressed by Tamir (1983 a) (and I strongly agree), there is no doubt that as far as transfer of desirable instructional strategies is concerned, the experiences of prospective teachers as science students will have decisive and long term effects on their teaching strategies. Innovative and diversified instructional approaches in college and university courses will probably benefit all students but they are of special importance to prospective science teachers.

It is generally accepted that

"the preservice education is but a first step in a continuous cycle of professional growth and inservice education" (Tamir, Lunetta and Yager, 1978).

Nevertheless there is not a consensus about the desirable division of labour between the two. As pointed out by Tamir (1983) one main reason for this is
that in most cases one cannot rely on the existence of systematic inservice programs so as to be able to structure a comprehensive well sequenced pre and inservice program.

As the main study focuses mainly on the component of teacher education that deals with the professional training or methods work (although it also focuses on the first year of inservice education) I shall now concentrate on it. The professional training comprises methods course and teaching practice.

i) Methods course

There is not agreement about the domain of a methods course, as was pointed out by Silva (1981); rather an overlapping between what is usually meant by methods course, teaching practice, educational psychology and audio-visual aids. Usually topics to be covered are: analysis of science curriculum projects, analysis of science methods, analysis of course materials, facts, principles and concepts in science, classroom management, motivation and discipline in science classes, evolution of theories of science teaching, science as inquiry, content analysis, learning theories and human growth and development, etc..

It is generally recognized that traditional methods courses fail to develop the competencies required of today's science teachers. Indeed a certain amount of dismay has traditionally been expressed by beginning science teachers and practising teachers about the outcomes of preservice courses for teacher education. How often have staff-rooms resounded to the echo of "forget everything you were taught in preservice courses, real classrooms are like this ....". The validity of such exclamation can, of course, be seriously challenged, but research into the preservice education of teachers in the past has pointed to important differences between course objectives and student needs. (eg. Pettitt, 1975; Gunstone and MacKay, 1975). Methods courses have been criticized for being too removed from classroom needs and some other times for lacking theory. One basic assumption underlying some suggestions for the preparation of science teachers is that

"teaching is an interaction and ... talking about teaching cannot be substituted for actually doing it." (Williamson, 1969)

Another related assumption is

"the greater the amount of direct active participation of teacher trainees in learning situations the greater the degree of behavioral change." (Lee, 1969)
This shows a tendency in methods course to move towards teaching experiences. One familiar strategy is microteaching which frequently follows the guidelines developed by Allen and Fortune (1967).

(ii) Teaching practice

As observed by Silva (1981) the aims of teaching practice are not very well specified. It is intended to provide a bridge between theory and practice and allow for a more gradual introduction to the hardships of teaching.

Very often teaching experiences have very little in common with the work done in a methods course. Tabachnik, Popkewitz and Zeichner (1979-80) have described the extent to which student teachers are constrained by the decisions that the real task in teaching practice is often that of pleasing a cooperating teacher to receive a favorable evaluation. Many researchers (e.g. Iannaccone, 1963; Silberman, 1970, Lortie, 1975) argue that student teachers, during their teaching practice, abandon university "theory" in favour of the "practice" of their cooperating teachers.

The organization of teaching practice in different countries varies very much in time spent in school and the way it is distributed. The commonest arrangement is for teaching practices to occur in blocks of time, comprising one-third of the academic year and to move from observation of lessons to real teaching. In Portugal, as already stated in Chapter 1, teaching practice comes as a one-year block, occurring in the fifth and last year of the teacher training degree.

During teaching practice the student teacher is usually supervised by a member of staff in the school in which he is practising and one or more members of staff in the College or University.

3.3.3 Some more recent training techniques in Science Teacher Education

In this section I shall review the following training techniques that have had their impact on the teaching of science teachers: simulation, micro-teaching, system approach, interaction analysis and a constructivist approach to teacher education.
Simulation

Simulation is a teaching/learning technique that has been used in the training of complex tasks, such as driving, piloting, being a doctor and also in teacher education. The simulated situation represents reality as closely as possible but the complexity of events is controlled so as to make it simpler. In teacher education the technique takes the form of peer teaching role playing. It has been used in the training of science teachers (Psillos et al., 1984), frequently in conjunction with microteaching (Perrot, 1977).

The student teacher is presented with a teaching task to perform, his peers acting as pupils. Given the artificiality of the situation, its instructional value has been queried. It has been said that, notwithstanding the constraints, the technique presents some advantages because it allows the possibility of breaking down the complexities of the task and having control over the teaching variables. And through a sequence of controlled simulated situations student teachers are progressively helped to master the whole situation. I personally do not share these views about this technique. I used it some years ago when I taught a methods course on "Physics Didactics". Although I recognize that in some training situations (driving, piloting, being a doctor, etc.) the technique can be very helpful, in teacher education I am convinced that in many occasions it can be very harmful for various reasons. One of the reasons is the fact that the simulated situation is too far from reality, or more, it is misleading reality. Teaching is a complex task but I do not agree that it is wise or fruitful to break down that complexity for training purposes. If when training for driving, piloting or even for being a doctor the trainee is dealing with passive entities, when training for being a teacher the trainee is dealing with active individuals, interacting with a desirable activeness. And it is this interaction that it is not real when peers are acting as pupils. It is very difficult, I would say even impossible for peers to react as pupils either in what concerns behaviours related to age or knowledge related to intuitive concepts or prerequisites. It is not a situation as close as possible of the real one but it is, most of the time, the opposite of the real one. My experience with this technique was very bad. I could not find just one single student teacher who had enjoyed this role playing. On the contrary, I came across with many situations in which the student teachers felt frustrated and unhappy with their performance for reasons not related with their competence as teachers.

Another reason for my lack of sympathy with this technique is concerned with the control over the teaching variable, a point in common with a traditional approach to microteaching a technique I shall discuss next.
It has also been said that one great advantage of simulation lies in the fact that the practice is free from harmful consequences in pupils. Again, I am in disagreement with this statement because if student teachers are being trained in situations which are misleading the real situation most likely they are getting wrong perspectives about teaching which will certainly affect their future performance as teachers and can have harmful consequences for their future pupils.

ii) Microteaching

By the 1960's many of those involved in the training of teachers had themselves come to share the same dissatisfaction with the existing training programmes that successive generations of teachers have showed when reporting that they had to learn to teach "on the job", and that their preservice training seemed to be of little or no help. Despite the obvious weakness of conventional practices, there was little development of alternative procedures. Among those alternatives which were suggested, one of the most promising appeared to be "microteaching", an approach developed at Stanford University from 1963 onwards (Allen and Ryan, 1969). The Stanford team first attempted to simulate teaching situations by having students "teach" groups of their peers but finding that student teachers tended to react negatively to this, they arranged for them to teach short lessons to small groups of school pupils, the aim being to provide experience of "real teaching", but in simplified conditions. McIntyre et al, (1977) point out that perhaps the most original idea was that of using these simplified conditions to help students practice specific skills of teaching, with both the student teacher and his supervisor focussing their attention on any one occasion on the predefined skill. A further innovation was the use of videotape recordings so that students might directly observe their own teaching instead of having to depend on the reports of others.

In microteaching, as it was initially developed by Allen and others (1967 and 1969), attention is focused on specific teaching skills, which are practised for short periods (from five to twenty minutes) with a small group of pupils, usually four to seven. Immediate feedback on the microlesson is usually provided by means of videotape recordings, but audiotapes, supervisors' and peers' comments, pupils' criticism, or some combination of these, have also been used. On the basis of the feedback provided, the student teacher analyzes and restructures the lesson in order to teach it to a second group of pupils. Again this is followed
by feedback, which is analyzed and evaluated for improvement. By employing this "teach-reteach" cycle, it is possible to give the student teacher the opportunity to put into practice at once what he has learned from the feedback on the first attempt. Variations and refinements of this basic structure have been noted in specific courses, but in general the characteristics are those of a systems approach which I shall describe next.

Allen and Eve (1968) defined microteaching as

"... a system of controlled practice that makes it possible to concentrate on specific teaching skills and to practise teaching under controlled conditions."

This "system of controlled practice" may also be described as a scale-down teaching encounter: scaled down in class size (4 - 7 pupils), lesson length (5 - 20 minutes), and teaching complexity, in that it concentrates on one or a small group of related teaching skills at a time. In other words, as Perrot (1977) puts it,

"the classroom in miniature is brought into an experimental situation, set up in a university, college, teachers'centre or school, where the effectiveness of variables in facilitating the acquisition of teaching skills can be assessed."

Operational definitions of specific teaching skills are essential to this conventional approach to microteaching. These teaching skills are derived from an analysis of the teaching process into specific techniques. The technical-skills approach was initially developed at Stanford (Allen and Gross, 1965; Cooper and Stroud, 1967). These technical skills (e.g. 'using higher-order questions') are not linked with specific subject matter. As McDonald (1973) puts it,

"each skill has an observable and easily countable teacher response linked (with some exceptions) to a specified and also easily countable student behaviour. These response pairs are thus defined functionally and independently of the substantive character of verbal utterances on the topic of interchange between student and teacher."

Fuller and Manning (1973) after their review of 320 studies related to self-confrontation reported that generally

"specifiable behaviours which are under the subject's control can be changed by microteaching"

and that the better specified the goal the more likely the change. With regard to studies which did not find significant changes after using procedures similar to microteaching, Weiss (1972) points out that this is particularly true when
other attention-getting treatments are used and outcomes are global. As Borg et al (1970) note

"... it is much easier for the teacher to incorporate a behaviourally defined technical skill into his classroom behaviour, than a vaguely stated exhortation, such as 'Be less directive', 'Establish rapport with the student', or 'Individualize instruction'."

It is worth mention that of the studies listed by Fuller and Manning (1973), as noted by Perrot (1977), those which found desired improvements in performance included videotaping together with additional components, particularly goal-setting or focus.

The Stanford microteaching model was adapted and extended to include the use of conceptual and symbolic models. It means that it bases learning on modelling, imitating and repeating. The teaching skills are presented as suggested behaviours. The rationale for modelling is derived from theories of imitation which indicate that even complex social behaviour can be acquired almost entirely through imitation (Bandura and Walters, 1963; Bandura, 1971). Three conditions are seen necessary to learning by this model. The learner must: (i) watch the actions of the person from whom he is learning; (ii) be cued on what is to be watched and later performed; (iii) have the capacity for making the responses required. Within this model, motivation to adopt the observed behaviour and reinforcement for doing so are other requisite conditions for learning.

Modelling may take the form of observing another's real or recorded teaching performance; it's what is called perceptual modelling. Filmed or videotaped models are a feature of the self-instructional learning systems which involve microteaching. It has been said that the advantages of using perceptual models in the form of videotaped or film excerpts of teaching behaviour is that they can focus on particular skills to bring out their essential features and that they can be viewed by many students any number of times. Stones and Morris (1972) pointed out, that by a variety of examples, students are able to acquire a particular class of teaching behaviour without the idiosyncratic features of any single teacher's performance.

The distinction between perceptual and symbolic models is that the latter ones are written or oral instructions on how to perform certain behaviours. Some authors use the term "symbolic modelling" to describe a printed transcript of a classroom situation which contains instances of the skills.
As indicated by Bhushan (1976) "microteaching" in preservice education training courses takes many forms. Although the use of closed-circuit television and the recording of a short lesson on videotape is uncommon, the practice of specific skills is less so. Quite often, television is used as a "mirror", providing video-recording of short lessons, which are commented upon by tutor or group of peers. Brown (1975) stresses that in these cases ratings are frequently global in character and often threatening to all but the most extrovert.

Where specific teaching skills are practised in preservice courses they frequently follow the Stanford model (Allen, 1967), i.e. student teachers are required to practice individual skills such as "reinforcement", "varying the stimulus", "use of examples", etc., in the context of a brief lesson. Such practice is frequently preceded by lectures or seminars given by their tutors in which these technical skills of teaching are defined and illustrated. Practice or microteaching is followed by appraisal sessions carried out with a supervision and in the light of this appraisal the microlesson is revised and taught again (Perrot and Duthie, 1969 and 1970). Perrot (1977) comments that although appraisal is sometimes carried out with the aid of an observation schedule or guide, which is specific to the skill being practised and which is used in a joint critique by both supervisor and student teachers. It is also quite common to find that appraisal is carried out without reference to any guide, with the result that there is often a lack of focus in the subsequent discussion during which an analysis of the teaching behaviours being viewed is attempted.

Some criticisms have been made to microteaching. Microteaching situations are said to be artificial and it is doubted that the skills developed in microteaching situations will transfer to classroom situations (Altmen and Ramirez, 1971, quoted by Silva, 1981). Nevertheless some studies (Kallenbach and Gall, 1969; Borg at al, 1970; Bredänge and Tingsel, 1974; Veenman 1974, Klinzing-Eurich, 1975, and Perrot et al, 1975) have shown that skills acquired in microteaching can be effectively transferred to the normal classroom. Kallenbach and Gall (1969) compared the teaching performance of elementary school trainees who received a summer microteaching course with that of trainees who received conventional classroom observation. It was concluded that microteaching was a more effective training strategy when compared with conventional methods.

Borg at al (1970), Veenman (1974) and Perrot et al (1975) also showed that skills, developed in self-instructional courses including microteaching,
can be effectively transferred to the normal classroom by both preservice and inservice teachers.

For Wragg (1979) the main criticism that can be made of microteaching is that it has ossified around the original Stanford list of skills. Ward's study of 141 secondary training institutions in the United States showed that most of these were using the first Stanford set, (Ward, 1970).

It has also been said that microteaching tends to fragment the teaching behaviour. This is true if it follows the guidelines developed by Allen and Fortune (1967) in which the approach to microteaching emphasized training in specific skills.

Applebee (1976) among others', has thrown some doubt on the efficacy of such an approach. Brusling (1974) noted that from 1963 to 1972 the emphasis has gradually changed from: (i) being teacher-centred to being pupil centred; (ii) general to subject specific goals; (iii) isolated to integrated skill training. Applebee (1976) states that

"one of the factors underlying this evolution has been the tacit recognition that it is not the 'technical skills' which must be taught, but how to integrate them into a more complex goal oriented teaching activity."

As also pointed out by Tamir (1983 b) the original approach to microteaching may be regarded as an antithesis to the teaching of science as inquiry and by inquiry. If we consider some of the suggestions for a reconceptualization of microteaching in which teaching skills are treated simultaneously and integratively with subject matter content and avoid the reductionistic-technical behaviouristic approach, the criticism that microteaching tends to fragment the teaching behaviour does not hold true. In a constructivist perspective of teaching the student teacher is conceived as a developing person; changes are to be perceived by oneself based on a reflective teaching and on a reflective learning. It is the learner, the student teacher who is construing himself his style of teaching not imitating or being modelled by others'style. My own approach to microteaching is compatible with a constructivist perspective of teaching. It is a common practice in preservice education, as already pointed out, to use videotapes showing teachers using specified skills in microteaching or in normal classroom teaching, together with a commentary drawing attention to specific instances of the teacher's use of the skill (McIntyre et al, 1977). I do not integrate this step on my approach to microteaching because I believe that one person ought to act in a reflective way and not by imitation and also because through my work with teacher preparation I have had strong evidence that the analysis
of one's own performance is much more efficient than the analysis of others' performance. I am more in favour of an approach to microteaching which concentrates on problems or issues that are raised during a particular lesson rather than on predetermined isolated skills. This approach involves a task analysis of the lesson in a preactive phase of teaching (a reflective analysis of the scientific abilities that can be developed through the contents of the lesson); the teaching of the lesson with real school students in a real classroom period time, and an opportunity to analyse the teaching of individual student teacher in the context of a particular subject matter. This approach provides not only in depth understanding of the subject matter but opportunity to reflect on the instruction and on the learning of secondary school students as related to a particular topic. It makes use of the positive feature of microteaching, but at the same time gives a more realistic and more useful experience to the student teacher as pointed out by Tamir (1976, 1983b).

A real difficulty with microteaching is the performing of a lesson with pupils whose background is usually unknown. Usually in preservice microteaching situations the student teachers who train a teaching skill with pupils do not know what they not yet know or what are already their ideas about the topic being taught. As stated by Ausubel (1968)

"the most important single factor influencing learning is what the pupil already knows. Ascertain this and teach him accordingly."

How can this be done in a microteaching lesson even when lesson time is extended to a normal class period? I agree that this is not an easy problem to overcome. Nevertheless in science teaching if student teachers are aware of the various alternative conceptions pupils usually held about the concept being taught they are more likely to lead the interaction towards pupils ideas even if they could not diagnose them in those pupils. The problem is also ameliorated if the pupils asked to come to the microteaching lesson are from known classes, either classes from which the supervisor or the student teacher have been able to observe and follow or classes taught by teachers to whom supervisor or student teachers can talk.

In my own case, as I have been supervising the teaching practice and at the same time giving the methods course "Physics Didactics", the first situation has been happening. I have been able to give the student teachers as much information as possible about the pupils she/he is going to teach. Usually student teachers find this very helpful.
Both simulation or microteaching when used as training techniques, have the characteristics of a system approach.

iii) System approach

The system approach, a trend on teacher education that has had impact on the training of science teachers, is described as consisting of a series of steps which occur in cyclical fashion: (1) precise specification of the behaviour which is the objective of the learning experience; (2) carefully planned training procedures aimed explicitly at those objectives; (3) measurement of the results of training in terms of the behavioural objectives; (4) feedback of the observed results; (5) re-entry into the training procedures; (6) measurement again of the results. Teacher education research on this theme clusters primarily around three special cases of the systems model: interaction analysis training, micro-teaching, and behaviour modification. Frequently the inter-relatedness of these three models is noted (McDonald, 1973; Langer and Allen, 1970).

iv) Interaction analysis training

Interaction analysis involves a set of procedures which may be used either to study teaching behaviour for research of curriculum evaluation or for teachers to analyse and possibly modify their own behaviour. The initial emphasis in the research of pioneers such as Anderson (1939), Withall (1949), Flanders (1970), Medley and Mitzel (1963), Bellack et al (1966) and Smith et al (1968) was largely on verbal interaction. In a recent study, Ogunniyi (1984) used a slight modification of Flanders' (1970) Interaction Analysis categories as an instrument to identify and describe the nature of teachers' verbal behaviours exhibited during science instruction. Increasingly investigators such as Galloway (1968), Argyle (1978), Hargreaves (1967), Klinzing et al (1985 a, 1985 b) have concerned themselves with non-verbal interaction. Teachers learn to analyse the questions they ask, their techniques of reinforcement, the information they give and many other aspects of classroom life. For over one hundred instruments for such an analysis have been developed in the past few years. One of the most widely used is the Flanders system aimed at systematically analysing the spontaneous verbal interaction between teachers and children. Such interaction analysis schedules are useful mainly in formal settings, for obtaining a description of events. However, they are less appropriate in more unstructured situations.
The categories themselves are open to question since many of them are too broad, and there may be other dimensions which could have been included.

Delamont and Hamilton (1976) note some factors which impose certain restrictions upon the use of the interaction analysis systems, as for instance: i) the majority of them ignore the temporal and spatial context in which the interaction takes place; ii) they usually are concerned only with overt observable behaviours. They do not take directly into account the differing intentions that may lie behind such behaviour; iii) they are expressly concerned with "what can be categorized or measured" (Simon and Boyer, 1968, p. 1); iv) they focus on "small bits of action or behaviour rather than global concepts" (Simon and Boyer, 1968, p. 1); v) they utilize pre-specified categories and vi) they place arbitrary boundaries on continuous phenomena which may create an initial bias from what it is extremely difficult to escape.

The Flanders system has been heavily criticized by Adelman and Walker (1975) who comment

"we do not consider that interaction analysis provides information appropriate or adequate for any but most limited of educational ideologies."

They point out that although the interaction analysis instruments are useful for roughly locating differences among centralized formal classrooms, they are

"virtually unusable in informal contexts." (p. 220)

The idea of identifying the specific competencies which teachers need in order to fulfill their role led the way or are related to the competency based teacher education programmes. Such programmes are designed so as to help the student to attain the required competencies. The student is held accountable when he evidences the necessary degree of competence in performing the essential tasks of teaching. The way many teacher educators use microteaching is an example of competency based teacher education. Tamir (1983 b) stresses that

"the problem in this approach is that the trainees spend much of the previous time allocated to teacher education in a kind of training which brings about improvement in a number of discrete skills, but often fails to deal with the more important aspects of teaching, namely the ability to weigh alternatives and to make decisions about 'what to do, when and how'."
And he adds that

"science teaching involves much more than acquiring mastery of certain discrete skills."

Reducing teaching to a set of particular behaviors may cause, in the long run, more damage than good. I strongly agree with Wragg (1979) when he says that

"at its worst competency based teacher education results in several separate skills being checklisted as they are acquired, and whether or not they add up to a competent teacher is a question not always asked."

New forms of interaction analysis and microteaching has been developed by educationalists as an attempt to bring the focus of inquiry where it can have most effect. Wragg (1979) stresses that such techniques should move towards active self-directed learning, both for teachers and pupils. He also points out that human resources are of the utmost importance. The student's own perceptions of the original lesson and his interpretation of sources of feedback will determine how he reteaches after a microteaching session. As noted by Pope and Keen (1981) there is then a growing emphasis on the person - a particular teacher or a particular student's opinions, attributes or decisions have become a prime focus of interest for those advocating educational built on "humanistic" foundations. This trend in teacher education, as well as in general education, emphasizes the idea that learning is a highly personal activity based on values and more influenced by attitudinal and motivational forces than by the application of specific techniques and methods. It has to do with the affectiveness as well as the cognitive domain of learning, as pointed out by Silva (1981). In the field of science teacher education Schibeci (1981) stresses that the cognitive training has been developed, but the affective domain has been understressed. In a study conducted with 202 science teachers he concluded that science teachers regard the cognitive domain as more important than the affective domain. While teachers may share the view that attitude objectives are important, they certainly (from teachers own reports) do not systematically teach towards attitudes. Rather, they teach towards students' acquisition of knowledge. Schibeci (1981) stresses the need for the affective training of teachers.

The humanistic approach to learning, which underlying a humanistic teacher education, is described most fully in the book "Freedom to Learn" by the psychotherapist Carl Rogers. The essential idea is that learning is personal and emotional. If the right emotional conditions can be found for each individual, then meaningful learning will take place. Carl Rogers (1969) differentiates between two processes in learning: teacher-based (the traditional "cultural transmission" approach) and learner-based learning.
Learner-based learning is self-initiated, has a quality of personal involvement and is evaluated by the learner, i.e. he knows whether or not it is meeting his needs. This significant learning is pervasive, i.e. it makes a difference in behaviour, attitudes and personality of the learner and its essence is meaning. The knowledge/truth that evolves in self-discovered learning is "private" knowledge — truth that has been personally appropriated and assimilated in experience (Pope and Keen, 1981). According to Carl Rogers this "personal" knowledge cannot be directly transmitted from the teacher to the student. This does not mean that the "public knowledge" or facts, ideas, etc., that the teacher is trying to impart can never become personal knowledge as Pope and Keen (1981) point out. What Carl Rogers is saying is that the process is not one of direct impersonal association between the issues to be learnt (stimuli) and knowledge of them (response). If the public knowledge to be imparted is personally appropriated by the learner and has significant influence on his behaviour and attitudes, then public knowledge becomes personal knowledge. Whilst distinguishing between the two processes, Carl Rogers makes a value judgement that personal knowledge should be the aim of the educational process. For Carl Rogers, personal knowledge is facilitated by a specific type of interpersonal encounter between the teacher and student.

v) Towards a constructivist approach to teacher education

The development of a personal model of teaching has been penetrating the field of teacher education. In a constructivist perspective this development is an integral part of the teacher training enterprise. The formal concepts presented in the college or university courses need to be transformed and assimilated into the particular frame of reference held by the student teacher. As pointed out by Pope and Keen (1981) the student teacher as learner should become aware of his frame of reference from the outset and continue to explore his developing assumptions which will underlie his teaching behaviour.

Notwithstanding, innovations in the training of teachers that emphasize the process of personal development have been more in the form of suggestions than in the form of practices. In the next section I shall overview the recent research in preservice teacher education which will give an idea of the paucity of research in the area of constructivist teacher training.
3.4. Research on Preservice Teacher Education: a literature review

Whilst there is a lack of consensus on many issues relating to teacher education, Pope and Keen (1981) note that there seems to be a growing agreement that more and varied research in this area is needed. They emphasize that

"much educational research has been devoted to the performance of pupils under a variety of teaching methods or organizational structures within schools; rather less emphasis has been on the behaviour and attitudes of teachers."

They also add that

"traditional research on teachers tended to concentrate on the development of inventories for selecting persons who would make 'good' teachers. Critical reappraisal within the whole framework of education has led to an increase in the scope of research into teacher training."

Koehler (1985), examining the research regarding preservice teacher education for the last four years, placed the selected studies into six relatively discrete categories: studies of skills, competencies, and attitudes of practicing teachers that reflect on their preservice teacher education; studies of the skills, competencies and attitudes of teacher education students that reflect either on their present or past education or on the future quality of the teaching workforce; evaluations of teacher education courses, of methods within courses, or of complete programs; studies of teacher educators; studies of institutions; and studies of various research reviews.

Within the first categories many researchers surveyed practicing teachers through mailed questionnaires or interviews (for example, Cheek, 1982). Other researchers observed teachers in their classrooms for the purposes of evaluating the results of specific preservice teacher education practices or for assessing the quality of preservice teacher education programs in general (for example, Ayers, 1982). Several of the studies were approached from a special interest perspective (e.g. school/community relations, handicapped, exceptional children, reading, mathematics). In these studies teachers generally suggested that they could know more; they or the researchers concluded on the basis of the perceived needs that their preservice education did not provide enough training in these areas. Some researchers assessed the basic skills of teachers with paper and pencil tests (for example, Sametz and McLoughlin, 1983); others asked teachers about their perceptions of the adequacy of their subject matter and pedagogical preparation (for example, Hegvedt-Wilson et al, 1982). Most
of the latter studies concluded that teachers were not well prepared in classroom management and in instructional strategies, and that these needs should be addressed at the preservice level.

Findings of studies investigating the skills, attitudes, perceptions, and/or beliefs of student teachers, indicate perceived student teacher deficiency in subject matter knowledge (Wheeler and Feghali, 1983; Diem, 1982). It was also found differences in the cognitive development levels of elementary and secondary preservice students (Silverman and Cresswell, 1982); and others examined math anxiety or perceptions of confidence in areas such as curriculum tasks and evaluation (for example, Beasley, 1981). Most researchers concluded that the preservice students needed more work in whatever knowledge, skills, attitudes or competencies were investigated.

Koehler (1985) notes that none of the studies on preservice students investigated their more general attitudes toward teaching, a topic extensively investigated in the 1970's. These attitude studies, reviewed by Veenman (1984) directed attention to the shift in attitudes from idealistic, progressive, or liberal during preservice to more traditional, conservative or custodial in teaching practice and in the first year of teaching. These studies have often been used to suggest that the treatment effects of teacher education wash out during field experiences. In a more recent study Wagner (1985) found that teachers after an intensive weekend workshop with a lot of skill practice and role playing, more often than not go back in their classrooms and do nothing.

According to Koehler's review (Koehler, 1985), the largest number of studies were conducted on methods, course, and program evaluations. The majority of them were non-comparative studies in the sense that one course or method was evaluated with pre/post or just post-testing (for example, Cohen and Alroi, 1981; Martin, 1981). The second largest group was comprised of comparative groups of students with two or three groups of students receiving somewhat different treatments (for example, Henry, 1982). A number of studies also involved the use of control groups (for example, Hay, 1983). The courses and methods included such topics as science inquiry methods, teaching models, early vs. later field experiences, history and philosophy of science courses for developing understanding of science, and sex stereotyping modules. All but one of the studies examined only changes in preservice teachers' skills/attitudes, competencies and other attitudes. In the one case, researchers also looked at changes in pupils' achievement in classrooms taught by the treated preservice students.
(Miller, 1981). None of the studies involved long-term follow-up of the students into classroom teaching, nor did they include descriptive research on the treatments themselves. Most of the studies found treatment effects. It was also noted that program, method and course evaluations do not assess the implementation of the method, nor what goes on in the "control" classrooms. Shortcuts are taken in reliability and validity tests of the measures; and there are ecological problems in assessing a skill conducted in front of peers or a videotape machine.

A special group of studies in the third category consists of the evaluations of teacher education programs. One of the studies conducted in Tennessee School of Technology developed an extensive data base on its teacher education students and followed them into classrooms (Ayers, 1982); other in Ohio State followed 450 of its graduates (Carter and DiBella, 1982) and still another in Indiana followed 97 of the graduates of its block program (Buffie, 1982). However, as Koehler (1985) notes,

"given the extreme conceptual and technical difficulties in attributing a teacher's behaviour, attitudes and/or beliefs to a teacher education program, these studies often say more about practicing teachers than about the quality of their preservice programs."

Although very few studies of teacher educators were found in this search, some findings are worth mentioning. Raths and Katz (1982) surveyed social studies methods professors and found that they used a narrow range of instructional techniques and that their descriptions of the attitudes of successful classrooms teaching did not match their goals for their classes. Similar findings emerged from the protocol analysis of the interviews with student teachers during the preliminary study when asked to comment on the way their classes were conducted. Griffin et al (1983) in a study concerning the role of the supervision in teaching practice found very little in clinical feedback sessions that related to the student teachers formal pedagogical education, or to research on teaching and learning. They noted that the feedback was particularistic and provided few explanations. Also Zimpher et al (1980) and Koehler (1984) found that university supervisors are relatively clear about and can define the nature of their roles, only one of which relates to clinical feedback.

Another interesting finding emerged for research conducted on supervising and cooperating teachers by different researchers is that the primary influence on the student teachers'instructional style is the cooperative teacher (Zeichner, 1980; Johnson, 1976; Seperson and Joyce, 1973; Yee, 1969).
I shall not consider the studies in the two other categories, institutional studies and research reviews and studies of studies, because, although concerning preservice teacher education, they are not relevant to this particular study.

As noted by Koehler (1985) much of the recent criticism of teacher education is based on the attitudes and perceptions of teachers, often beginning teachers, about the adequacy of their skills and their teacher preparation programs. Katz et al (1981) in reviewing follow up research referred to the problem with this evaluation model as the "Feed-Forward Problem":

"All preservice training can be characterized as anticipatory socialization, which inevitable involves giving students answers to questions not yet asked and not likely to be asked until students are in the thick of actual service. This aspect of socialization can be called the feed-forward problem. It includes resistance from the student at the time of exposure to given learnings and, later, protestations that the same learnings had not been provided, should have been provided, or should have been provided in stronger doses." (p. 21)

The question of the relative impact of colleges and universities on one hand and public schools on the other hand with regard to the socialization of teachers has received a great deal of attention in the literature of teacher education both in the United States and in the United Kingdom. Zeichner and Tobachnick (1981) comment that there has been very little direct analysis of the role that the form and content of university teacher education plays in shaping the professional perspectives of students. They stress that

"By focussing on how things were to be done without asking students to consider what was to be done and why, the university initiated discussions which tended to encourage acquiescence and conformity to existing school routines."

If teacher educators adopt a constructivist view on teaching, the development of a personal model of teaching is an integral part of the teacher training enterprise. The formal concepts presented in the college and university courses need to be transformed and assimilated into the particular frame of reference held by the student teacher as already pointed out in section 3.3.

As stressed by Pope and Keen (1981), the student teacher as learner should become aware of his frame of reference from the beginning and continue to explore his developing assumptions which will underlie his teaching behaviour. If teacher educators want to break the existing school routines and implement significant innovation in education, they ought to provide for their student
teachers innovations similar to those they propose for the education of pupils in schools. Postman and Weingartner (1971) commenting on this say:

"Following the medium is the message or you learn what you do theme, it is obvious that teacher education must have prospective teachers do as students what they as teachers must help their students, in turn, to do. How might such a teacher-education programme operate? In general something like this: it would shift the prospective teacher into the role of the inventor of viable new teaching strategies. It would confront him with problems specifically intended to evoke from him questions about what he's doing, why he's doing it, what it's suppose to be good for and how he can tell." (p. 138)

Despite a growing interest in constructivism within psychology and education very few studies on its use in teacher education have been reported. Implications of a constructivist view on teaching how to teach has taken more, the form of suggestions than the form of report of practices (for example, Pope and Keen, 1981; Olson, 1981; Zylbersztajn, 1983; Gilbert, 1983; Postman and Weingartner, 1971; Diamond, 1981; McQuater, 1985;). Bean-Peretz (1984) presents results of some research projects focussing on teachers' thinking about curriculum materials, research methodology and instruments exploring the personal construct systems of teachers and student teachers. Pope and Scott present a case study concerned with the teaching of psychology to student teachers. Reguzzoni (1983) describes specific methodological innovations conducted in the Association for Teacher Training (OPPI) which can be viewed as having a constructivist perspective. They are mainly concerned with inservice training. No studies with a constructivist perspective on preservice physics education or even in science education were found.

Zylbersztajn (1983) stresses that, for teacher education to follow a constructivist approach, it would seem important starting with a critical reflection on the part of the teacher and student teachers of the existing practices and materials, and of the usually "taken for granted" assumptions underlying them. He also points out that the creation of opportunities for teacher education does not, however, seem to be restricted to formal courses. And he exemplifies

"One encouraging new avenue for the introduction of changes in science education is the recently established Secondary Science Curriculum Review Project (West, 1982). The aim of the project is to promote the development of new approaches to science teaching through the interaction between science teachers and researchers. It would be advisable for those researchers advocating a constructivist approach to involve themselves in such, or similar, collaborative efforts."

The main study reported here is an attempt to put the theory into practice in one of the steps of the physics teacher education (the methods course)
and to follow the development of the practice in the two next steps, teaching practice and the first year in the teacher profession.

3.5. Summary

In this chapter a constructivist approach to physics education was considered as a fruitful alternative to the "cultural transmission" approach. It was stressed that the current philosophies of science as those of Popper, Kuhn, Lakatos and Feyerabend are compatible with the psychological perspective of George Kelly and his constructivist view of knowledge. They all recognise the role of personal construction in the development of scientific knowledge.

Aims for physics teaching at the general education were derived within a constructivist perspective and the purpose of the main study was stated.

The component of teacher educators that deals with the professional training was considered. Particular attention was given to methods course and teaching practice within which most of the main study took place.

Some more recent training techniques used in teacher education were considered and their implications on a constructivist view of education were analyzed.

Despite a growing interest in constructivism within psychology and education a review of past research suggests that this philosophy has scarcely been underlying the practices of science teacher education.
4.1. Introduction

As already stressed, one of the findings of the preliminary study was that physics classes are held in a traditional way and are primarily content-oriented. Teachers are less concerned with the process of personal development than to transmit knowledge. The majority of students do not like physics classes and they get bored and lose interest in physics.

Notwithstanding, physics student teachers tend to reproduce the same pattern of teaching when they are required to perform as a teacher. This is probably because opportunities have not been provided for them to reflect and critically analyse the model of teaching conveyed to them. Once student teachers get an awareness of their idiosyncratic meanings for "physics teaching", the next task is to emancipate them from their dependence on habit and tradition by providing them with the skills and resources that will enable them to reflect upon and examine critically the inadequacies of the outcomes of their models. It is my belief that in teacher education opportunities should be provided for an unreflective attitude to be abandoned so that a more critical scientific attitude can be adopted towards established educational creeds.

To bring about the change in student teacher's perspective on physics teaching from a traditional to a constructivist one I designed a scheme within which the change could take place and in which situations are provided to enable the student teachers to develop teaching skills to teach according to the latter approach. This approach to physics teaching is for them a kind of innovation, meaning by that what Rogers (1967, p. 13) defines as:

"An innovation is an idea perceived as new by the individual."

Rogers points out that it really matters little, as far as human behaviour is concerned, whether or not an idea is objectively new provided that it is perceived as new.

As pointed out by Cryer (1983) Rogers' definition of innovation has influenced the thinking of workers in innovations. Over time the definition
has been subjected to some alterations to widen the scope of its application. So, Rogers and Shoemaker (1971), added to the concept of 'idea' two further concepts, "practice" and "object", and two years later Zaltman et al (1973, p. 50) changed the word "individual" by "unit of adoption" where the adopting unit can vary from a single individual to a group or an organization.

Miles (1964) suggests that innovations may usefully be considered as being willed or planned for, rather than occurring haphazardly. He was concerned with innovation in Education, an area where, for an innovation to be

"a species of the genus of change."

it must be carefully and accurately thought and planned. Miles' view supports my concerns to design carefully a scheme and to plan activities within it which could foster the student teachers' will to adopt the innovation and prepare them to act on it.

I found inspiration to designing the scheme in Rogers' developmental model of change and innovation. The reasons for this are expounded in the next sections.

4.2. System and developmental models

Rogers (1967) defines a change-agent as:

"a professional person who attempts to influence adoption decisions in a direction that he feels desirable."

The term "change-agent" was first used in laboratory studies of small groups in 1947 (Lippitt et al, 1958, p. 10). The term has since been utilized by a number of research workers in their analyses of the diffusion of innovations.

As a change-agent in the process of changing student teachers' perspectives on teaching I had to find ways of thinking about and figuring out situations of change. In the literature on change and innovation I looked for models which have been used by workers on the field. An appraisal of the literature on the issue reveals a very mixed picture due to the ambiguous and synonymous use of such terms as models, theories, paradigms, frames of reference, etc. Nevertheless I found in a distinction made by Chin (1961) a very useful synthesis and organization of what has been written about models of change and innovation. Chin makes the distinction between two kinds of models of change. The "system" models and the "developmental" models. He characterizes system models as
the ones in which the change is derived as a consequence of how well the parts of a system fit together or how the system fits in with other surrounding and interacting systems. The source of change lies primarily in the structural stress and strain externally induced or internally created and the process of change is a process of tension reduction. Psychologists, sociologists, anthropologists, economists and political scientists have been "discovering" and using the system model. In so doing, they find intimations of an exhilarating "unity" of science, because the system models used by biological and physical scientists seem to be exactly similar. Thus, the system model is regarded by some system theorists as universally applicable to human relationships in small or large units. By developmental models, Chin means those bodies of thought that centre around growth and directional change. Developmental models assume change; they assume that there are noticeable differences between the states of a system at different times, that the succession of these states implies the system is heading somewhere; and that there are orderly processes which explain how the system gets from its present state to wherever it is going. Developmental models postulate that the system under scrutiny - a person, a small group, interpersonal interactions, an organization, a community or a society - is going "somewhere"; that the changes have some direction. Chin (1961) points out that working within developmental models, change-agents find it necessary to believe that there is direction in change. As the system develops over time, the different states may be identified and differentiated from one another. Terms such as "stages", "levels", "phases", or "periods" are applied to these states. As Chin (1961) notes, no uniformity exists in the definition and operational identification of such successive states. Chin (1961), points out that a system model is more appropriate to analysing how stability is achieved being weakest in clarifying and explaining development over time, whereas a developmental model is more appropriate to an analysis over time. Developmental models, therefore, have important utility for change-agents.

The difference between system and developmental models can be illustrated by Lewin's force field theory of change. Lewin (1951, p. 200-201) sees behaviour in an institutional setting as a balance of forces working in opposite directions within a social-psychological space. Change takes place when there is an imbalance between the forces. Such imbalance "unfreezes" the pattern which alters until the opposing forces are again brought into equilibrium. An imbalance may occur through a change in magnitude of any one force, a change in direction of a force, or through the addition of a new force. The process of change consists of three main phases: unfreezing, moving
and refreezing. Unfreezing occurs when the possibility for change is created; moving when there is continuous disequilibrium; and refreezing when the balance is created around a new equilibrium. Lewin's model is therefore both system and developmental; system in its aspects of force-field analysis and developmental in its aspects of stages of change.

There is an indication in the literature that the use of Lewin's model has been predominantly system rather than developmental. As Cryer notes (Cryer, 1983), for a developmental model its three stages are rather simplistic. In practice only the first two are usually relevant for the researcher, as change-agent, who in the limited time available for most studies, is reluctant to regard any change as permanent. Zaltman et al (1973, p. 58) give an example of this when referring to that, in the late 1960s, in many universities many fringe programs were cut back or dropped in result of loss of moral and financial support from many segments of society.

4.3 Some models for change and innovation

Many strategies and models of change and innovation have been developed by workers in the field. The distinction between strategies for innovations and models for innovations is very often difficult to make because, as Cryer (1983) notes, when a worker develops what he calls a strategy it becomes requoted as a model and where a worker develops a model, it is invariably reprocessed as a strategy.

According to Lindquist (1978) in order to innovate successfully, a message should be created and delivered in such way that the receiver accepts it and acts on it. Accepting this three attributes for classifying models (the creation of a message, the acceptance of the message and action on it) the models most widely mentioned in the literature can be nested into three categories: models which stress the creation of the message; models which stress the delivery and reception of the message and models which stress the acceptance of the message. The empirical/rational models can be included in the first category. These models (Benne and Chin 1969) are concerned with generating data in such a way that rational people are bound to be convinced (eg. expensive and exhaustive research studies conducted by academics with a high reputation). These models raise questions of how to collect this sort of data, how to set up networks to communicate it, whether or not it is worth the expense, how
long it would take and whether people always are convinced by it.

People tend to behave in more or less the same way as they have always behaved. Consequently they are cautious or even antagonistic to change. Normative/re-educative models (Benne and Chin, 1969), which can be included in the second category, focus upon "re-educating" people to change their attitudes so that the new "norms" are favourable to the change. These models raise questions of how people can be re-educated to new norms, how long it would take and whether it is ethical.

In certain circumstances people do what they are told to do. Power/coercive models (Benne and Chin, 1969), which can be included in the last category, consider the use of power to coerce and enforce change. These models raise questions of ethics, how to acquire the necessary coercive power and whether the change is likely to remain in force once the source of the power turns its back.

The models considered above are not developmental because they do not give equal stress to each aspect or particular consideration to sequencing. Most of them have the perspective of offering strategies to the change-agent.

4.4 Rogers' model of the adoption process

4.4.1 The adoption process

Rogers (1967) defines the adoption process as the mental process through which an individual passes from first hearing about an innovation to final adoption. The adoption process should be distinguished from the diffusion process which is the spread of a new idea from its source of invention or creation to its ultimate users or adopters. A major difference between the diffusion process and the adoption process is that diffusion occurs among persons while adoption is an individual matter. As pointed out by Rogers, the adoption process is one type of "decision-making". The adoption of an innovation requires a decision by an individual. He must begin using a new idea and, in most cases, decide to cease using an idea that the innovation replaces.

Decision-making is the process by which an evaluation of the meaning and consequences of alternative lines of conduct is made. Johnson and Haver (1953, p. 8) listed the following steps in decision-making: (1) observing
the problem, (2b) making an analysis of it, (3b) deciding the available course of action, (4b) taking one course, and (5b) accepting the consequence of the decision.

Decision-making is thus a process that may be divided into a sequence of stages with a different type of activity occurring during each stage. Likewise, the way in which an individual adopts an innovation is viewed by most researchers as a process. Adoption of a new idea is a bundle of related events flowing through time. It is then a process. Similarly to the decision-making process, Rogers conceived the adoption process to be arbitrarily broken down into stages for conceptual purposes. He broke it according to three attributes: (1b) congruent with the nature of the phenomena, (2b) congruent with previous research findings, and (3b) potentially useful for practical applications.

Ryan and Gross (1943) were probably the first to recognize that the adoption of a new idea consisted of stages. But is was Wilkening (1953, p. 16) who first pointed out that and individual’s decision to adopt an innovation was a "process" composed of stages or steps. Wilkening (1953, p.9) described the adoption of an innovation as

"... a process composed of learning, deciding and acting over a period of time. The adoption of a specific practice is not the result of a single decision to act but of a series of actions and thought decisions."

4.4.2. Rogers’ stages

Although previous workers identified stages in the mental process of adopters within their own separate disciplines, Rogers was the first one to generalize them after a thorough review of publications from different research disciplines. He identified the following five stages: (1b) awareness, (2b) interest, (3b) evaluation, (4b) trial and (5b) adoption. The five stages are characterized by Rogers in the following way.

At the awareness stage the individual is exposed to the innovation but lacks complete information about it. The individual is aware of the innovation, but is not yet motivated to seek further information. The primary function of the awareness stage is to initiate the sequence of later stages that lead to eventual adoption or rejection of the innovation. Hassinger (1959) points out that information about new ideas often does not create awareness, even though the individual may be exposed to this information, unless the individual has a problem or a need that the innovation promises to solve.
At the interest stage the individual becomes interested in the new idea and seeks additional information about it. The individual favours the innovation in a general way, but he has not yet judged its utility in terms of his own situation. The function of the interest stage is mainly to increase the individual's information about the innovation. The individual is more psychologically involved with the innovation at the interest stage than at the awareness stage. Previously, the individual listened or read about the innovation; at the interest stage he actively seeks information about the idea. His behaviour is now definitely purposive rather than nonpurposive. His personality and values, as well as the norms of his social system, may affect where he seeks information, as well as how he interprets this information about the innovation.

At the evaluation stage the individual mentally applies the innovation to his present and anticipated future situation and then decides whether or not to try it. A sort of "mental trial" occurs at the evaluation stage. If the individual feels the advantages of the innovation outweigh the disadvantages, he will decide to try the innovation. The trial itself, however, is conceptually distinct from the decision to try the new idea. The evaluation stage is probably the least distinct of the five adoption stages and empirically one of the most difficult about which to question respondents.

At the trial stage the individual uses the innovation on a small scale in order to determine its utility in his own situation. The main function of the trial stage is to demonstrate the new idea in the individual's own situation and determine its usefulness for possible complete adoption. The individual may seek specific information about the method of using the innovation at the trial stage.

At the adoption stage the individual decides to continue the full use of the innovation. The main functions of the adoption stage are consideration of the trial results and the decision to ratify sustained use of the innovation. Adoption implies continued use of the innovation in the future. Rejection can take place at any one of these stages.

As Rogers, (1967) points out, there is not complete agreement as to the number of stages in the adoption process, although there is general consensus on the existence of stages, and that adoption is seldom an "impulse" decision. He refers (Rogers, 1967, p.80) that in 1943 Ryan and Goss utilized four stages, as did Wilkening in 1953. The North Central Rural Sociology Subcommittee described five stages in 1955 after a review of literature available in
1954; so did Beal and others in 1957, and Copp and others in 1958; in 1958, Emery and Oeser in 1958 and Wilkening in 1956 utilized a three-stage process, while in 1961 Lavidge and Steiner postulated six stages. Rogers (1967, p. 81) also mentioned that in 1960 Holmberg utilized the concept of a seven-stage adoption process in his Cornell University anthropology course. The first stage in his process of "individual cultural change" is availability of the innovation to the individual. His middle five stages are similar to Rogers' stages, although Holmberg conceptualized the trial stage as preceding the evaluation stage. Holmberg's seventh stage is integration of the innovation into the individual's routine.

The conceptualization of innovation stages has been refined and extended to adoption made by adoption units such as groups and organizations as well as individuals.

In 1973 Zaltman et al reviewed the state of stage conceptualization for individuals and organizations. Figure 4-1 and 4-2, overleaf, summarize some of the various models of the innovation process. Fig. 4-1 provides a summary of the individually oriented, more micromodels as most completely specified by the Robertson (1961) and Zaltman and Brooker (1971) models. Fig. 4-2 provides a summary of the organizational model as represented by Zaltman, Duncan and Holbek (1973).

4.4.3. The validity of the concept of stages

The five stages or steps in the adoption process were theoretically postulated by Rogers (1967). Although evidence that these stages actually exist is extremely difficult to provide because researchers can probe only indirectly the mental processes of individuals who adopt an innovation, there is evidence that the concept of stages in the adoption process is valid. Two major investigations of the validity of the stages concept came to the same conclusion (Beal and others, 1957; Copp and others, 1958). Four main types of evidence are available: (i) interviewer's opinions; in an Iowa study of adoption of two farm innovations utilizing a relatively instructed interview approach, Beal and Rogers (1960) found that most of the respondents recognized that they went through a series of stages as they moved from awareness to adoption: (ii) the fact that, in the same study, only a few respondents reported skipping any stages also provides some evidence that the stages concept is valid: (iii) although it is quite possible for an individual to use the same sources of information, perhaps in different ways, at several stages in the adoption process, if respondents reported different
**Figure 4-1 - Summary of individual-oriented models of the innovation process.**
(from Zaltman, 1973, p. 61)

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**Wilson (1966)**

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<td>2. Proposing of change</td>
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<td>3. Adoption and Implementation</td>
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**Figure 4-2 - Summary of organizational models of the innovation process.**
(from Zaltman, 1973, p. 62)
sources of information at each stage, this would indicate some differentiation of the stages. Many research studies (e.g. Beal and Rogers, 1960; Coop and others, 1958) indicate a differentiation of information sources at different stages in the adoption process; (iv) if individuals reported they adopted on impulse – that they became aware of an innovation and adopted immediately – a logical question about the validity of the stages concept could be raised. On the contrary, research studies show that most individuals seem to require a period of time, that can often be measured in years, to pass through the adoption process. This provides some indication that adoption behaviour is a "process" and one that may contain stages.

Rogers (1967) points out that research evidence seems to support the validity of the adoption stages concept, but there is very little evidence as to exactly how many stages there are in the adoption process. He also mentions a study made by Mason (1961) which although supporting the concept of an adoption process composed of stages his analysis suggests that the stages (except for awareness and adoption) may not always occur in the same time sequence for all individuals.

4.5. A scheme for promoting perspective change and for developing appropriate teaching skills.

As it was already indicated in section 4.2., models for innovation tend to be system rather than developmentally oriented and most have the perspective of offering strategies to the change-agent. In contrast to them, Rogers' model of innovation is purely developmental and is concerned with the individuals who might adopt an innovation (which they have not designed themselves) rather than with the change-agent who encourages them to adopt it. Examples of use of system models of innovation within higher education can be found in the literature, for instance in a book of case studies edited by Collier (1974), a book of papers edited by Entwistle (1976) and two works by Berg and Ostergren (1977 and 1979) all concerning innovations in higher education; articles concerning changes in universities by Elton (1981) and Caston (1977); works concerning professional education (Schein, 1972; Martorana and Kuhns, 1975; and Lindquist, 1978).

Also in general education models of innovation used are predominantly system models (e.g. Martin, 1975, Whitehead, 1980). Although some works on general education offer a developmental orientation (e.g. Rudduck
and Kelly, 1976; Miles, 1964, and Havelock, 1972) they are more concerned with strategies for the change-agent than with the mental processes of a person progressing towards adopting an innovation, as stressed by Cryer (1983). Nevertheless some developmental models for change have been recognized in general education. Hall, Wallace and Dorsett (1973) describe the Concerns Based Adoption Model (CBAM) as a theoretical sequence of stages, which indicates that teachers pass through a series of stages of concern when they are attempting or expected to use new innovative materials.

Although Rogers' model of the innovation process cannot be regarded directly as a strategy, it inspired me in the design of a scheme for promoting change in student teachers' perspectives on physics teaching from a traditional to a constructivist one, as well as for developing in them teaching skills to teach accordingly to the "new" perspective. Being aware, by Rogers' work on innovation, of the stages in the mental process of a person, progressing from first awareness of an innovation towards adoption or rejection of it, helped me in the development of situations within which the different stages could take place.

Some points must be mentioned about my thought processes when designing the scheme. In Rogers' model the awareness stage starts when the individual is exposed to the innovation. But, as stressed by Hassinger (1959), information about the new idea does not create awareness, even though the individual may be exposed to this innovation, unless the individual has a problem or a need that the innovation promises to solve.

Student teachers have a "need" although most likely they are not conscious of it. Due to their contact with the school world and the approach of teaching conveyed by the majority of their teachers all through their schooling, they already held a traditional perspective on teaching. In consequence of this I felt the necessity of considering three substages in the awareness stage. In the first substage, student teachers should be helped to an awareness of their own model of teaching and be able to express in their own words their own ideas and perspectives of what they really mean by "teaching physics".

In the next sub-stage opportunities should be provided in which student teachers are helped to make a reflective analysis of the implication of their models, their shortcomings, their incongruencies, etc..

At the third and last substage of the awareness stage opportunities should be provided in which student teachers can get an awareness of alternative
perspective and through which they are able to construe themselves a "new", a constructivist perspective on teaching. Believing myself to hold a constructivist view of knowledge, and strongly in sympathy with the "perspective of the personal", it would not be consistent with my own beliefs if I presented student teachers with a model of teaching or an innovation "not designed by themselves". Rather I shall provide opportunities which help them and enable them to construe themselves a constructivist view of teaching. In Chapter 6 the tasks designed to achieve these purposes will be described in detail.

All these substages are concerned with the individual, similarly as Rogers' stages, although they give me information about the strategies to adopt which can lead the individual to go through the mental processes from an awareness of an innovation towards adoption or rejection of it.

For the interest stage I consider also three substages. The fundamental assumption underlying the creation of the first substage of the interest stage is that in teaching, there is a relationship between perspectives and aims as well as in thoughts and actions. Thus, once student teachers became sufficiently interested in the new perspective on teaching they should be helped to derive aims for physics education seeking the rationale for them through various sources.

My own experience of dealing with student teachers has led me to an awareness of the different alternative meanings for words usually used when talking about aims for education and specially for science education.

Although it looks strange many science student teachers have never heard about the processes of science and cannot identify them. Similar findings have been reported by various researchers. Tobin (1984) points out that although process skills have been a desired outcome of the majority of elementary and middle school projects developed since 1960s, casual observation and conversation with teachers suggest that process teaching is still uncommon. It is also stressed that, although in universities and colleges methods instructors still implore preservice and inservice teachers to incorporate processes in their programmes, there is evidence to suggest that a significant proportion of secondary and college students is unable to utilize the skills necessary to plan and conduct investigations (Dillashaw and Okey, 1980; Tobin, Capie and Bradley, 1980). Thus it is of the greatest importance that during the interest stage situations should be provided in which each individual aim's is scrutinized and sources for the clarification of the meanings should be provided.
Another point needs to be mentioned. After providing opportunities for the student teachers to be aware of (1st stage), and to be interested (2nd stage) in the innovation, I found it desirable, to provide opportunities for the trial stage. Only after student teachers proceeded this stage of the adoption process were they more able to enter the evaluation stage. Other researchers having utilized the concept of adoption process conceptualizing the trial stage as preceding the evaluation stage (Holmerg, 1960; Mason, 1961) are mentioned by Rogers (1967).

Consequently to what have been said, the starting point of the scheme is the identification by student teachers of their meaning of "teaching physics". This means that the first step in the adoption process of the innovation - a constructivist perspective on teaching - is to get student teachers aware of the model of teaching they already held. I say 'to get them aware' because most of the time they already have a model of teaching due to their schooling experience in which they have been taught by a fairly large number of teachers but they have not had opportunities to reflect and be conscious of it.

Figure 4-3, overleaf, presents a diagram showing the various steps of the scheme with the tasks provided for the five stages to take place.

In the next chapter I shall discuss some methodological problems in order to justify the research approach I took in the study of the implementation of the scheme.

4.6. Summary

In this chapter some models of change that have been used by researchers working in innovations were described. The distinction between system and developmental models was considered. Although system models have been predominantly used in higher and general education, a developmental model was used in this study. System models are more appropriate to analysing how stability is achieved in the adoption of an innovation. Developmental models are more appropriate to clarifying and explaining development over time, therefore they are more useful for the change-agent.
1. awareness of a S.T.'s own model of teaching
2. reflective analysis of the implication of that model
3. awareness of alternative models. Exposition of the innovation
4. discussion of aims for physics education at the secondary level
5. analysis of the meanings of the aims
6. task analysis of the teaching skills needed to achieve the aims proposed
7. development of the teaching skills in teaching sessions with small groups of pupils
8. reflective analysis of the outcomes in terms of the S.T.'s learning
9. development of teaching skills in real classroom situations
10. reflective analysis of the outcomes in terms of S.T. and pupils' learning

Figure 4-3 - A scheme for promoting perspective change in physics teaching, and for developing and monitoring the development of, teaching skills in student teachers
The Rogers' developmental model of the adoption process, with its five stages, is not a strategy for innovation in the sense that it is concerned with the individuals who might adopt it rather than with the change-agent who encourages them to adopt it. Nevertheless it was used in the present, study as the framework for the design of a scheme to promote change in student teachers' perspectives on physics teaching and for developing adequate teaching skills.
CHAPTER 5

RESEARCH METHODOLOGY

5.1 Introduction

Building upon the work of Kuhn, Patton (1975) defines a paradigm in these terms:

"A paradigm is a world view, a general perspective, a way of breaking down the complexity of the real world. As such, paradigms are deeply embedded in socialization of adherents and practitioners, telling them what is important, what is legitimate, what is reasonable. Paradigms are normative; they tell the practitioner what to do without the necessity of long existential or epistemological consideration. But it is this aspect of a paradigm that constitutes both its strength and its weakness, its strength in that it makes action possible, its weakness in that the very reason for action is hidden in the unquestioned assumptions of the paradigm."

If one accepts the above definition the decision to follow a certain research paradigm is not, per se, an independent problem, a matter of convenience or fashion or sympathy. The "unquestioned assumptions" of the paradigm are the commitments inherent to the researcher's view of the world. Rist (1977) puts it in this way,

"the adherence to one paradigm as opposed to another predisposes one to view the world and the events within it in profoundly differing ways."

He points out that the power and pull of a paradigm is more than simply a methodological orientation. It is a way by which to grasp reality and give it meanings and predictability. Kuhn (1970b, p. 46) stated:

"That scientists do not usually ask or debate what makes a particular problem or solution legitimate tempts us to suppose that, at least intuitively, they know the answer. But it may only indicate that neither the question nor the answers are felt to be relevant to their research. Paradigms may be prior to, more binding, and more complete than any set of rules for research that could be unequivocally abstracted from them."

The implication of this statement is that the research orientations are themselves grounded in a perspective beyond simple questions of methodological procedure. The decision to follow a particular line of research is profoundly theoretical, regardless of its relative availability. Research methods represent
different means of acting upon the environment. To choose one line of action over and against another is to have foregone others available from a different perspective and orientation.

Each method reveals peculiar elements of symbolic reality. And to accentuate one aspect of that reality versus another is to influence both observations and conclusions (Denzin, 1970, p. 298).

As Rist (1977) points out, all knowledge is social. Thus the methods employed by one researcher to articulate knowledge of reality necessarily flow from beliefs and values she/he holds about the very nature of that reality.

Due to these theoretical considerations and to the fact that current research efforts in education are paradigmatic, I feel the necessity to discuss in this chapter the two major methodological approaches adopted by educational researchers in order to justify the line of action I followed in this study. Then the settings of the field trial, the nature of the participants and their roles will be described. In the last part of the chapter the particular procedures used for data collection in the different settings will be explained and the methods of analysis used will be discussed.

5.2 The two major research paradigms in educational research

There have been two basic research paradigms in educational research. These two paradigms are a reflection of a dichotomy that some argue exists in research in social sciences generally (Pope and Gilbert, 1982). Kuhn (1970a) suggests that if one is operating within a paradigm then there will be a particular group of axioms, meanings for words, methods used etc., which typify that paradigm and make it "incommensurate" with any other paradigm. This means that each one of the paradigms is typified by a different research methodological approach.

Although no one approach has a hegemony in educational research, the one that has been more widely published, taught, accepted, and rewarded is the psychostatistical experimental approach. This psychostatistical Fisherian-type experimental approach aims at the formulation of universal laws using the methods of experimental design and statistical analysis developed by R.A. Fisher for the agricultural sciences. Its adherents have developed methods of measurement that depend on the context-free assumptions. Their procedures are aimed at isolating variables from the personal and social context in which
they operate. Subjects are then randomly assigned, standardized methods of measurement are applied, data are correlated and findings are generalized on the basis of statistical analysis. The emphasis on qualitative methods and reliability of measurements leaves to the experimenter the role of an outside observer while the subjects are considered mere objects of study, Silva (1981). This approach, frequently referred to as "the Scientific Method" was lauded by Campbell and Stanley in 1963 as "the only available route to cumulative progress." The rules of experimental design and the technical procedures of measurement and statistical analysis are the time-tested methods of the biological and natural sciences. Their demonstrated success in those fields has served to justify applying them to the study of persons, groups, social processes, and social institutions, as pointed out by Mishler (1979). The view that the methodology developed in the natural sciences is applicable to the study of social events and processes is usually referred to as positivism. It means that the mainstream tradition in social sciences derives from and depends upon the assumptions at the core of the positivist conception of science. These include the assumption of the unity of scientific method despite the diversity of subject matters, the ideal of explanation as consisting in the subsumption of individual cases under general laws, and the formal structure of mathematical physics as a methodological ideal.

Despite the philosophical critique to this traditional model of science, its application to human affairs was dominant until some years ago. The first criticism to this methodological approach comes from investigators who have used the prescribed methods and found them wanting. Some signs of disappointment started showing in the field. Campbell and Stanley (1968) note that

"the overoptimistic grounds upon which experimentation had been justified were undercut, and a disillusioned rejection or neglect took place ... (when experiments) often proved to be tedious, equivocal, of undependable replicability, and to confirm pre-scientific wisdom." (p. 3)

Magoon (1977) notes that

"there are some good indications that educational research may have reached a crisis stage with regard to its major Fisherian experimental design tradition."

He also suggests that "the paradigm has never worked". In social psychology Gergen (1973) argues that the laws found in experimental and field studies are bound to their historical contexts and that the search for transhistorical laws is illusory. Also in developmental psychology Bronfenbrenner (1976), by comparing different studies, demonstrates that well-accepted findings on cognitive and
social development are context-specific rather than having the generality claimed by investigators. Elton and Laurillard (1979) raise strong objections to this approach in educational research such as: (i) teachers hold an integrated, holistic, view of student learning. Investigations in the psychometric tradition have not succeeded in reunifying work based on variables to produce such a perspective. Therefore such research is seen as unfruitful, in that it is not acceptable for use in the classroom; (ii) its basis is the ascription of "causes" and "effects". For learning phenomena, these interact in such a way that they cannot be observed separately.

On commenting about research on student learning, Entwistle and Hounsell (1979) point out that the main weakness in the psychometric approach is perhaps the inevitable restriction of the analysis to the set of statements contained in the inventory, a restriction which constrains the student to describe his approach within the framework of ideas provided by the researcher. Stenhouse (1978) notes that

"although some progress has been made in educational research within the statistical-experimental paradigm there is widespread disappointment with its yield."

He suggests that the principal methodological problem appears to be the breakdown of the sampling procedures associated with the statistical-experimental paradigm. Problems of internal validity were classically dealt with by Campbell and Stanley (1963), while Snow (1978) dealt with problems of external validity. Stenhouse (1978) comments that both Campbell and Stanley, and Snow were optimistic about the potential of modifications of the paradigm as expressed in "quasi-experimental" (Campbell and Stanley) and "quasi-representative" (Snow) designs. Nevertheless, although he does not suggest that the seam should be abandoned as unworkable, he advises that other seams should be found and worked. In the field of classroom research, Delamont and Hamilton (1976) point out that despite results in classroom research in the U.S.A.

"have grown to voluminous proportions, their contribution to understanding has been disproportionately small."

Also Biggs (1976) points out that

"there is a growing body of opinion that the existing technology of psychometrics is largely irrelevant to education, from the application of psychometric techniques of analysis to the construction of tests." (p. 280)

He agrees with Snow (1974) who pinpointed the source of problem in the fact that educational researchers have been obsessed for years by "systematic" research designs borrowed from agricultural research.
Koehler (1978) identifies several types of problems associated with classroom research conducted under the psychostatistical experimental paradigm. Briefly they are: lack of reliability and validity of observation measures (the observation measures and analysis procedures do not take into account the nature of the teaching situation and context; they are unable to indicate the appropriateness, or correctness, of a teacher behaviour and they make it difficult to characterize the important chunk of activity); outcome measures (standardized tests are seen as highly unsatisfactory for two reasons: they do not necessarily reflect what the teachers are trying to teach and there are many other outcomes besides cognitive achievements which are deemed to be important); statistical problems (major statistical problems are related to difficulties in reducing masses of data into manageable units, to the unit of analysis issue — individual student or classroom average, to attempts to discern casual relationship with correlational data, and to a host of problems related to the use of regression techniques).

There have been two major types of reactions to the problems with the psychostatistical experimental approach. The first is to attempt to improve upon the paradigm, and the second is to abandon it entirely and seek other ways of thinking about and of conducting educational research.

Rist (1982) points out that two remarkable and interrelated developments in educational research have occurred during the past ten years. The first was

"the dissolution of the natural science model of inquiry as the preeminent model in education."

He notes that

"researchers have come to recognize that there are multiple routes and multiple destinations for their efforts. The causes of this recognition include the inability of the "scientific" approach to: (1) answer many of the most pressing questions in education, (2) respect fluidity and change, (3) address the processes of education."

According to Rist (1982) the limitation in the view that "what cannot be measured cannot be important" have come apparent for all to see.

The second of the important changes, derived from the first, is that the conceptual and epistemological vacuum created by the retreat of quantitative methods has been filled by a vigorous and growing interest in qualitative methods. Rist (1982) stresses that the two pithy phrases "generalizations decay", and "statistical realities do not necessarily coincide with cultural realities" suggest the reorientation in much current educational research.
Pope (1981) points out that the relativistic approach to knowledge that appears to permeate much of modern scientific writing gives an image of man which requires a fundamental shift in the methodological approach adopted by social scientists. Esland (1971) suggests that the psychometric epistemology constrained development in education by its notions of "objectivism".

To take the place of Fisherian techniques, Cronbach (1975) proposes that a researcher simply but radically reverses the priority he has traditionally placed on building generalizations about effects of variables and gives careful attention to particular cases first.

"As he goes from situation to situation, his first task is to describe and interpret the effect anew in each locale, perhaps taking into account factors unique to that locale of series of events (cf. Geertz, 1973, Chap. 1, on thick description)." (p. 125)

Thus the recoil from the statistical-experimental paradigm has been towards an alternative paradigm that has been described as "illuminative" by Parlett and Hamilton (1976) and has a close affinity with social anthropology (with its emphasis on interpreting actions within the whole social context) and with humanistic psychology (with its concern for understanding a person's own phenomenological world). The researcher is required to take on a role akin to that of a sympathetic listener, seeking to understand through empathy and intuition the perspective or world view of the person or group of people in whom he is interested (Entwistle and Hounsell, 1979). Rather than presuming that human environments and interactions can be held constant, manipulated, treated, scheduled, modified or extinguished, this new perspective on research posits that most powerful and parsimonious way to understand human beings is to watch, talk, listen, and participate with them in their own natural settings. The perspective has come up in what appears as a phenomenological (Carini, 1975; Patton, 1975), constructivist (Magoon, 1977), ethnographical (Wilson, 1977; Berliner and Takanoff, 1976; Spinder, 1982), anthropological field-oriented (Lutz and Ramsey, 1974), naturalistic (Cronback, 1975; Smith, 1982), case study type (Stenhouse, 1978; Stake, 1978; Walker, 1980; Tripp, 1985) and action research (Elliot and Whitehead, 1980; Nixon, 1981) approach. "Participant observation" has been used by some naturalistic researchers to describe their work, but, as noted by Smith (1982) it describes a role that a researcher might assume rather than a methodology. "Qualitative research" has also been used (Reichart and Cook, 1979; Rist, 1977) but it implies that the data to be collected are all of one form (and sets up an unnecessary dialectic between quantitative and
"one can readily imagine, however, quantitative data being collected by a researcher in a later stage of naturalistic study to verify the field data collected earlier."

The term "naturalistic research" does not mean the same when used by different authors working in the different fields. In sociology Dezin (1971) used it to refer to the researcher's "studied commitment to actively enter the worlds of native people to render those worlds understandable." (p. 166)

taking ethnographic descriptions and intensive interviews as point of departure, but also employing any of the methods of social research to understand the nature of human interaction. In science education Easley used the term in a different way:

"the term 'naturalistic' is intended to suggest that all sciences go through a natural history phase in which one learns about the underlying structure of the phenomena and how they are organized and then, from that knowledge, one can proceed to a more quantitative or formal type of methodology ... If we approach educational research in a naturalistic way, it will be simultaneously more scientific in the sense that it emulates the natural sciences ..." (Easley, 1978)

In common they both believe that hypotheses, explanations, and theory are the products, not the cause of empirical study. What makes naturalistic research different from the traditional research methods of experiments is the logic of discovery. That is, the data come first. Out of data are teased descriptive patterns, hypotheses, perhaps theory, or even "a story". The data gathered during the study direct the design of each step of the study as it evolves. The categories, themes, and subsequent hypotheses that emerge are "grounded" (have their initial foundation) in the data themselves. This process is used for hypothesis generation rather than hypothesis testing. The proposed outcome of this research is the generation of hypotheses which will eventually be tied together in theory. The procedure is suitable for social units of any size, ranging from men and nations to small organizational units such as a science class in a school (Spector, 1984).

The research methods used within this paradigm are mainly observation, interview, "action research", and "natural" experiments which aim to mirror real-life situations, and, at their best, they provide powerful qualitative descriptions of individuals and their perceptions of the world about them. Entwistle and Hounsell (1979) point out that these methods are essentially complementary to the psychometric approach. They take account of those aspects of learning
situation excluded from the traditional paradigm. They seek to describe the whole learning situation as experienced by individual students. The approach is not constrained by predetermined frameworks of theoretical ideas, although it cannot avoid an initial set of assumptions. The researcher is free to respond to the student's unique set of experiments and to seek on issues which emerge during investigations as the most significant ones for the participants. There are opportunities to explore and to probe in a way denied to the traditional researcher. But, as Entwistle and Hounsell (1979) stress

"the very sensitivity and flexibility which are the essence of the illuminative research are also its 'Achilles hell'."

The insights which emerge from qualitative analysis are necessarily to some extent subjective and impressionistic. And here comes a common criticism direct to the naturalistic research approach. According to traditional researchers it fails to adhere to canons of objectivity as well as reliability and validity. Rist (1979) points out that while objectivity is considered the sine qua non of quantitative methodologies, qualitative approaches emphasize the need for a subjective interpretation of the social phenomena in question. Rist (1977) stresses that the meanings attached to these terms have been constantly confused; and "the perspective that extols the one is used to condemn the other". Attempting to clear out the confusions in understanding, Scriven (1972, p. 95) gives the following definitions:

"The terms 'objective' and 'subjective' are always held to be contrasting, but they are widely used to refer to two quite different contrasts, which I shall refer to as the quantitative and qualitative senses. In the first of those contrasts, 'subjective' refers to what concerns or occurs to the individual subject and his experiences, qualities and disposition, while 'objective' refers to what a number of subjects or judges experience - in short, to phenomena in the public domain. The difference is simply the number of people to whom reference is made, hence the term 'quantitative'. In the second of the two uses, there is a reference to the quality of the testimony or to the report or the (putative) evidence, and so I call this 'qualitative' sense. Here 'subjectivity' means unreliable, biased, or probably biased, a matter of opinion, and 'objective' means reliable, factual, confirmable, or confirmed, and so forth."

It is in the latter sense that the traditional researchers claim about the lack of reliability and lack of work towards a cumulative body of "scientific knowledge" concerning the naturalistic research approach. It is also in the latter sense that naturalistic researchers claim about the lack of validity and lack of understanding the "meanings" concerning the psychostatistical approach.

In an attempt to address to the above mentioned issues, traditional researchers would pursue confirmation through the use of a number of subjects
while naturalistic researchers might undertake an intensive case study of a small group or even some particular individuals. Thus the emphasis within psychostatistical methodologies on an emulation of "the scientific method" had led it to emphasize reliability while naturalistic methodologies have emphasized validity. As Patton (1975) points out

"the overriding issue in the 'verstehen' approach to science is the meaning of the scientist's observations and data, particularly its meaning for participants themselves. The constant focus is on a valid representation of what is happening...."

Another point raising controversies between the two approaches is the one relating generalization. Because psychostatistical paradigm of research operates through the accumulation of actual descriptions into averages, it tends to attempt to prove the truth of a hypothesis across a population itself defined by variables accumulated into average. Generalizations based upon statistical inference tell that something is or is not true for that population, usually

"in total and complete disregard for the ways in which it was or was not true in terms of the individual members of that population." (Tripp 1985)

Elliott (1981) points out that the fact that the very statistical rules of the psychostatistical paradigm prohibit particularization from grouped data to individual cases is conveniently forgotten, especially by policy makers. As Tripp (1985) stresses

"the tyranny of the norm is the loss of precise contextualization, the very information we need to understand and utilize the generalization."

Naturalistic generalization can be defined as the perception of similarities among empirically different phenomena. It is, at its simplest, a matter of applying the facts of one case to another case instead of attempting to sum them. The process of generalization is performed by the person making the comparison, it is the realm of personal experience, not in some formal technical realm where universal statements may be produced in the sense that they lie outside individual experience. Thus naturalistic generalizations develop within a person as a product of experience. They derive from the tacit knowledge of how things are, why they are, how people feel about them, and how things are likely to be later or in other places with which this person is familiar. They seldom take the form of predictions but lead regularly to expectation. They guide actions, in fact they are inseparable from action (Kemmis 1974). Stake (1978) points out that these generalizations may become verbalized, passing of course from tacit knowledge to propositional; but they have not yet passed
the empirical and logical tests that characterize formal (scholarly, scientific) generalizations. The naturalistic generalization is a kind of movement from particular to particular; it is a form of generalization which is directly useful to people involved in education, particularly teachers, precisely because its location in context (it is carried out in natural settings) enables them to judge whether it is useful in their situation and how much of what kind of allowance is required.

This brief description of the two approaches, their scope and limitations, helps me to justify the line of research I took to conduct the present study.

Novak (1980) has pointed out the need for research methods to be epistemologically congruent with the philosophy underlying the enquiry. As can be seen from the above considerations, a realistic view of knowledge supports a psychostatistical research approach while a naturalistic research approach is supported by a constructivist view of knowledge.

Consistent with the knowledge that the focus of enquiry and method of investigation usually mirror the implicit philosophy of science of the investigator, I took a naturalistic field study approach in the conduction of this investigation whose basic assumptions are derived from Kelly's epistemology of constructive alternativism. Kelly suggested that in viewing man as if he were a scientist means that the

"ultimate explanation of human behaviour lies in examining man's undertakings, the questions he asks, the lines of enquiry he initiates, the strategies he employs rather than analysing the logical pattern and impact of the event with which he collides." (Kelly, 1969)

This statement stresses the importance of taking a phenomenological approach in human behaviour's research.

Constructive alternativism and Kelly's view on the conduct of research, represent the spirit of Kelly's work which, due to my own assumptions of psychological development and philosophy of the nature of knowledge, I find most attractive. These assumptions provided the conceptual framework for the conduction of my study, determining a methodology based on my epistemological position which emphasises the personal relevance and endeavour, relativity of knowledge, expansion of the curriculum and extension of the objectives of educational research. Thus, these assumptions suggested a carefully delineated in-depth study of what happens to individuals in terms of processes as they interact with the components of their environment.
The framework proposed for the implementation of the scheme stresses the role played by student teachers' perspective on teaching in the process of perspective's change, the adoption of the innovation. Innovation that will not be presented to the student teachers but will be constructed by themselves as a consequence of the activities in which they will be involved. This framework is compatible with the recent constructivist trend in educational research (Magoon, 1977). The constructivist position which underlies the model of change implies a view of knowledge that considers it as being reconstructed by the knower (interacting with physical and social world) rather than a commodity being transferred.

Adopting a psychology which sees man as constructivist rather than reactive could only lead myself to take a construct theory approach to research, which is in opposition to the traditional emphasis on psychometric and nomothetic studies found in educational research.

5.3 The settings of the field trial

Three parts were considered during the main study: Part A - Teacher Formation, in which an investigation was conducted into the implementation of the four first stages of the scheme; Part B - Teaching Practice, in which a study was conducted of some of the student teacher's adoption stage; and Part C - in which three student teachers in three different states of the adoption stage were followed in their first year of professional life. Parts A, B, and C took place respectively in the first, second and third year of the main study.

The study of the implementation of the scheme took place in three main settings. The implementation of the four first stages of the scheme, Part A, was set within the context of a methods course named "Physics Didactics", given by me in the two academic years of 1983-84 and 1984-85. This is a compulsory course in the 4th year of a five years teacher education programme for Physics and Chemistry teachers run at the University of Aveiro, Portugal. It precedes the teaching practice and follows courses in the scientific area, such as: "Mechanics", "Electromagnetism", "Waves", "Thermodynamics and Statistical Physics", "Introductory Nuclear Physics" and "Modern Physics" and courses in the basic educational science area such as: "General Didactics", "Psychopedagogy" and "Evaluation". The contents of "General Didactics" had focused on the analysis of the teaching/learning process: definition of behavioural objectives, designing of instruction, evaluation of learning. "Psychopedagogy" had covered topics such as educational objectives in a philosophical perspective; factors,
stages and problems in child development; analysis of learning in the classroom
(the role of the teacher, group, content, environment), types of teacher/pupil
interaction.

The course "Physics Didactics" focusses on the teaching of physics
to secondary school pupils (age range between 14 and 17). In the years of the
experiment each course took a total of 14 weeks with 7 hours per week.

The adoption stage of the scheme took place within two different
contexts: the teaching practice, Part B (second year of the main study) and the
first year of professional life, Part C (third year of the main study).

The school in which the teaching practice took place was a large
secondary school at Aveiro. Its capacity is for three thousand pupils who ranged
in age from just 12 to 19 years old. It comprises classes from the 7th grade
to the 12th grade.

Physics classes took place in three different types of classrooms:
(i) one was a more usual classroom in which pupils desks were arranged in four
or five rows facing a teacher's small table in the left corner on a slightly raised
platform, behind which was the blackboard. When necessary an overhead projector
and the screen were brought to the classroom. The pupils' desks were either
individual or for two pupils, the latter being flat tables and the former old desks
with slightly inclined tops. The capacity of these rooms were usually between
36 to 40 pupils; (ii) another was a large physics laboratory which had a teacher
small bench on a corner at the front, behind which was the blackboard. Twelve
work benches with water and electricity points were disposed in four rows over
the lab. Each work bench could have room for four pupils working in normal
conditions; (iii) the other type of classroom, usually used when teachers want
to provide demonstrations, was a kind of lecture theatre which had a teacher
long bench at the front, behind which was the blackboard. The pupils seat on
desks disposed in an amphitheatre configuration. Only this type of classroom
could be completely blacked-out.

The setting of the first year professional life took place in three
different cities in the country. All three were about two hundred kilometers
away from Aveiro. The particular characteristics of each school will be described
in detail in Chapter 8.
5.4 The nature of the participants and their roles

Three types of participants were involved. The researcher, the student teachers and the pupils.

5.4.1 The researcher

During this study my role as researcher took different forms. During the course of "Physics Didactics" which I taught I played the dual role of teacher and researcher. As a teacher I acted as a participant. As a researcher I acted as an observer. Thus during the implementation of the four first stages of the scheme I took the role of a participant observer. Although the role is a difficult one, it is not an uncommon position for teachers who are continually monitoring their teaching/learning designs and conducting educational action research. This type of research is concerned with the measurement of planned change, in which the researcher is involved at both the planning and the action stages.

As pointed out by Margerison (1973), in such research, the researcher involves himself in an ongoing situation and plays a role to influence the events that take place, whilst at the same time measuring the effect of her/his interventions. The teacher in such experimental projects has a difficult role, for s/he is simultaneously a researcher. There is always the temptation to manipulate the discussion and behaviour in the direction s/he feels will most aid the research. However, the basic principles of the philosophy underlying the present study emphasized the need for the student teachers, wherever possible, to make the decisions and decide the priorities. As a teacher my participation was basically to provide opportunities and conditions which would enable the student teachers to be aware of a new (for them) approach to teaching. Also to help them in their attempt to develop teaching skills for teaching according to the "new" approach. And also to reflect and analyse with them the outcomes of their learning and diagnose their problems in learning and teaching.

As a researcher I had to develop the dynamic tension between the subjective role of participant (the teacher) and the role of observer (the researcher) so that I was neither one entirely (Wilson, 1977).

Although all group discussions were recorded, with the student teachers' permission. I did not tell them about my role as a researcher. This was done intentionally because I did not want the situation of being observed
as a case study to interfere with their performance during the course.

As a participant observer I was always seeking to understand behaviour, finding ways to learn the manifest and latent meanings for the participants, mainly the student teachers, and also to understand the behaviour from the objective, outside, perspective.

During the teaching practice I played also a dual role, supervisor and researcher. My role as supervisor was to help student teachers in the resolution of some problems they may feel during the pre-active phase of their teaching, to observe some lessons all through the year and discuss with them the emerging classroom problems. This role was well known by the student teachers.

The purposes of my role as a researcher during the teaching practice were:

1) to evaluate to what extent the adoption stage was achieved by each student teacher;

2) to evaluate the outcomes of the scheme concerning the development of teaching skills in student teachers during the course of "Physics Didactics", when they were acting in real classroom situations;

3) to study the progress of each individual student teacher in the teaching skills to teach in a constructivist perspective;

4) to evaluate the outcomes of the pupils' learning when taught according to a constructivist model of teaching.

In order to achieve the aims proposed for this phase of the study I needed, not only to observe lessons, but audiorecord some of them. This recording helped me on the analyses of the lessons either in relation to the development of the teaching skills of each student teacher or in relation to the pupils' reactions to this approach to teaching and to the outcomes of their learning. In addition to watching the student teachers I was studying, seeing what situations they ordinarily met and how they behaved, I needed to discuss with them their interpretations of the events I had observed. Thus, I needed to have their collaboration. By that time the student teachers were told about the study and asked about their collaboration. All student teachers accepted my role as researcher and showed a great interest to collaborate adding that the result of the study would most probably be very helpful for them.

Although as a supervisor I also had the role of assessor it was made
very clear that the role as researcher would not interfere in any way with the role of assessor.

During the first year of professional life of some of the student teachers my role was only as a researcher working as a participant observer. I observed and audiorecorded some lessons in the student teachers' new schools and collected their views and perceptions of the new situation.

5.4.2 The student teachers

In the implementation of the first four stages of the scheme there were six student teachers, two males and four females, enrolled in the first course (1983-84) and seven, four males and three females, in the second (1984-85). They were concurrently enrolled in 5 or 6 other courses and had a total of 26/27 hours of class time per week. The student teachers ranged in age from 21 to 27 years.

With only two exceptions the student teachers were of average academic ability compared with students who are usually enrolled in this particular degree (Physics and Chemistry teacher education program). The characteristics of these students were already pointed out in section 2.1 of Chapter 2. Only 4 out of the 13 students had chosen this degree as a first priority. The two exceptions mentioned, were of opposite types. Judging from their academic records and from their performance during the course, one of the students was of high ability and the other of low ability. The former was concurrently being a monitor (helping in lab classes for six hours per week) in the physics department. Apart from this case and another student who had some experience of private lessons in physics at the secondary level, the group had no previous teaching experience.

During this first phase of the study the student teachers participated as students taught in a constructivist approach. This, I must say, was not very easy to achieve. The reason is, most probably, the following. They were not used to be requested to decide for themselves, to construct their own knowledge, to express their own perceptions and feelings, to express their own frameworks when explaining scientific phenomena. In short, they were not used to be the builders of their own knowledge. The tendency to ask the teacher (the authority) what to do, what to say, what to choose, how to perform, how to make, etc., was too strong to be easily abandoned.
The student teachers followed during teaching practice were five out of the six student teachers enrolled in the first course (1983-84). One of the students failed the fourth year and, in consequence, was unable to enter the teaching practice. During her/his teaching practice the student teacher was supervised by an experienced secondary school teacher, (the supervisor from the school where the teaching practice took place) and also by three members of the university staff, one coming from the Chemistry department, one from the Physics department and another from the Education department. This group of people, the student teachers and supervisors, form the so called "teaching practice nucleus". They met regularly to discuss some problems raised during teaching practice. During the year each student teacher had full responsibility for two classes, one of the 8th grade and one of the 9th grade. It was also required that each of them gave some lessons to a 10th grade class, of which the supervisor at the school was in charge. The student teachers had also to attend an eight hours per week scientific-pedagogical seminar at the university.

The characteristics of each student teacher's class will be described in detail in Chapter 7.

In the first year of professional life only three out of the five student teachers, by this time, beginning teachers, participate in the study. The two other student teachers finished their degrees but they did not apply for a job in the secondary teaching level. One was assigned a post at the university level. The other one did not get a job.

5.4.3 The pupils

The pupils can be separated into two categories according to the nature of their participation in the present study: (i) the ones that volunteered to go to the university to participate as pupils in the sessions of microteaching; (ii) the ones attending their normal classes in the schools where they were enrolled.

During the course of "Physics Didactics" each of the thirteen student teachers, with two exceptions, taught two lessons to five groups of 8th and 9th grade pupils whose size varied between 4 and 11. The two exceptions were two of the first year of the experiment's student teachers who, due to some constraints, only taught one lesson to pupils in these grades. The constraints will be presented in Chapter 6. Each group of pupils went, in average, three times to the university. The number of pupils involved in this part of the study
was 13 and 17. They were enrolled at different secondary schools in Aveiro and were invited by me or by the student teacher to go to the university after being told about the activity. They all accepted with enthusiasm. To participate in a microteaching session and to be filmed seemed to be the strongest motivation.

Their roles were similar to the ones played by the student teachers: to act as pupils being taught in a constructivist way whenever the student teachers were performing within that approach. It is interesting to note here that it was easier for pupils to take an active, creative and emotional participation than their older colleagues, the student teachers. They adapted more easily to a constructivist approach to learning than did the student teachers.

During teaching practice and the first year of professional life the pupils involved in the study were in quite different position from the ones considered above. As much as we try to create microteaching situations that represent reality as closely as possible, they always will be simulations of the real classroom life. While in the earlier situation pupils attended the sessions voluntarily, they wanted to go, they were enthusiastic about the idea of participating in the activity, their status was considered more as a helper (they were helping the formation of new teachers) than as a learner; in the later situation their participation was different. Here they were attending their normal physics classes in their normal school life. Their attitudes towards events were consequently different. A priori their perceptions about classes and about learning were usually not very enthusiastic. Some of them were still in schools only because other people wanted them to be there. For the majority of them the school was a very dull place. Lessons, in general, were too boring and physics, a priori, was not a very interesting subject. The context of their participation was quite different from the microteaching sessions. Here their participation was in a real classroom situation.

There was also a considerable diversity among classroom settings due to the fact that each class was composed of a certain number of individual pupils with their own characteristics. Each individual contributed to the context in which each lesson took place and thus, each context had its own features. As stressed by Misheler (1979), the findings in educational research are context dependent and therefore the importance of the context is vital for our understanding of human action and language. Thus, it is important to describe in detail the characteristics of each particular class, the context in which Part B (teaching practice) and Part C (1st year of professional life) took place. This will be done
in Chapters 7 and 8.

During teaching practice five 8th and five 9th grade classes were followed and observed through the academic year. During the first year of professional life three 8th grade and six 9th grade classes were observed, though not followed along a full year.

Table 6.1 presents the number of student teachers, beginning teachers and pupils involved in the main study at each of three years.

Table 6.1 - The main study: number of student teachers beginning teachers and pupils involved during the three years.

<table>
<thead>
<tr>
<th></th>
<th>First year</th>
<th>Second year</th>
<th>Third year</th>
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<tbody>
<tr>
<td>Part A</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Teacher</td>
<td></td>
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<td></td>
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<tr>
<td>Formation</td>
<td>Student teachers: 6</td>
<td>Student teachers: 7</td>
<td></td>
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<tr>
<td></td>
<td>(S1 to S6)</td>
<td>(S7 to S13)</td>
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<tr>
<td></td>
<td>Pupils</td>
<td>Pupils</td>
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<tr>
<td></td>
<td>microteaching lessons: 23</td>
<td>diagnostic activity: 20</td>
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<td></td>
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<tr>
<td>Part B</td>
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<tr>
<td>Teaching</td>
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<tr>
<td>Practice</td>
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<td></td>
<td>Student teachers: 5</td>
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<tr>
<td></td>
<td>(S1, S2, S4, S5, S6)</td>
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<tr>
<td></td>
<td>no. of classes: 10</td>
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<td></td>
<td>Pupils/class: 30</td>
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<tr>
<td>Part C</td>
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<tr>
<td>1st year of</td>
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<tr>
<td>life</td>
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<tr>
<td></td>
<td>Beginning teachers: 3</td>
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<td></td>
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<tr>
<td></td>
<td>(S2, S5, S6)</td>
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<tr>
<td></td>
<td>no. of classes: 9</td>
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<tr>
<td></td>
<td>Pupils/class: 30</td>
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5.5 Data collection procedures

The data collection strategies central to naturalistic research are: observation, interviewing and document analysis. Rist (1982) points out that while none of the procedures is especially unique to qualitative work,

"the multiple combinations and the opportunity to triangulate them is what contributes to the distinctive approach that is qualitative."

Nevertheless he stresses that naturalistic approach is not simply the sum total of various research strategies.

"It is, as well, a process of inquiry grounded in certain assumptions about knowledge and respect for the order and logic of each research setting."

The study being a naturalistic one, the data collection procedures varied according to each research setting.

During the implementation of the awareness and interest stages within the context of the course of "Physics Didactics" the main data collection strategy was observation. In this observation the researcher acted as participant, totally engaged with the group and clearly identified as an active member. This kind of naturalistic inquiry

"seeks to discover the meaning structures of the participant in whatever forms they are expressed." (Wilson, 1977)

Hence, this research is multimodal and all the following are relevant kinds of data: i) form and content of verbal interaction between participants, ii) form and content of verbal interaction with the researcher, iii) nonverbal behaviour, iv) patterns of action and nonaction, v) traces, archival records, artifacts, documents. I used basically two procedures for getting access to that information, tape recording of group discussions and field notes with my observations about the nature and results of my interactions with student teachers and the interaction between them.

During the implementation of the trial and evaluation stage two others procedures were used. The microteaching sessions were videorecorded. It has been said (Mackey, 1968 and Wolfe, 1971) that the main advantage of videorecording in teacher training lies in the possibility to make a provision of documents in teaching and learning which can be preserved, filed and analysed. Usually documents are used to: a) provide model standard lessons, b) function as an initial step in learning to analyse classroom behaviour, c) provide examples of practice from which to derive theory and d) enable the opportunity of examin-
ing one's own teaching in an objective and analytical way. I do not view this use of videorecording as being compatible with the philosophical stance of a Kellian theory. As pointed out by Pope (1981) the constructivist view of knowledge lends support to teachers and researchers who are concerned with the investigation of students' views, who seek to incorporate these viewpoints within the teaching dialogue and make known their construction of some aspect of reality. This is in contrast with the claim of the advantages of the videotapes which can result in rote learning and pure modelling.

In the present study the purposes of videorecording the microteaching sessions were basically three:

i) to provide opportunities for each individual student teacher to examine her/his own teaching;

ii) to provide opportunities for group discussions when watching the tape. These allowed an exchange of views between student teachers and myself in which alternative strategies to cope with particular situations occurred during the lesson taped could be suggested;

iii) to provide opportunities to the researcher to review the tape at any time after the lesson.

The microteaching lessons, as well as the group discussions, were audiorecorded. The idea was to obtain a more easily available document for the reanalysis of the verbal interaction.

The lessons were taught and videorecorded in the teaching lab of the University of Aveiro. Two mobile videocameras, one videocassette recorder, one TV monitor and one stick microphone placed on stand were used.

The classroom arrangement for each lesson was left to the judgement of the student teacher who was going to perform that particular lesson.

During each student teachers' performance one of the peer-group or myself worked with the videocamera while the others watched the lesson in a place that would disturb the situation as little as possible. The observers took their notes during peer's performance and that helped them to develop skills of observation, assessment as well as providing elements for feedback to the peer who was performing.

As another source for data gathering, relating to student teachers' perceptions of their learning experience, a questionnaire was used. The student
teachers were requested to answer the questionnaire at the end of the course. Although an individual interview would have been a more appropriate instrument for this purpose, the questionnaire was seen as a more adequate solution due to time constraints (end of a semester is a period of tests and assignments for other courses). The questionnaire is presented in Appendix 10. The student teachers were also requested to answer another questionnaire concerning their own development of scientific "abilities". The questionnaire is presented in Appendix 12.

During teaching practice, Part B of the main study, three data collection strategies were used: audiorecording of group discussion; classroom observations; interviewing. After the student teachers' first contact with the school where the teaching practice took place, a group discussion was audiorecorded. This group session aimed at investigating the extent to which the views, held by the student teachers at the end of the preparatory course, still remained and what were their expectations after the first contact with the school. In order to gather this information three basic questions were asked individually:

1. After your first contact with the school what are your ideas about the way you are going to teach?
2. And what are your expectations?
3. Are there any problems that you can foresee?

The group conversation then focussed on issues that emerged from the questions raised.

The data collection procedures used during classroom observations were basically three: (i) audiorecording of the lessons; (ii) observer's field notes; (iii) analyses of the documents available to the researcher. The last included lesson plans, sheet works, the different types of tests for pupils developed by the student teachers, their analysis of the diagnostic tests applied at the beginning of each topic, and pupils homework papers.

Two audiorecorders were used during classroom observations. One placed on the teacher's table and another at the back of the room where the observer, myself, was seated. For lessons to the whole class, this arrangement was efficient for the recording of the verbal interactions taking place during the lesson. Nevertheless, for lessons in which group activities took place the system, was not the most appropriate. It would have been necessary
to use videorecording and microphones on each group table to catch what was going on in each group. This was impossible to practise in the context in which the present study took place. To minimize the problem, one of the recorders was placed in one group table but the recording was not clear enough for the reconstruction of what was happening. In these cases more important than verbal interactions are the nonverbal interaction, the manipulation of materials, the skill of team-work, the attitudes to the others and the way pupils conduct investigations. When observing lessons of this type, I concentrated my observation on one group, trying to disturb its activity as less as possible and by taking field notes.

At the very end of the student teachers’ teaching practice each one of them was interviewed. An open-ended interview with each student teacher was conducted and audiorecorded with the purpose of gathering information about their ideas, perceptions and experiences on their teaching and learning situation.

The data collection strategies used in Part C of the study consisted of observer’s field notes taken during classroom observations, audiorecording of some lessons (in the same conditions set up during teaching practice) and audiorecording of an interview with each one of the three beginning teachers.

Table 6.2, overleaf, presents a summary of the data collection strategies used during the three parts of the main study.

5.6 Methods of analysis

As pointed out by Rist (1982) there are two important considerations in the analysis of qualitative data. First, analysis must occur concurrently with, as well as subsequent, to data collection. Second, there is no single way, but rather a variety of ways, in which the analysis can be conducted and the frameworks within which the data can be organized. In working over the material on the present study various procedures of analysis were used at the different stages of the research. The analysis of the data was carried out continually as the information gathering proceeded.

In the analysis periods of the data relating to Part A, group discussions, transcripts, observation notes, video and audiorecordings of the lessons and the answers to the questionnaire were reviewed repeatedly seeking to understand the meanings of the participants and each incident or bit was coded into
Table 6.2 - The main study: data collection strategies used during the three parts.

<table>
<thead>
<tr>
<th></th>
<th>First year</th>
<th>Second year</th>
<th>Third year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part A</strong></td>
<td>(i) observations</td>
<td>(i) audiorecording of group discussions</td>
<td></td>
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<tr>
<td><strong>Teacher Formation</strong></td>
<td>(ii) audiorecording of group discussions</td>
<td>(ii) classroom observation</td>
<td></td>
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<tr>
<td></td>
<td>(iii) video and audiorecording of microteaching sessions</td>
<td>a) audiorecording of lessons</td>
<td></td>
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<tr>
<td></td>
<td>(iv) questionnaires</td>
<td>b) observer's field notes</td>
<td></td>
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<td></td>
<td></td>
<td>c) analysis of documents</td>
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<tr>
<td></td>
<td></td>
<td>(iii) interviewing</td>
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<tr>
<td><strong>Part B</strong></td>
<td></td>
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<tr>
<td><strong>Teaching Practice</strong></td>
<td>(i) audiorecording of group discussion</td>
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<td></td>
<td>(ii) classroom observation</td>
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<td></td>
<td>a) audiorecording of lessons</td>
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<td>b) observer's field notes</td>
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<td>c) analysis of documents</td>
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<td></td>
<td>(iii) interviewing</td>
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<tr>
<td><strong>Part C</strong></td>
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<tr>
<td><strong>1st year of professional life</strong></td>
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<td></td>
<td></td>
<td>(i) classroom observations</td>
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<td>b) observer's field notes</td>
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<td></td>
<td></td>
<td>(ii) interviewing</td>
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</tbody>
</table>

Tentative conceptual categories.

The analysis of data relating group discussion and interviews with student teachers conducted in Part B followed the same framework described above.

For classroom observations, either in Part B or in Part C, the approach adopted in observing and analysing the lessons followed the trend in classroom studies associated with "insightful observation". Such studies involve the detailed observation and commentary of recorded lessons and detailed analysis of the actual events occurring during lessons.
The main question which was addressed in the analysis of the lessons was:

How does the student teacher guide the interaction that takes place in the lesson toward the achievement of the stated objectives and aims?

Thus the analysis was intended to look at the lesson in terms of its purposes. Knowing in advance what were the aims and the objectives stated for the lesson, the analysis could be made considering the situations provided by the student teacher to promote those specific objectives and aims. It was therefore concerned with aspects related to the nature and the content of the interaction. Simultaneously with the transcripts of the lesson a series of comments concerning these aspects were made.

5.7 Summary

In this chapter, the two major methodological approaches adopted by educational researchers were discussed in order to justify the line of research I followed in this study. The naturalistic research approach followed was seen as consistent with the philosophical assumptions underlying the present study. These assumptions are derived from Kelly's epistemology of constructive alternativism.

Believing that the contextual grounding of the meanings of human action and language is vital to the understanding of our own and others' behaviour, the research findings being then viewed as context dependent, the setting of the field trial, the nature of the participants and their role were described.

In the last part of the chapter the particular procedures used for data collection in the different settings of the study were explained. The methods of analysis used were also discussed.
6.1 Introduction

It was stressed in Chapter 4, section 4.5, that, although Rogers' developmental model of the innovation process was not regarded directly as a strategy for the change-agent, it was used as the framework for the design of the scheme for promoting student teachers perspectives' change on science teaching and developing appropriate teaching skills. Being aware of the stages in the mental process of a person in the adoption or rejection of an innovation, I saw my role as a change-agent to be consistent with my role as a teacher working within a constructivist perspective. As a change-agent I needed to identify situations in which the different stages could take place. As a teacher adopting a personal constructivist approach, acting as a facilitator of the student teachers' learning of "how to teach", I needed to develop strategies to help them develop their own personal models of teaching, scientifically based on their own reflections and experiences. However, as a change-agent, I was working within a developmental model which postulates that the changes have direction, that the system under scrutiny is "going somewhere". Chin (1961) stresses the necessity for change-agents, working within these models, to believe that there is direction in change. Having adopted a constructivist approach, I believe this approach should be in the direction of a change in the student teachers' perspectives. Thus, my dual role as teacher and change-agent should be to provide opportunities for the adoption of the "new" model of teaching by the student teachers.

In the next section the different activities taking place during the implementation of the four first stages of the scheme will be described.

6.2 Description of the activities taking place during the implementation of the four first stages of the scheme

In the next four sub-sections each stage will be considered separately. The annual average time spent in the implementation of each stage will be indicated and the activities that took place and their purposes will be considered.
6.2.1 Awareness stage

This stage is divided into three substages according to the types of activities undertaken and their purposes.

Substage 1 - Awareness by student teachers of their own models of teaching

This substage took place in the first lesson of the course. At the beginning, student teachers were asked to write down their meanings for "teaching physics". The activity was intentionally designed to be in a written answer format because the purpose was to help student teachers to become conscious of, and explicitly express their views about, "teaching" and "teaching physics" without any influence from their peers. When this was accomplished a discussion of the individuals' perspective took place. The time spent on this activity was two hours in each year. It corresponds approximately to the first lesson period of each course. Each course was assigned 7 hours weekly during approximately 15 weeks.

Substage 2 - Reflective analysis of the implication of their models

This substage began at the second lesson and took about three hours. During this second substage a reflective analysis of the implication of the student teachers' models of teaching took place. In a group discussion, the activity focused on: the sharing of student teachers' learning experiences; the implications of their feelings about learning, teaching and physics as a subject. But the aim of the activity went beyond that. The conversation itself, and the atmosphere of the conversation, were very important factors that influenced all the subsequent work. Emphasis was placed on the development of positive interpersonal relationship with the student teachers and between student teachers. This is essential when working in a humanistic perspective. Carl Rogers suggests that the initiation of learning in the dyadic situation does not rest solely upon the skills of the teacher but rests upon certain attitudinal qualities which exist in the relationship between student and teacher. In this case, student teachers should perceive that their ideas, their feelings, their values, their perceptions are important not only for them individually, but are considered important by the others to whom they were working: both the teacher and other peers. The teacher's role in this kind of group discussion is of great importance in the development of capacities such as, self-confidence, team-work, respect of other's opinions and on the creation of an atmosphere which enables individuals to realize themselves in their own terms - emotionally, intellectually, and socially. This was easy to achieve in the two cohorts of the experiment
due to two factors. One was the size of each cohort (7 and 8 persons). It would not have been so easy if the groups had been larger, as is the case in secondary school classes. On the other hand, it was easier to achieve this type of atmosphere with children, because in general they are more 'open' than adults are. Another factor was the personal constructivist approach used in this particular course on "Physics Didactics". One of the implications of this approach is the recognition of the importance of incorporating, within teacher methodology, the views of all those involved in the particular educational context. A constructivist teacher is concerned with the investigation of students' views, seeks to incorporate these viewpoints within the teaching dialogue and sees the importance of encouraging students to reflect upon, and make known their construction of, some aspect of reality.

When the conversation was completed the student teachers were presented with the findings of the preliminary study after a brief description of the study. The purpose was to help them to be aware of some of the current problems of the physics teaching/learning process in Portugal.

As a consequence of this reflective analysis some questions arose:

- Why should physics be taught at secondary school?
- Which alternatives should be thought of as aims for physics teaching at the unified level?
- What should be the most important things that teachers should bear in mind when teaching physics at this level?
- How could it be taught in a constructivist perspective?

Substage 3 - Awareness of alternative models

The above questions were the starting point of the third substage of the awareness stage. To find answers to them the student teachers felt the necessity for a deep reflection on the problems involved. In order to help them in this task I provided some materials, mainly research papers concerning these issues. Constraints of time and language problems (most of the papers were in English and the majority of students consequently had difficulty with them) imposed conditions on the number of papers presented and analysed. Also, the papers were not the same in the two years. Nevertheless some were common, the most relevant being "What is Science", an unpublished address delivered to the Fourteenth Annual Convention of the U.S. National Science Teachers Association in 1966 by Nobel Prize winner Richard Feynman; "Thinking, reasoning and understanding in introduc-
tory physics courses", by A. Arons, (1979), a paper presented at the meeting of GIREP (Groups International de Recherche sur l'Enseignement de la Physique) at the Weizman Institute of Science, Rehovot, Israel; "Significant physics content and intellectual development- cognitive development as a result of interaction with physics content", by John W. Renner, (1976); "The death of an investigation", by Robert E. Samples, (1966); "The power of purpose", by John W. Renner, (1982) and "Children's science and its consequences for teaching", by John K. Gilbert, Roger J. Osborne and Peter J. Fensham, (1982a). The papers were presented and analysed by this order. They are provided in Appendix 2.

Why these papers? It has been suggested that after twenty years of SAPA, ESS, SCIS and other science programs with an emphasis on processes, most people still find the concept of science process skills new (Cohen, 1983). Tobin (1984) points out that, although process skills have been a desired outcome of the majority of elementary and middle school projects developed since the 1960's, casual observations and conversations with teachers suggest that process teaching is still uncommon. He adds that in universities and colleges, methods instructors still implore preservice and inservice teachers to incorporate processes into their programme. However, there is evidence to suggest that a significant proportion of secondary and college students is unable to utilize the skills necessary to plan and conduct investigations (Yeany et al., 1978; Dillashaw and Okey, 1980; Tobin et al., 1980). My own experience with preservice secondary school teachers leads me to say that, in spite of being taught science for at least 14 years, student teachers are still unaware of the existence and the relevance of process skills to science. Through "What is science", by R. Feynman, student teachers could accommodate their views about science as being a fundamental instrument for exploring whatever may be tested by observation and experiment. In a very persuasive way it is shown that science is more than a body of facts, a collection of principles, and a set of machines for measurement; it is a structured and directed way of asking and answering questions through the processes of observing, hypothesising, designing and planning experiments, recording, organizing and interpreting data, manipulating and communicating.

Through Aron's paper student teachers became aware of some very basic cognitive difficulties shared by many pupils in introductory physics courses. Some procedures that offer help in resolving the difficulties are suggested in the paper.

In "Significant physics content and intellectual development- cognitive development as a result of interacting with physics content" Renner points out that, regardless of the reason for its grade placement, physics teaching, up to
the present time (although written in 1976 it still stands for 1986), has assumed that students possess a level of intellectual development adequate to handle the abstractions of the discipline. According to Renner (supported by my findings of the preliminary study), the manner in which physics has been taught both at secondary school level and in colleges demonstrates that those teaching it felt little (if any) responsibility for promoting intellectual growth. As pointed out by Renner, the discipline of physics can be used to promote intellectual development if the teacher recognizes three premises:

(1) - the central purpose of secondary school and the early years of college instruction is intellectual development;

(2) - intellectual development takes place while investigations are being conducted and is not adequately represented by an investigation's end product, that is, its facts, principles, laws and generalizations. In fact, until intellectual development has taken place, many of the end products of an investigation cannot be understood;

(3) - the discipline of physics is structured around investigation which ultimately leads to the understanding of natural phenomena.

In "The death of an investigation" the differences between two approaches are illustrated by the problem of involving students in laboratory activities in the science classroom. The first approach is what may be called "authoritarian", whereas the second is often referred to as "investigative". A complement of what is said in the last paper is given in "The Power of Purpose". In it, student teachers were confronted with two different learning theories, one that leads pupils to master the content just as a teacher gives it to them and a second one that leads pupils to develop understandings of content that are their own, not the teacher's. To illustrate the second theory I provided an activity in which student teachers worked with some material concerning electric circuits and were questioned about electric phenomena which they were first predicting and then testing. The type of tasks involved were similar to the ones described by me in "Investigating pupils' understanding of phenomena occurring in simple D.C. circuits: Implications for Teaching" (Thomaz, 1984). The description and findings of this study are presented in Appendix 3.

Through the paper "Children's Science and its Consequences for Teaching" student teachers were aware of the existence of children's personal frameworks in 'scientific observation' (children's science) and its implication for the teaching/learning process.
After the reading and analysis of this last paper student teachers were individually presented with some questionnaires and tasks to provide them feedback on their personal frameworks in 'scientific observation'. Examples of these tasks and questionnaires are presented in Appendices 3 and 4 respectively.

A group discussion of the outcomes took place after the performance of these tasks. Both groups became aware that, even then, despite their long formal instruction they still showed a retention of early intuitive ideas. It has been suggested that physics teachers may well have overemphasised the mathematical aspects of physics to the exclusion of any admission of the role of language in the representation and development of physical concepts (Jackson, 1979). Evidence of this was given by the outcomes of these activities. This led student teachers to feel the necessity of practising them with their future pupils before starting a new topic in their teaching.

As an illustration of the existence of these intuitive ideas in Portuguese students, the student teachers were presented with the findings of two studies conducted by me, one concerning the concept of force and another the concept of electric current (Thomaz, 1982, 1984). In the first study a questionnaire in a 'multiple-choice-with-explanation' format developed by M. Watts and A. Zylbersztajn (1981) concerning the concept of force was administrated to a population of 357 students with a large range of ages (14 to 25 years old) and different science backgrounds. Appendix 4 presents the results of this study.

The second study, concerning the concept of electric current was conducted by me in an 'interview-about-experiments' format. It involved 26 pupils from the 8th grade with ages between 13 and 15. As already mentioned, Appendix 3 presents this study and its findings.

The purposes of presenting these studies to the student teachers were twofold:

1. to show that: the findings of this type of research conducted in Portugal are similar to the ones conducted in other countries; intuitive ideas or alternative conceptions are also left untouched by the Portuguese system;
2. to illustrate two different techniques for investigating pupils' understanding of physics concepts and the implications of their applicability in real classroom situations.

A "new" approach to physics teaching as an alternative to the traditional one emerged from the reflective analysis carried out throughout these last
three substages. A model of teaching that aimed at equipping each child with competences in the processes of science through the medium of physics content and to help them to progress in their intellectual and cognitive development within a constructivist perspective turned out to be worth trying to implement. The last substage took an average of sixteen hours in each year.

6.2.2 Interest stage

The interest stage is also subdivided into three substages. Altogether they took an average of fourteen hours in each year.

Substage 1 - Aims for physics education at secondary level

Once student teachers became sufficiently interested in the new model, they derived aims for physics education and sought the rationale for them from various sources. At this substage my role was to provide additional information and to lead the group discussions about the issue.

Substage 2 - Analysis of the meanings of the aims

During this substage an analysis of the meaning of the aims took place within the group of student teachers and myself. Each individual aim's meaning was scrutinized and sources were provided for the clarification of the meanings.

Substage 3 - Task analysis of the teaching skills needed to achieve the aims proposed

In a group discussion activity, a task analysis was made of the teaching behaviours, during a teacher's interaction with pupils, which would facilitate the achievement of specified types of the aims derived. This was done on a theoretical basis by applying principles from the field of psychopedagogy as well as by a reflective analysis of the nature of the interaction that should take place in order to achieve the aims proposed.

6.2.3 Trial stage

The question put by Farganis (1975)

"... how does one move from the theoretical critique to the necessary action that will bring about the desired end?"
can be used as the starting point in describing the trial stage.

Action research can be seen as an answer to this question. By action research it is meant, in the context of this study, a form of self-reflective inquiry undertaken by student teachers in order to improve the rationality and justice of:

a) their own educational practice;
b) their understanding of this practice;
c) the situations in which the practices are carried out.

In terms of method, a self-reflective spiral of cycles of planning, acting, observing and reflecting is central to action research approach (Carr and Kemis, 1983). Lewin (1952), who coined the phrase "action research" in about 1944, described the process in terms of planning, fact-finding and execution:

"Planning usually starts with something like a general idea. For one reason or another it seems desirable to reach a certain objective. Exactly how to circumscribe this objective and how to reach it is frequently not too clear. The first step then is to examine the idea carefully in the light of the means available. Frequently more fact-findings about the situation are required. If the first period of planning is successful, two items emerged: an "overall plan" of how to reach the objective and a decision in regard to the first step of action. Usually this planning has also somewhat modified the original idea. The next period is devoted to executing the first step of the overall plan. This second step is followed by certain fact-finding".

He then describes four functions of this fact-finding.

"It should evaluate the action by showing whether what has been achieved is above or below expectation; it should serve as a basis for correctly planning the next step; it should serve as a basis for modifying the "overall plan"; and finally, it gives the planners a chance to learn: that is, to gather new general insight. The new step again is composed of a circle of planning, executing and fact-finding or reconnaissance for the purpose of evaluating the results of the second step, for preparing the rational basis for planning the third step and for perhaps modifying again the overall plan".

Lewin (ibid.) documented the effects of group decision in facilitating and sustaining changes in social (including educational) conduct, and emphasized the value of involving participants in every phase of the action research process (planning, acting, observing and reflecting).

The approach used, to induce the trial stage in the mental processes of the individual student teacher when developing teaching skills, was based on this method of action research. A single loop or cycle of the spiral included: planning a lesson at a pre-active phase; acting or performing the lesson at an interactive phase; observing the lesson and reflecting about the lesson at an evaluative phase.
At the pre-active phase, the planning was made either through teamwork or individually. According to the content chosen, the aims for the lesson in terms of pupils' learning were stated. Then, student teachers analysed the lesson aims and objectives in order to establish the link between them. Then, they decided on types of activities, the nature of feedback to be provided, the nature of presentation and evaluation which best suits the achievement of the aims proposed for the lesson. This means that student teachers engaged in the analysis of teaching activities with a view of getting clarity on the nature of the pedagogical provision necessary for achieving the prescribed aims and objectives for the lesson. Through this task analysis, student teachers were developing teaching skills like definition of objectives, the setting of activities to identify the pupils personal frameworks in 'scientific observation' or meanings for scientific words; the identification of the prerequisite capacities, the ability to make the link between objectives and aims, the skill of "decision making" when deciding on types of pupils activities, the nature of feedback to be provided, etc...

In the interactive phase, one student teacher acted or performed a lesson for 50 minutes (normal time for a real class) with a small group of pupils, usually five to eleven. The pupils were from grades whose syllabus included the chosen content. When acting or performing, the student teachers were developing skills as: questioning for feedback; varying the stimulus; concept teaching; using examples; providing clarity of explanation; encouraging pupils to answer questions, to make suggestions and generally to participate in classroom discussions; beginning and ending lessons. Above all they were developing the overarching skill that all the other skills aim to facilitate; "the skill" of knowing what to do in order to develop in their pupils scientific "abilities" and to help them to progress in their intellectual and cognitive development in a constructivist perspective. All the other teaching skills relate to this superordinate skill in different ways. For example, the skill of questioning for feedback is desirable if a teacher is going to be able to stimulate pupils' inquisitive, critical, imaginative or creative minds in such a way as to develop these scientific capacities. But it is no good asking questions that demand no cognitive exertion; if teachers do that, they may get the "right" answer from the pupil but his/her understanding may be quite unchanged. Questions unrelated to any pedagogical plan are of dubious value.

Each individual performance was observed by peers and their skill of observation was developed by the process. They observed critically the peer's performance in order to provide feedback and, at the same time, evaluated the outcomes of the strategy adopted to achieve the aims proposed.
The performance was videorecorded and each student teacher had the opportunity to observe her/himself. Through this process s/he was able to make an analysis of her/his performance.

The last step in a single cycle is reflecting. This was accomplished either during observation or during group discussion about planning and acting. What was learned in one cycle was applied judiciously in further cycles of modifying plans, implementing them, monitoring the amended action and reflecting again. Carried out in this way this stage of the scheme became a process for continued learning and development. Each activity is an action consciously and deliberately undertaken on the basis of rational reflection by the practitioner, rather than on the basis of custom, habit, unreflective perception or hear-say. It is a strategic act. Carr and Kemmis (1983) point out that

"Teaching is a human action. Human action, as opposed to mere behaviour is a "probe" into an unknown future. Strategic action is constructed and essentially risky. It takes place in the space between the foreseen and the unforeseeable, the intentional and the actual, the is and the ought."

Carr and Kemmis (1983) stress also that action research makes the "probing" character of strategic action problematic; it reconstructs past action on the basis of observation and future action in the light of the reflection. It does not treat the space between these polarities as empty, but as in a state of dynamic tension which is resolved by a living dialectics of action and reflection. I believe this is the suitable method for the achievement of the aims proposed when designing the scheme.

6.2.4 Evaluation stage

At the evaluation stage opportunities were provided in which the student teachers evaluated their learning experiences, their development of teaching skills, the advantages of the model in terms of their own and their peers' experience to see if they outweigh the disadvantages. They then decided if they were going to try it in real classroom situation, in their teaching practice and in their future life career.

Altogether these two stages took approximately 63 hours each year.
6.3 Analysis of the data relating to the implementation of the four first stages of the scheme

The data relating to the implementation of each stage, its analysis and interpretation will be presented separately in the next sub-sections. This study being a naturalistic one, the analysis was carried on sequentially and, as pointed out by Smith (1982), the findings themselves are the culmination of systematic procedures for analyzing the data.

6.3.1 The awareness stage

From now on the thirteen student teachers who participated in Part A of the main study will be identified by $S_1$, $S_2$, ..., $S_{13}$.

In general the student teachers' first reaction to the activity they were asked to perform at the beginning of the awareness stage - to write down their meanings for "teaching physics, was of a certain astonishment followed by a certain hesitation. This was conveyed by pithy phrases like: "What?", "I never thought of it", "That's difficult", "Well, that's hard to say", "My goodness ... what a problem!". This reaction is itself hard to accept. It discloses a shortcoming of our teacher training program. It is a bit odd that student teachers arrived at their fourth year of a teacher education degree without having had opportunities to reflect on the purpose of their degree: "teaching". They "have never thought of it". I think this reaction is, per se, of enough importance to make us rethink the curricula of the teacher education degrees of our university.

The student teachers' written answers to the question "What does 'teaching physics' mean to you?" are transcribed below.

$S_1$ - "Teaching physics is to help pupils to develop their capacities of knowledge on physics through a process of motivation, in order to get a better understanding of the real world".

$S_2$ - "Teaching physics is not only to transmit knowledge, laws, formulas, etc., but it should also be, perhaps, to help the understanding and explanation of phenomena which happen around us and also at the Universe".

$S_3$ - "Teaching physics is to get pupils aware of the physical phenomena, helping them to understand those same phenomena, trying that pupils can explain them by themselves".

$S_4$ - "Teaching physics is to transmit a series of knowledge and to explicit concepts".

$S_5$ - "I don't know what 'teaching physics' is. I only know what 'teaching physics' shouldn't be and that is the way I have been taught physics".
S6 - "Teaching physics is to develop in pupils capacities which lead them to understand physical phenomena ... but how? ... I don't know".

S7 - "Teaching physics is to make the discipline of physics more enjoyable for pupils. It is to instill in pupils the idea that physics is always linked with the physical world surrounding us and thus conveying the idea that the study of physics can be a good way to understand the world".

S8 - "Teaching physics is to transmit the basic principles of physics, enabling pupils to see its relations with practical life ... as much as possible".

S9 - "Teaching physics is to help the understanding of physical phenomena not only at a theoretical level but more at a practical level. To open new views to the learner".

S10 - "Teaching physics is a wish I have had through the years during which I have acquired and improved scientific and pedagogical knowledge. So, teaching physics is a continuation of this learning but now in practice; I mean linked with the reality, the pupils".

S11 - "Teaching physics is trying that pupils learn basic concepts of science which command us every moment. I also think I only can teach physics that can really be learned by the pupils".

S12 - "Teaching physics is to instill in pupils an interest toward physics, to transmit basic concepts according to the syllabus, to make them learn and enjoy the subject and remember those concepts through all their lives. To make them understand the world around us".

S13 - "Teaching physics is trying to transmit to pupils basic concepts of science in a clear way and above all linked with everyday life".

The majority of these answers show a strong influence of the classical academic tradition of western education. It is interesting to note the similarities between these views and the ones given by most of the teachers and student teachers interviewed during the preliminary study. The main aim for physics teaching is seen as the transmission or explanation of knowledge, basic concepts, laws, formulas, etc., made by the teacher.

Another interesting point is the concern, conveyed by the majority of these statements, for the learner's understanding of the world around her/him. Emphasis is made on the "understanding": "implementation" was never mentioned.

A few of the statements, contain a judgement on the model of teaching conveyed to the student teachers through their schooling: "... it should be ...", "... I know what physics teaching shouldn't be ...". At the same time an uncertainty about the aims of physics teaching can also be perceived.

When the task was finished, I collected the student teachers' writings and read them aloud, one by one. Then we discussed together the meaning, the perspectives conveyed and the implication of each one.
In each cohort (first and second year of the experiment) it became apparent that, as time passed, the student teachers became increasingly relaxed, more inclined to expand freely on their own ideas and give personal examples and anecdotes. The conversation took a more informal tone which contributed to a more relaxed and sincere atmosphere. This could only happen, I believe, because no judgement was made of their meanings, no statements about what "teaching physics should be" were made and because a reflection on and a discussion of the advantages and disadvantages were made within the whole group, each one feeling that his own contribution was important. As a consequence of this approach some features of each group emerged from the beginning of the conversation. The first cohort (first year of the experiment), composed of two males and four females, showed from the beginning a great heterogeneity either in what concerns individual personalities or intellectual, cultural and cognitive development. Student teacher S1 was a very self-confident, and very alert young man, with a cultural background more advantaged than his peers. He was a very critical and inquisitively minded person and also a very ambitious one. He recognized himself as being the leader of the group, the person who had always the last and valid word. His attitudes inhibited the participation of the others. S2 was a very introverted and quiet person. She wouldn't talk unless individually invited and her contribution to the discussion was always made in a very unenthusiastic way. From the start, she did not show, from the start, a great willingness to change the status quo. Student teacher S3 was a very shy and dependent person and, although she talked more freely than S2, she was always very insecure in her opinions. Judging from student teachers' records, her academic abilities were very poor. S4 was the oldest in the group because he had failed some years during the degree. His scientific and cultural background was also very poor. He was a person with great difficulties in communicating. He expressed himself, whether in oral or in written form, in a very bad Portuguese, showing a great difficulty in communicating his ideas clearly. To some extent, he was aware of this and it constrained his participation during group discussions.

In contrast with S2, S5 was a very dissatisfied person. She was not happy with the way she had been taught and showed a great interest in changing it. She was secure in her opinions and expanded on them freely. Nevertheless she wasn't very alert. Her discourse was, most of the time, dull and sluggish. Student teacher S6 was, in some way, what could be called a difficult person. Difficult in the sense that it wasn't easy to be acquainted with her. She was a very introverted person and it was difficult to make her disclose her own feelings. In my opinion, she was the most mature of the group. She had her opinions but she didn't bother to defend them against the arguments of the others. She closed in on herself and
did not argue with them. She showed some scepticism towards changing things even though she wasn't happy with the existing arrangements.

Being aware of the great differences that existed between the elements of this cohort I had to make an effort in order to get a more balanced participation within the group.

Compared with the first cohort, the second one (second year of the experiment) seemed to be a more homogeneous one. It was composed by three females and four males. The superiority in number of the males, and the fact that two of the females were very shy, contributed to an unbalanced participation between males and females. An effort was made to help the two girls feel at ease and openly enter in the conversation. Although more homogeneous than the first one, this group showed, from the start, signs of some tension within it. One of them, $S_8$, was very often in conflict with the group. He was a very emotional person. His peers blamed him of not being open minded and not being able to consider other's opinions. It is worth describing here an episode which occurred a few lessons after the beginning of the course, in which the main activity was a group discussion. Talking to me privately, $S_8$ told me of his intention of leaving the group and giving up the course because, "... I don't match with them", "they are against me", "they don't know how to work in a group". Although they have been together for some years during their degree, this problem emerged only now. This was most probably, because, for the first time, they were, within the context of a course, in situations in which each individual's opinion was asked for and taken into consideration. In such situations these conflicts can rise. After our talk he reconsidered his views and became more conscious of his own attitudes. He re-entered the group and, to some extent, the problem was overcome. He was really too wedded to his opinions and too stubborn to listen to others' points of view. This was really apparent when the discussion about the meanings of the aims for physics education took place.

$S_7$ was the eldest of the group and the most reluctant to consider innovations. However he showed some discomfort with the way in which he had been taught physics. Contrasting with this last student teacher, $S_9$ was a very open minded person in the sense that he was willing to change his perspective and to approach teaching in a new way if he perceived it to be more suitable for the improvement of physics education. He was usually very spontaneous and one of the first to give his opinions, although always willing to 'negotiate' views in order to reach consensus. He appeared to be very interested and his manner was generally friendly and kind. The same attributes were shown by $S_{10}$. This student,
S₁₀, was a very mature young man, very interested in improving his competencies as a teacher and showing a great willingness to start teaching.

Neither of the three females of the group were active in the group discussions, nor did they evidence a great creativity and willingness to change. At the beginning of the course, all three seemed to be very accommodative persons, but more interested in taking a course which could get them nearer to professional life, not so much interested in teaching itself but more in getting a job. Student teacher S₁₁ was a family mother extremely concerned with her family problems. Her academic record wasn't very brilliant. She entered into discussion when asked, but not spontaneously. Usually her opinions were well founded, but it appeared that she didn't care much to change things. Throughout the first sessions of the group discussion student teacher S₁₂ became a much more interested person than she appeared to be at the beginning if the course. She was willing to innovate although she didn't openly show it. She was always very quiet, observing very accurately what was going on and when personally invited she gave her point of view with great assurance. She was a very discrete person but each step taken by her was done in a very precise way. She always talked quietly but without hesitation. Contrasting with S₁₂, student teacher S₁₃, the youngest of the group, was very insecure in her opinions, showing a great lack of self-confidence and, worse than that, without any willingness to overcome it.

I gathered this data through my observations of the nature and outcomes of my interaction with the student teachers, and the interactions between them during the awareness stage and the interest stage.

A first general impression of the discussion taking place during the two first substages of the awareness stage was that there was a shared feeling of dissatisfaction between student teachers concerning the way physics had been taught to them. Interpersed throughout the conversation terms such as "transmission", "imparted", "exposition", "instilling", conveyed a "cultural transmission" prospective on teaching. At the same time a feeling was also latent that something was wrong with that. To some extent, a traditional teaching model was conveyed to them through their experiences as learners. Among occupations, teaching is unique in that, by the time one starts to be faced with the demands of the profession one has at least fifteen years' experience of seeing teachers at work. This does not necessarily mean that everyone forms an accurate perception of teaching and what it may involve. It wouldn't, however, be surprising that the attitudes to teaching, and more concretely, teaching models, one holds were considerably influenced by one's experience as a learner.
After a reflective analysis of the shortcomings of the traditional model of teaching, all the student teachers, without exception, although with a greater or lesser degree of enthusiasm and willingness, expressed the view that some change on the way physics has been taught was inherently good. The findings of the preliminary study helped them to reinforce that view. As a change-agent I found this the right time to expose them to the innovation. As a teacher I acted as a facilitator of activities to guide the student teachers in finding a direction for that change that they already perceived as necessary.

During the analysis of the research papers, an increase of interest and motivation was evidenced by the way they made comments, they shared opinions, and prepared the analysis of the papers. The ones with fewer difficulties with the translation helped the others with more problems.

Relating to the topic "Electric Current", the second unit of the syllabus of the 8th grade, I found an opportunity to involve student teachers in an activity through which they could be aware of their personal frameworks on 'scientific observation' as well as to help them to shift their views on the role of experiments. Instead of following a "recipe", as is usually done in physics classes, the experiment was used to help the development of "abilities" such as team-work, predicting, inferring, planning, communicating and inquisitive, creative and critical-mindedness. The activity was, in some way, similar to the one designed for the study "Investigating pupils' understanding of phenomena occurring in simple D.C. circuits: Implications for teaching" (Thomaz, 1984), presented in Appendix 3. With very simple materials (bulbs, batteries, wires and toy motors) student teachers were, for instance, asked to predict, using their own conceptions, what would likely happen in situations provide by me. They were asked to test their predictions and then to infer. They could perceive the importance of having opportunities to predict events and test those predictions. With some of them, their predictions didn't match with their observations and they had to revise their own frameworks. Some other tasks were provided in order to give student teachers feedback about their personal frameworks or alternative conceptions. Research studies on alternative conceptions have shown that children bring to learning situations intuitive ideas acquired through interaction with the physical world without formal instruction which are, therefore, very functional in and adaptable to most circumstances. These children's alternative conceptions can be very resistant to change and can also be found in college and university students (e.g. Viennot, 1979; Posner, 1981; Thomaz, 1982). The kind of activities, mentioned above, revealed that these intuitive ideas still exist in the student teachers one year before starting teaching.
For instance, it was evident that some of the student teachers still held the "sequence model of current flow" so called by Shipstone (1983). Through these activities they could perceive to what extent the way they were taught left some intuitive ideas untouched despite their long schooling. It is actually more important to have personal experience than reading about it. All of them, although some more than others, realized the existence in themselves of these intuitive ideas, as well as in their peers. I must say, that, when we discussed the results of these activities I could see in their faces a certain sign of astonishment and frustration. This was also conveyed by their own words, as for instance, "I couldn't believe I had such ideas"; "My goodness! How could I say that!"; "I never thought of it!". "Of course, this wouldn't be possible ... but I had never realized that". It wasn't my intention, in the present study, to analyse in detail student teachers' intuitive ideas on concepts, such as force, electric current, light or whatever. My purpose, when presenting them with these activities, either in the form of performing small experiments or answering some questionnaires, was to make them aware of the existence of personal frameworks in scientific observation which in some cases were considerably different from the scientists' and might lead to some difficulties in learning science. The way they reacted to them brought to light, once more, the features of the teaching they have had in their schooling. They accepted the instructions they were given without realizing that they could have their own personal interpretations or their own personal meanings which were different from the accepted scientific views that they were presented with.

It was with a great interest, curiosity and, to some extent, with a feeling that "we are not alone", that they analysed the findings of the two studies conducted by me and already mentioned in section 6.2.1. At the same time that they became aware of the existence of "alternative conceptions" which, for any individual, are strongly held and extensively used, they were getting a higher degree of awareness of a constructivist approach to teaching. One of the implications of personal constructivism - that individuals will have meanings for words, which are commonly used in academic subjects, particularly in physics subjects before formal teaching - was then explored after they had got an awareness of it in themselves and in their peers. Also, the complex of understandings produced by the interaction of these alternative conceptions with teacher's views was considered, as well as some different approaches to the identification of these conceptions that have been developed.

Throughout the sessions in which all the above mentioned activities took place, the student teachers were constructing for themselves a "new"
perspective toward physics teaching in which the emphasis is on the learner as the meaning-maker and on the development of the learner as a scientist rather than on the transmission of knowledge by the teacher.

6.3.2 The interest stage

By this time student teachers were already interested in the "new" perspective on physics teaching. They favoured the "new" approach in a general way but they needed to be helped to have more precise and organized ideas about the aims of physics teaching in the light of this "new" perspective. With this purpose I asked them to reflect on the activities they had performed and list the scientific "abilities" they perceived could be developed during their performance. This was done differently in the two cohorts. The first cohort worked together and they presented me with one list. In order to explore student teachers' understanding of the meanings of the aims listed by them a discussion focussing on this issue took place and the conversation was audiorecorded. During the discussion I perceived that most of the students had no clear ideas about the meanings of the aims listed. Although the list was said to be elaborated by the six, it could easily be seen that student teacher S1 was the leader, the one who had the clearest ideas, the main author of the list. Throughout the discussion I could perceive that they had no solid ideas about the meanings of the aims and that the group-work was not going very well. Many times they had very different views and the prevalent one was always from S1. To overcome this situation they were presented with a list of aims, elaborated by me, asked to compare both lists and to undertake a task analysis of the aims to clarify their meanings. The next session took place four days after and the student teachers presented me a new, more concise list. The list is shown in Appendix 6.

The following group discussion revealed that all of them realized the importance of each one's contribution in team-work. Each one being personally invited to comment, all of them were able to perceive that they could not and, more important, they should not, rely on others' work. During the discussion clarification was made of the meaning of each specific aim and a more organized and operational list was elaborated. The list is presented in Appendix 7. At this time the conversation was more balanced as regards participation. Some of the "abilities" listed were developed in the student teachers during the whole process, which, per se, was considered by me as an aim of the course.

With the second cohort, (second year) this activity was done differently. They were also asked to list the "abilities" they perceived could be developed
when performing the previous activities but, this time, it was done individually. Done in this way, the activity worked better because the following discussion was enriched with each one's contribution. Some "abilities" appeared in most of the lists but others were considered only by some students. This fact gave rise to a deeper reflection on the meanings of each specific "ability". With the contribution of all participants we elaborated a more complete and organized list of aims for physics education at the unified level. The list was similar to the one presented in Appendix 7.

It has been suggested by various teachers educators (e.g. Dussen, 1985) that the relationship between teachers and learners is essentially a reality-sharing, world-building enterprise. An understanding of the individual meanings for words is of vital importance for that reality-sharing. For developing teaching skills appropriate for the achievement of certain aims it is, then, vital to undertake an investigation on each individual aims' meaning. With this purpose a group discussion took place on this issue. At the same time suggestions of teachers behaviours, during teachers' interaction with pupils, which would facilitate the achievement of the different aims proposed, were considered. The conversation was audiorecorded and the analysis of the transcript revealed the following points:

a) It was noticed that there was, on the part of the student teachers, a tendency to analyse the aim's meaning through a pupil's perspective. Although this perspective is important it could limit the scope of the aims. Actually they were still students, although the activity expected a teacher's perspective. It took some time to shift this perspective. This was most clearly achieved when they started teaching small groups of pupils in the microteaching lessons.

Some extracts of the conversation can illustrate this point.

(In this transcription T stands for myself as the teacher responsible for the course).

"T - receptivity to criticism ... how do you think it can be developed in pupils ... during physics classes?

S₅ - ... I think this is more applicable to teachers than to pupils ... I think normally teachers are not too receptive to criticism ...

S₃ -... yes ... I think teachers should be .... if they are forming future adults ... they should help pupils to be receptive to criticism.

S₁ - it looks to me extremely important that persons should be receptive to criticism but ... this doesn't mean to accept it .... I mean, one should be open to criticism .. to discuss it ... that is the most important thing ... not only in physics lessons .... but in everyday life ... and teachers must give the example
they should ask students to assess them at the end of the course ..., because in doing this they are developing this spirit in students ... of course it isn't only important for teachers, it is also important for pupils .. but the teacher is still ... the detached element at the classroom ... and pupils see teacher .. even because normally he is an older person ... they think he has more experience .... they have more tendency to accept and follow the teacher's example .. and then that example must be particularly correct".

In other occasion, when discussing the attitude of honesty with the first group, I asked them about their meaning of the scientific attitude of honesty.

"S₃ - honesty in the reports of our measurement in our observations ..... which we haven't been helped in our learning (laughs) ..... if our results don't agree with the exact teacher's answer ... we cheated on them.

S₅ - .. yes ... honesty .... it's very easy to say the meaning of honesty ... in scientific observations .... it's the opposite of what we have done ... (laughs).

S₁ - it also has a lot to do with a situation that occurs frequently during tests ... and I'm afraid I don't know how to deal with it ... how can we avoid cribs?"

Another occasion, when discussing the capacity of critical thinking, I asked them what they meant by 'methodical doubt'. The small extract transcribed below also illustrates the above mentioned point.

"S₄ - .. for me it means to go against the rule that ... it is the teacher who knows everything ... and then .. the student faced with a teacher's explanation .... well it doesn't mean that we (the students) doubt ... but we try to see if the teacher is .. cheating upon us. (laughs).

S₃ - it is also to doubt about what is present to us ... it isn't to think that everything that is presented to us is completely wrong .... it is trying to know if things are or aren't the way they are told to us ... it is not to accept things just like teachers told us".

b) A recurrent theme in both cohorts' discussion, relating to the analysis of the aims' meaning, was that the student teachers were aware of the fact that if the teachers have, as an aim for their teaching, the development in their pupils of certain kinds of "abilities", they ought to have them developed in themselves.

Some extracts of the conversation can illustrate this point.

The group was discussing the meaning of open-mindedness.

" T - so do you think that it is important ... it is useful to develop in your pupils this capacity?

S₁₀ - .. for me to have an open mind is ... in a certain way, to acknowledge our fellow creature ... for example .. thinking in a classroom ... if a pupil gives an idea .. and if the teacher doesn't have an open mind he doesn't take into account the pupil's idea ... and tells him to shut up .... if the teacher is an open minded person he will recognize the existence of the pupils .. he will recognize their right to give their own opinions.

T - you are talking about an open minded teacher ... how can you help the pupil to develop this capacity?
S10 - well .. that is my starting-point ... if I show this open-mindedness I think that's a good start to achieve that aim. If I don't have an open mind, surely I can't help my pupils to develop it".

In other occasion talking about inquisitive mind,

"T - to develop inquisitiveness .. how according to you can it be developed in pupils during physics classes?

S9 - ... that activity we did on bulbs and batteries .. I think it's a good example. If we ask pupils about what would happened if we did this or that ... I think this is a way of fostering curiosity.

S11 -.. yes ... even the fact of trying to fuse a lamp ... (laughing) ... there ... it was curiosity!

S10 - the way teacher treats the subject matter ... I'm remembering that activity we did ... there is always a way of leaving some doubts that will give rise to curiosity .... but if the teachers explains things in such way ... transmitting ...

S7 - sometimes that happens because most of the time teachers don't realize that it is important to develop the capacity of inquisitive-mindedness.

S9 - ... or even the teacher is not aware of that.

S10 -... or even he hasn't got an inquisitive mind.

S9 - yes .. if one hasn't got an inquisitive mind ... one cannot develop it in others ...

During a group discussion with the first cohort, S5 summarized her peers' feelings on this issue saying: "Really ... if we don't have all these abilities developed in ourselves how can we help others to develop them in themselves?"

This awareness was very important in the sense that they were much more sensitized to catch all the opportunities provided for that purpose. At the end of each course student teachers were asked to make a self-assessment on the development of their own abilities along the course. The schedule for this self-assessment is shown in Appendix 12. Data relating to this self-assessment is shown in Appendix 13. The analysis of the student teachers' perception of self development will be presented later.

c) One interesting point, elicited by the analysis of the transcripts of the group discussions, was the fact that most of the doubts relating to the applicability of the "new" approach to teaching came from the student teachers who had already some teaching experience at the secondary level (see subsection 5.4.2). The next episode will illustrate this point. The second cohort was discussing the meaning of the scientific capacity of creative-mindedness. An episode that occurred during the teaching practice of their colleague, S1, student teacher of the first cohort, came up as an example of an opportunity provided by the teacher for the development of this capacity in pupils. The topic being under study was the mixing
of two substances and its separation. The teacher, S₁, asked pupils to think about possible solutions for the separation of a mixture. One of the pupils came up with the following solution: "Suppose we have a mixture of rice and beans. If we let the mixture fall down in front of a fan ... the rice will be swept away and the beans will fall down". The pupils discussed that possibility but as some doubts about the efficiency of the technique arose, the author of the solution decided to try it at home. In the next lesson he told the class that actually it did not work very well because not all the rice was separated from the beans. Then another pupil came up with another solution. "It would work better if we brought a chicken near the mixture. The chicken would eat all the rice and leave the beans". The discussion about these techniques of mixture separation continued but this bit of the episode was the one which gave rise to the episode occurring during the discussion (in the second group) about the meaning of creativity.

The following extract will give the flavour of the discussion and will illustrate the point I want to stress.

After some discussion about creativity in which different opinions were put forward the conversation followed like this:

"S₇ - .... I think we must define what is creativity.

S₁₁ - I think .. well really I looked for a definition of creativity and I found this ... creativity is an inventive function of the imagination independently of the intellectual activity.

S₁₃ - right .. it is the result of imagination

S₇ - exact ... that's true

T - so you think it's important to develop this capacity in pupils. Why?

S₈ - it is important for the progress of society .. I mean what would happen to a society if there weren't creative persons? It would stagnate .. even ... for living .. if a person doesn't have a creative mind his life .... well I think it will be a very dull life ... I think so

T - and how can you provide opportunities in classrooms to achieve that?

S₈ - for example ... that experiment with the fan we talked about before ... I think the teacher provided an opportunity for the development of creativity ... I think the pupil who gave that solution showed signs of creativity

S₁₁ - and the other solution with the chicken was also creative (laughs).

S₇ - .. that was much more creative..

T - well now suppose that instead of asking pupils about different possible solutions for the problem the attitude of the teacher was describing the physical techniques listed in the textbook ...

S₇ - .. but .. well .... let's talk now about this .. if ... analysed on the scope of the discipline ... I mean within the discipline that process wasn't accepted ... it couldn't be accepted .. if we were a bit ... let's say rigorous ..
$S_8$ - if we had a closed mind!

$S_7$ - no it's not that here the subject the content it doesn't talk about those techniques

$S_8$ - but obviously the teacher who wouldn't accept those solutions would show a very closed mind.

$S_8$ - (all talking at the same time)

$S_7$ - yes I agree with that but we are now seeing things in concrete within the discipline

$T$ - Why? That's interesting!

$S_7$ - well the teacher has enough reasons for considering that answer perfectly incorrect

$S_{13}$ - which one?

$S_7$ - the one about the bird there is no physical techniques to solve the problem with a bird.

$S_8$ - but does it work or not?

$S_{11}$ - of course it works actually you are making the separation of the two components of the mixture only the problem is that you can keep only one of the components the beans.

$S_7$ - exactly

$S_9$ - you could kill the bird and take out the rice

$S_8$ - (laughs)

$S_8$ - well it depends on the way of putting the question

$S_7$ - but we are talking about physical techniques to solve the problem what would you do in this case?

$S_8$ - I would consider the answer

$S_8$ - (all talking at the same time)

$S_8$ - it depends on the way you put the question if you narrow the possibilities of the answers if you specify if you ask the physical techniques that's on thing but if you simply ask about ways of making the separation you leave doors open to the imagination you must take into account all the hypotheses given by pupils

$S_7$ - let's go to the extreme situation my objectives were that the pupils should give physical techniques of separation.

$S_8$ - and why isn't the first technique the one with the fan why isn't it a physical one?

$S_7$ - yes that's true well but let's think about the techniques for separating rice from beans that process the birds eating the rice is absolutely incorrect.

$T$ - why?

$S_7$ - it doesn't have any reasons to be concerning the separation we want to create a technique of separation
The conversation continued but what I want to point out is the way S7 reacted. He had taught within the system and he showed during the conversation, to some extent, a lack of flexibility to adapt himself to the consequences of the new approach to teaching.

Another recurrent point emerging from the analysis is related to the fear shown by most of the student teachers of being unable to resist pressures to conform to institutional norms for teacher behaviour. A small extract of the conversation can illustrate this situation.

We were talking about curiosity and motivation.

"S8 - .. motivation ... well well ... for instance one leaves the university motivated to implement a certain model of teaching ... and .. right away in the first year of activity ... well .... they "cut our legs out from under us"

T - but .. you should resist that

S8 - the problem is when one needs the other persons ... you know .. if one wants to survive one need to submit to the institutional forces ... at least it is what I heard from others ...

S7 - yes the pressure of the ... system is too strong .... would we be able to resist to it?..."
This concern was, for me, a positive sign. If they felt fear that was because they were aware of the situation. And if they were aware of the situation they were more able to fight against it. Knowing about this situation helped me to bring this issue into the conversation and to discuss with them possible strategies to deal with it.

e) Another fact emerging from the analysis of the transcripts was the lack of clarified ideas concerning the meanings of the aims mainly the meanings of the scientific process skills. This evidence convinced me of the importance of these group discussions because, if the student teachers were going to embark into an approach to teaching in which emphasis is made on the development of man-the-scientist, they needed to have very clear ideas about the aims they proposed to achieve.

To illustrate this point I will transcribe an extract of a group discussion concerning the meanings of the scientific process skills "inferring" and "predicting".

(Extract of the group discussion).

"S7 - in what concerns inferring and predicting ... well I really don't know how to make the distinction between them I looked at the dictionary but it isn't very clear about the difference between them ... both are ... predicting ... conclusions based on reasoning ... reasoning in order to reach a conclusion according to initial conditions ..

T - what are your ideas about it?

S13 - I think they are different

S7 - of course they must be ... but I cannot tell you the differences

S13 - I think ... well inferring is to draw a conclusion without enough data

S9 - no ... no

S7 - no .. it is deduction through reasoning to draw conclusions as consequence ... this is inferring ... but ... for me predicting ..... is the same thing

S9 - no ... you can make a prediction without inferring.

S7 - well if I say "tomorrow is going to rain" .. I'm predicting something but with some basis .... if there is Sun I wouldn't say that .... I can't predict without any basis.

S13 - for me the two are different .... I think .. predicting .... well we are faced with a phenomenon ... we can predict without drawing conclusions ... and in order to make an inference we need to have concrete data.

S9 - to predict ... I think is working more in abstract .. whereas if you want to draw a conclusion you need to have concrete things
I don't agree with that. For instance, the meteorologists make predictions, but they are based on concrete data.

really I think they can't be discriminated

what do you mean by that?

well, predicting is with data, but inferring, it must necessarily be based on data and predicting well, perhaps it isn't necessarily based on data.

I don't agree... I can't predict without data.

well... really inferring contains predicting

I think we first predict and then we infer.

I'm lost

I think inferring implies having data and based on that, conclusions can be drawn and predicting is imagining what is going to happen.

.. really predicting is not concluding and inferring is concluding... concluding is inferring from premises... that's it... that's the difference.

so predicting is not concluding... is it?

it isn't... making a prediction is... like making an hypothesis.

look... remember the activity on bulbs and batteries... I was going to connect a wire between the poles of the bulb... what did I ask you?

to predict.

yes and once done it should be asked "what do you infer"?

right so... predicting it to assert based on data but in advance of proof.

right... and to infer is to conclude or accept from evidence

all right... I see now.

Various situations similar to the last one happened during the conversation. Notwithstanding by the end of the session I could infer that a reasonable clarification of the meanings of the aims was achieved. Constraints of time and space make the illustration of all the interesting situations that occurred during the group discussions impossible.

The step into the next stage is well represented by the words of S6 and S9 respectively in the first and second cohort of the course, when the discussion about the meanings of the aims and the task analysis of the teaching skills appropriate to achieve them was ended.

"I think there is nothing more to be explained by now... what is needed is to put them into practice... for instance if you give the experiment already designed you cut at once the possibility of developing scientific process skills like designing and planning, experiments, predicting... inferring etc.
but all this we have been talking about are ideas ... now how to get it .... how to achieve these aims ... well that is another matter .. and I think that is what is difficult".

"Sg - well ... after this I think we are ready to put all this in practice .. when will we start?".

6.3.3 The Trial stage

Throughout the sessions preceding the trial stage the model of teaching that aims at helping the development of pupils in their 'scientist-like aspects' through physics content turned out to be worth trying to implement. All the student teachers were conscious of what they wanted to do with their teaching, although some with a higher degree of acuteness than others. They were aware of and interested in the innovation. They were ready to initiate the trial stage in which they used the innovation on a small scale in order to determine its utility in their own situation for possible complete adoption. Thus the trial stage was a kind of validity test of the "new" perspective on teaching for each student teacher.

The patterns of the implementation of the trial stage were very similar in both years of part A of the main study. Since thirteen student teachers were involved in this phase of the study, it would be impossible to report on all the cases, analysed in depth, with the same detail. Thus, the data from the implementation of the trial stage of the first cohort of student teachers (first year), its analysis and interpretation will be reported in great detail. The intention is to give a thorough picture of the teaching situation, its consequences on learning, as well as, providing a clear description of the procedures used for collecting and analysing data. Having this background information in mind it is hoped that the reader will have no difficulty in understanding the report of the implementation of the trial stage of the second cohort. The remaining seven case, studied in depth, will be presented in the form of summaries. These summaries will take the form of condensed versions of the case studies, mainly omitting the extracts of the transcripts of the lessons and in-depth descriptions. However participants' own words and particular episodes will be reported wherever possible to retain the flavour of what was going on.

6.3.3.1 By the first cohort

The key aspects of any teaching encounter are its planning, its execution, and its evaluation, frequently referred to as the pre-active, interactive and
evaluative phases of teaching. In the approach taken in this phase of the study, the student teachers of the first cohort were divided into two groups. Group A was composed of the student teachers $S_1$, $S_3$ and $S_4$. Group B comprised the student teachers $S_2$, $S_5$ and $S_6$. The composition of the groups was the responsibility of the student teachers. The purposes of this division were threefold. The first one was to facilitate the coherent planning of the lessons that each member of each group was going to perform. The second one was to create a situation as close as possible to the everyday class situations: teachers in the same area, working with different classes, should plan and work together. The third purpose was to provide opportunities for student teachers to develop their skills of team-work and communication.

During the pre-active phase of this first cycle, the student teachers of each group worked together on the planning of the lessons that each one was going to perform.

The unit selected by the student teachers for this first cycle was "Electric Current", the second unit of the syllabus of the 8th grade. The first unit was "Electrostatics". The reasons for the choice were: i) at the time that this activity would take place the pupils available for the microteaching sessions were finishing the first unit in their schools and were about to start the next unit. It meant that, at least theoretically, they were in a good condition to embark on meaningful learning in Ausubel's sense; ii) although opportunities for investigating pupils' alternative conceptions relating to the concept of electric current could not be provided for the student teachers, I was able to report to them findings of studies conducted on that subject (including my own study with Portuguese pupils - Thomaz, 1984); iii) their performance of the activity on "bulbs and batteries" which has already been mentioned, had given them some experience with which to feel a bit more at ease with this unit.

1. The first lessons of groups A and B

1.1 Pre-active phase

Although there were individual variations, the six student teachers were relatively alike in their apparent perceptions of the innovation in the approach to teaching when they started the planning of the lessons. Although the choice of the topic to be taught was made in common, they were not given either the aims for the different lessons nor detailed objectives nor formal instructions. I was available merely to "answer" student teachers' questions and to act as a
resource for providing feedback and the requisite material.

The general content chosen for the first lesson by each group was the following: group A - "An introduction to the electric current"; group B - "Electricity. Electric current. Experiments of Franklin and Galvani".

The task analysis of the pre-active phase of each lesson involved the statement of the aims in terms of pupils' development and the objectives in terms of pupils' learning, the analysis of the lesson's aims and objectives in order to establish the link between them, the decision on type of activities, the nature of presentation, the feedback to be provided and evaluation which best suited the achievement of the aims proposed for the lesson.

The discussion concerning the different steps of the task analysis was made in common but no standard format for presentation of this task was provided. It meant that each group or each individual, in the second cycle, elaborated it in different ways. In order to facilitate my own analysis of the student teachers' work in this phase, I organized the data gathered from their documents in a standard format. Tables 1 and 2, overleaf, present the task analyses of the first lesson of groups A and B respectively.

From the analysis of the two task analyses of the pre-active phase some points emerged.

a) There was, in both cases, a concern for the development in pupils through content of some specific "abilities". Nevertheless it was apparent that the potentialities of the content for the development of other "abilities" were not thoroughly explored. The task analysis of group A showed less concern in this respect than the one made by group B. Although the analysis of the lesson aims and objectives made by the latter group to establish the link between them was very incomplete, it could be perceived through the description of the pupils activities that, with the strategies proposed, the stated aims could be achieved.

b) It was also apparent from the comparison of the decisions on the type of pupils activities and the nature of presentation that the perspective of group A was more teacher-centred than the one showed by group B. Although some evidence of concern on the development of the pupil as a scientist was shown by group A, no account for pupils' ideas and opinions were considered in the planning. Group B showed a more pupil-centred approach.

c) Both task analyses conveyed the view of a very structured scheme for the lesson although group B showed relatively more flexibility on pupils' activities and on the nature of presentation.
| A. Statement of the aims of the lesson in terms of pupils' development of "abilities" | B. Statement of the objectives of the lesson in terms of pupils' learning | C. Analysis of the lesson aims and objectives to establish the link between them | D. Decision on type of:  
| a) pupils activities  
| b) nature of presentation  
| c) nature of feedback to be provided  
| d) evaluation |
| --- | --- | --- | --- |
| Through the contents of this lesson pupils could be helped to (see Chap. 3, Sec. 3.1.2 or App. 7):  
| A₁  
A₄  
A₆  
D₄  
D₅ | After the lesson pupils should be able to:  
(1) - identify natural phenomena where the concept "electricity" is present  
(2) - establish analogies between flashes of lightning and electricity  
(3) - design an experiment to prove the relation between flash of lightning and electricity  
(4) - explain the relation between flash of lightning and electricity | According to this group if pupils are able to:  
- (1), (2) and (3) they will get a better understanding of the world around them and this helps them to develop C₆, D₄ and D₅  
- (2) they will be helped to develop A₁, A₄ and C₆  
- (3) they will be helped to develop A₄  
- (4) they will be helped to develop D₄ and D₅ (because they will get a better understanding of the world) and C₆ | a) (i) answering questions about: examples of electric apparatus machines; benefits brought to the world by electricity; a possible relation between flashes of lightning and electricity  
. (ii) designing an experiment to test the existence of electricity in a flash of lightning  
. (iii) summarizing Franklin's experiment as a history of the discovery of electric current (after the description of the experiment by the teacher)  
. (iv) discuss Franklin's Kite experiment with teacher and peers  
b). the teacher starts the conversation and stimulates pupils' participation  
. the teacher presents a trace of an electrocardiogram and an electroencephalogram  
. the teacher presents a OHP transparency with a picture representing Franklin's Kite experiment  
c). (not mentioned)  
d). (not mentioned) |
| A. Statement of the aims of the lesson in terms of pupils' development of "abilities" | B. Statement of the objectives of the lesson in terms of pupils' learning | C. Analysis of the lesson aims and objectives to establish the link between them | D. Decision on type of:
|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| Through the contents of this lesson pupils could be helped to: | After the lesson pupils should be able to: | According to this group if pupils are able to: | a) pupils give examples of the day-
- day phenomena related to electricity |
<p>| A₁ | (1) - make a distinction between scientific and non scientific attitudes | - (1) they will be helped to develop A₃ | . pupils explain what happened during Franklin's Kite experiment (aj being presented with a picture representing the same experiment) |
| A₂ | (2) - make a distinction between conductor and insulator | - (2) and (3) they will be helped to develop D₂ | . pupils explain why Franklin did experiment |
| A₃ | (3) - identify the features of the material of a lightning conductor | - (3) and (4) they will be helped to develop C₆ | . pupils draw the conclusions of experiment |
| A₄ | (4) - explain the utility of lightning conductors | | . pupils point out the relation between a flash of lightning and Franklin's experiment |
| B₁ | (5) - enumerate possible causes for accidents provoked by electricity | | . pupils point out the danger of doing such experiments |
| C₆ | (6) - infer precautions to be taken against thunderstorms | | . pupils explain the difference between attitudes held by different persons on the explanation of thunderstorms |
| D₂ | | | . pupils tell what they would do if they saw a dead frog having contractions |</p>
<table>
<thead>
<tr>
<th></th>
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<th>pupils give an explanation to what happened during Galvani's experiment with frogs</th>
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<td></td>
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<td>pupils imagine a way of designing a lightning conductor based on what happened during Franklin's Kite experiment</td>
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<td>pupils point out the features of the material of a lightning conductor</td>
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<td>pupils give their opinions concerning the conclusions drawn by Galvani from the experiments with frogs</td>
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<td></td>
<td><strong>b)</strong> conversation about a projected picture representing Franklin's Kite experiment</td>
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<td></td>
<td><strong>c)</strong> (not mentioned)</td>
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<td></td>
<td></td>
<td><strong>d)</strong> based on answering to question put by the teacher</td>
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</table>
d) The nature of feedback to be provided was not taken into account by either groups. This could have meant that no student teachers knew how to do it or why would it be necessary.

e) Whilst group A showed no concern about the evaluation of pupils' learning, group B intended to evaluate it by use of pupils' answers. The evaluation strategies to achieve the aims proposed were not considered in either cases.

To some extent, during this first activity of undertaking the task analysis in the pre-active phase, student teachers were diagnosing their own entry capabilities by a kind of pre-test of their competence in this phase. From the interactive phase they got feedback on that diagnosis and on the basis of that diagnosis they were able to prescribe for themselves the necessary instruction or information they needed to improve the next piece of planning.

During this pre-active phase the elements of group B felt some difficulties concerning their lack of knowledge of some of the content they proposed for the lesson. They knew very little about the historical aspects concerning the discovery of electric current and showed no critical awareness when interpreting the historical documents they were presented with. Nevertheless they made an effort to overcome the problems encountered and their team-work was quite satisfactory. In contrast, the team-work of group A was not quite so good. It was dominated by the activity of S₁, a student teacher with a strong personality and with a solid scientific basis as contrasted to that of his two peers. This allowed him to take the leadership of the group, thus enabling the other two to hide their own deficiencies. These two student teachers, S₃ and S₄, showed a significant lack of scientific knowledge, mainly concerning basic concepts, and a poor development of their scientific capacities. I had no responsibility for that and my purposes for the course, as well as for the study, were not to teach physics, but to help them to develop teaching skills to implement the model of teaching they perceived appropriate for improving physics education. In order to accomplish these purposes my role, as a teacher adopting a constructivist approach to teaching, was to provide opportunities for fostering the development of student teachers own "abilities" as well as for helping them to develop their capabilities as teachers working within the same approach. This was always in my mind when working with them.
1.2 Interactive and evaluative phases

While the pre-active phase was supposed to be accomplished by the three members of each group, the interactive phase was of the entire responsibility of each individual student teacher.

i) The lesson performed by $S_1$

In group A the first lesson was performed by $S_1$. The pupils were five 8th grade boys from a secondary school of Aveiro. Their ages ranged between 13 and 15 years old. The way they were contacted was already mentioned in Chapter 5, section 5.4.3.

Before the lesson started $S_1$ made the room arrangement according to his view of the best way to get communication with pupils. He put one row of desks in front of the blackboard and a chair at some distance in front of the desks. He ordered the five pupils to sit on the desks, he sat on the chair and began the lesson. Obviously this situation was far from the real one in which the average number of pupils would be 30 and in which, by the time this lesson would take place, teacher and pupils would have a good acquaintance with each other. Nevertheless it ensured a high level of student teacher success in the achievement of teaching skills according to a constructivist model.

Instead of reporting the full transcription of the lesson, which is not too relevant to this phase of the study, I will make some comments about the performance and illustrate them with some extracts of the transcription.

Being informed, by the task analysis made for this lesson, what the student teacher had in mind, we (his peers and myself) were able to analyse it. $S_1$ started the conversation by trying to motivate the pupils towards the topic to be taught. He tried to stimulate pupils' participation, asking them about the relation between everyday life and the subject they had been studying. Pupils were not very enthusiastic about electrostatic and he kept saying that at the end of the lesson they would be able to understand and find it interesting in a large variety of things.

The following is an extract from the beginning of the lesson.

Symbols used: $T$ - teacher, $B$ - boy, $G$ - girl, $P_s$ - various pupils.

"1 $T$ - ... are you understanding the subject you have been studying? ...do you find it funny? ... do you like it?"
2 Pₜ - yes

3 T - .. it's funny isn't it?

4 B - .. I don't like it ..... 

5 T - you don't like it ...

6 B - .. well ... I don't like it .. and I like it ... but I don't find it funny

7 T - you don't find it funny ... but do you think ... it has something to do ... with our life ... our day-to-day life ... something you can see when you go out there ... in the streets ... do you think that what you have been studying in physics until now ... has something to do with that?

8 Pₜ - (no answer)

9 T - don't you think it is interesting ... er ... one day when you go out and ... er ... let's say ... you see something odd happening in a thunderstorm day ... or something like that ... do you think ... the physics that you have been studying ... could have some interest for you?

10 B - may be that what we are going to study has some interest ... but until now ... what we have been doing .... I don't think it has got any interest

11 T - ... and what about you? ... do you also think the same thing?

12 B - I don't agree .. I think it has .. because .. everything needs a beginning .. and if we don't study these things without interest .. then .. when we arrive to the ones with interest ... we won't understand them

13 T - .. you wouldn't understand them ... and what about you?

14 B - .. well the same thing ..

15 T - .. do you think the same way .... well then I'm going to show you .. at the end of this lesson .. we all are going to conclude .. that what you have been studying and this .. that we are going to see during this lesson .... it really has interest .. really you can .. one day ... going out there .. for instance in a thunderstorm .... one thing we are going to study today here ..... what happens in a thunderstorm ...... and that has something to do with electrostatics .. and with something else .... right? ..... well let's start ... you .. everyday .. here for instance .. we are surrounded by many .. many machines ... they work by electricity ... as you know they work by electricity .. could you be able to give some examples of some machines that we have in our houses .... or we see in the streets .... or .. well ... any apparatus that work by electricity

16 B - .. a washing machine

17 B - .. a radio set

18 B - .. a tape recorder

19 B - .. an electric toaster

20 T - a toaster ... yes .. so .. you see .. electricity is present in things you see everyday .. nowadays electricity ... is practically in almost everything .. the modern man doesn't make practically anything without electricity ... but .. there are many things that you haven't mentioned yet .. for instance the telephone ... it also works by electricity ....
21 B - .. the train

22 T - the train also works by electricity".

During about 15 minutes the conversation (if it can be called conversation) went like this and the student teacher remained seated on the chair, which wasn't very helpful for communication. The pupils' participation was very poor. It was mainly the teacher who talked and in a monotonous way. The interaction was only in one direction, teacher to pupils, and it required the pupils only to recall information. The pupils' participation only involved very short sentences because the student teacher was unable to explore the opportunities to let the pupils expand their ideas. For instance, after utterance 6, $S_1$ could investigate what did the pupils mean by "I do not like it and I like it", and by "I don't find it funny". He lost, perhaps, the first opportunity in the lesson to create a more informal atmosphere and consequently an environment in which all the pupils, not only this particular one, could feel at ease. Utterance 7 shows how the teacher was more concerned to steer the conversation toward the problem of the thunderstorm than to understand pupils' meanings and feelings. Even the way in which this was done shows the gap between what was going on in the teacher's and the pupils' minds. The response to this is given in utterance 8 by the pupils' silence.

Meanwhile he steered the conversation towards the phenomenon of lightning, primitive man, and the way they interpreted lightning. He tried hard to get pupils' participation but without great success. The constraints of the situation, there being only 5 boys, in an unknown setting, surrounded by a lot of equipment, being filmed, could also have contributed substantially to their restraint.

Although, as can be seen by the transcript of the lesson, the student teacher made some attempt to promote pupils thinking, he was completely unable to achieve it. The follow extract illustrates this point. The conversation transcribed was preceded by some talk about electrocardiograms and electroencephalograms. $S_1$ had shown some pictures about it, as examples of the application of electricity in medicine.

"1 T - well .. I hope that with all this talking you have already understood that electricity is very important in our modern life ... but .. nevertheless ... it isn't so decisive for Man's life .. if you remember the primitive man .. the one who used bows and spears .... and dressed with furs .. you must have talked about him in History ... haven't you? .. yes .. that man .. in his time he hadn't electricity

2 B - .. he had fire

3 T - but fire isn't electricity .... do you think it is?

4 B - it gives us light

5 T - yes fire also gives light .... so you think electricity also can give light?
B - yes
give me an example where ...
lamps
lamps ... yes lamps ... there ... that is an example where you can see that electricity can produce light ... yes ... but at that time ... if man hadn't electricity to light lamps ... he couldn't listen to radio ... but at that time he already perceived that there was something odd around him ... he didn't call it electricity ... but ..... in nature there are phenomena which we can relate to electricity

B - yes ... for instance lightning ...
lightning ... that's a very good example ... but we will turn back to lightning later ..... before I would like to know if you remember some other phenomena related to electricity
when we strike a stone against another we can see a spark
when we strike two stones against each other we can see sparks ... well that is an example very similar ... to certain extent to what happens with a lightning ... besides ... shortly we are going to see that ..... but ... by now give me more examples

Ps - (silence)

T - ... you ... who are from a maritime region ... haven't you ever heard of stories about ships on stormy days ... at the mast of ships some sparks appear

B - ... I have never heard of it .."
The lesson continued with a long talk by S1 about Saint Elmo's fire, and then he returned to lightning.
"well ... could you imagine an experiment through which we could draw the conclusion that a flash of lightning is an electrical phenomenon? ... do you have any ideas ?

Ps - (silence)

T - well if you think hard ... you will get it

B - perhaps if we use a lightning conductor

T - what could we do with it? ... to catch the spark ? ...

B - ... no ... to get an electric shock
to get a shock .... so that was a way ...
to show that it was electricity

T - ... yes ... well you couldn't do that because if you did it ... you certainly would die

B - ... we could use a lamp

T - a lamp (laugh) ... so you put a lamp on the clouds ... and it would light .... well we would need a way to make the electricity ... that we suppose is in the cloud ..... well it would be very difficult ... don't you think so? .... but we have already talked about lightning conductors ... we said that they attract lightning .. why is it?"
The analysis of this small extract reveals one of the characteristics of this particular student teacher, as well as his deficient teaching skills for the implementation of a constructivist model of teaching. He had prepared a nice OHP transparency reproducing the Franklin's Kite experiment. He was anxious to show it. Thus he was more concerned to reach that point, to show his knowledge, than to help the development of the pupils. Utterances 2, 3, 4 and 5 illustrate how he disregarded opportunities to explore pupils' ideas about electricity, fire and light. Whatever those ideas were, they remained untouched because the student teacher was unable to identify them, or even worse, did not show any sign of being aware of them. He lost several good opportunities to let the pupils expressed their ideas (for example, after utterances 10, 12, 20, 24 and 26), and he was the only one to draw conclusions. He performed the lesson in a traditional way, although the task analysis of the pre-active phase showed a concern with the development of the pupils.

When the lesson was over and the pupils had left, we did an initial analysis of it. The first person to give his views about the lesson was S1. It is interesting to note that his feelings about this teaching experience were very positive. His first impressions about the lesson were that: the lesson was interesting; the pupils' participation had been quite good, although he had to "pull them up" all the time; the aims for the lesson had been reasonably achieved. Nevertheless he recognized that being seated for part of the lesson did not really work; he would not do it again.

His peers' feelings about the lesson were then individually given. In general they were very different from S1's but had many common features. According to them the lesson was boring, the teacher talked too much, the teacher did not provide opportunities to achieve the aims of the lesson, the pupils got bored and disinterested from the middle of the lesson.

S1 did not recognize the weakness of his performance and strongly disagreed with his peers' opinions. Then we watched the videotape and each situation was scrutinized and discussed. After watching his performance S1 recognized that he "really talked too much" and "didn't let pupils express their ideas completely". Once more I got evidence of the important role of videorecording in self-assessment. It is much more convincing to criticize one's own performance than to be told by someone else.

During the analysis and discussion of the lesson, no alternative strategies were advanced. This was done only after the performance by the next student teacher from group B had taken place.
In group B the first lesson was performed by S2. The pupils were 4 boys and 3 girls from the same school as before but from another class in the 8th grade. Their ages ranged between 13 to 14 years old. S2 started her lesson with a brief conversation with the pupils about the topics they were studying in physics and then she quickly got to the topic of the lesson. The first extract illustrates the strategy she used to achieve the aims proposed for the lesson.

"1 T - well .. today we are going to study other electric phenomena .... can you tell me about some phenomena that happen naturally ..

2 B - ... electric discharge in the sky

3 T - .. electric discharge in the sky .. when does it happen?

4 G - in a storm

5 T - do you know anything about it?

6 P5 - (silence)

7 T - well ... have you ever imagined that one of your toys .. a kite ... probably some of you have already made a kite ..

8 P5 - yes ... yes ..

9 T - have you ever imagined that a scientist could have used a toy to discover something?

10 B - I heard something about a Benjamin Franklin that used a kite to explain electric discharge

11 T - yes ... I see you know about it .. (she projected a transparency with a picture representing Franklin's kite experiment) ... here is a picture that represents more or less what he did .. looking at the picture .. you can imagine what he did .. why he did it .... he was a north american physicist in the 18th century .. and what you see over there .. is ..

12 P5 - a kite

13 T - yes .. can you invent a story based on what you see in the picture ? ..

14 G - may be he wanted to see what kind of objects attract the storm

15 T - what kind of objects attract the storm ... so looking at these pictures .. can you see something that ..

16 G - ... I see a piece of metal

17 T - where?

18 G - .. up there ... there is a nail on the kite .. and down there .. there is a key .. a metal key .. it looks like ..

19 B - may be the kite is made of some conducting material and the electricity comes through that material towards the key and then it gives a small spark
20 T - you said .. and very well .. that the kite should have some conducting material ... look at the picture .. you see these dashes ... they mean that it is raining ... when I said that it should have some conducting material .. what do you think helps here to get better conduction?

21 B - ... the water .. it is a good conductor

22 T - .. and what do you mean by that?

23 B - .. well good conductors are materials that make electric conduction easy

24 T - ... so you have already said that metals ... a nail up there and a key down there ...

25 P_s - they are good conductors

26 B - they let energy move through

27 T - energy ..?

28 B - .. well charges

29 T - ..... right .. what did you study about charges in electrostatics?

30 B - bodies can be charged positively or negatively or be neutral .. if they are positively charged they have a deficit of electrons .. they have more protons than electrons ...

31 T - and which of them can move?

32 P_s - the electrons

33 T - .. well so .. you said that conduction will take place here ... where did the electrons come from?

34 B - .. they should be in the clouds .. and then .. there must have been an electric discharge that reached the kite and as there were good conductors the electrons came down".

This extract of the beginning of the lesson gives the flavour of the conversation and reveals the strategy she used in conducting the lesson. Through questioning and prompting she provided opportunities for pupils to develop all the "abilities" which were intended to be developed through this content. All the pupils were stimulated to express and discuss their own ideas with the teacher and each other. Nevertheless there were some situations in which the student teacher did not feel at ease when dealing with some statements made by the pupils, mainly because she had not mastering the subject matter very well. Utterances 26, 27, 28 and 29 give an example of this. As she told me, when discussing the lesson, she did not explore the pupil's utterance 26 because "I wasn't very sure how to handle that".

She used another OHP transparency, representing persons with different attitudes towards thunderstorm phenomena, and pupils were asked to make some criticisms of those attitudes. With this approach pupils were
lead to conclude for themselves the nature of the differences between scientific and non scientific attitudes. They discussed the interpretation of a thunderstorm and they became aware of the necessity of looking at the phenomena around them in the same scientific way as Franklin did in relation to thunderstorms.

Throughout the class the pupils showed great interest and they were encouraged to think, to communicate their thinking to others and discuss their points of view. By the end of the lesson when they were asked to make a synthesis of the lesson they were able to do it.

At the end of the lesson when the pupils had left, $S_2$ was the first to give her perception of her performance. She enjoyed the lesson and found the strategy used very fruitful, leading to the possibility of achieving most of the aims stated. Nevertheless she felt that she needed to work out better ways for exploring the situation. She felt that it had been a very interesting and fruitful experience for her and that after the performance she was more self-confidence.

In contrast to what happened in the analysis of $S_1$'s performance, general comments from her peers were very much in line with $S_2$'s own analysis. The general feeling was that the performance was satisfactorily good. We then watched the tape and some particular aspects were discussed. Some alternative approaches to dealing with them were advanced. These activities were of great interest because they allowed an exchange of views between student teachers, and of course myself, that led to the exploration of imaginative ways of tackling the problems encountered.

2. The second lessons of groups A and B

Commenting on naturalistic work, Rist (1982) notes that, in contrast to studying behaviour and interactions in the artificial and contrived setting of a laboratory where the investigator attempts to control and selectively manipulate the environment, naturalistic research seeks to study people where they are and as they go about their normal routines.

"It is to the study of things as they are that qualitative work addresses itself"  

(Rist, 1982)

Probably the best feedback $S_1$ had of his performance was provided by the pupils who came to his lesson. When they had been initially contacted about the sessions at the university, they had agreed to come three times (once each week, on the same day of the week and at the same hour). Thus, they were supposed to attend the second lesson a week after the first. They did not come. We could
not really find out what had happened, but we could infer the reason. Our interpretation was that they did not enjoy the lesson and did not feel interested enough to come again. It was S1 himself who made this interpretation. This incident, instead of being an undesirable variable that could be rejected in experimental work, was used in this naturalistic study as a variable contributing to the understanding of the phenomenon under study.

In the meantime I talked to the pupils and they excused themselves on the grounds of some misunderstanding about who should go to the second lesson. They agreed to go to the third lesson. Due to this episode student teacher S4, the one who was going to teach the second lesson of the 1th group, had to perform in a more simulated situation. The peers acted as pupils and he performed the lesson to them. This situation was far from everyday work. Its disadvantages were considered in Chapter 3.

2.1 Pre-active phase

The general content chosen for the second lesson of each group was as follows: group A - Ways of producing electric current. The Volta Cell; group B - The Volta Cell. The dry cell.

Tables 3 and 4, overleaf, present the task analyses of the second lesson of groups A and B respectively. As already mentioned, the format of the presentation was my decision. Its organization was based on the students' documents available to me.

The analysis of documents revealed the following points.

a) It is apparent that there had been significant progress both in the exploration of the potentialities of the content to develop some of the aims and in the analysis of the lesson aims and objectives to establish the links between them. This can be seen to be a result of the reflective analysis of the previous piece of teaching. Nevertheless, still aims, which were important and possible to achieve through the content, were not considered. Among these is, for instance, D1 (to be aware of their personal frameworks in 'scientific observation'). Also, through the planning and realization of experiments proposed by both groups, some other aims could have been achieved, depending on the way the activities were conducted.

b) As can be seen from both task analyses, the groups chose different approaches to the lesson. Group A decided on an exposition by the teacher of the experiment of Galvani, followed by questioning related to its interpretation. Next,
| A. Statement of the aims of the lesson in terms of pupils' development of "abilities" | B. Statement of the objectives of the lesson in terms of pupils' learning | C. Analysis of the lesson aims and objectives to establish the link between them | D. Decision on type of:  
a) pupils activities  
b) nature of presentation  
c) nature of feedback to be provided  
d) evaluation |
|---|---|---|---|
| Through the contents of this lesson pupils could be helped to:  

- $A_1$  
- $A_4$  
- $A_6$  
- $C_2$  
- $C_3$  
- $C_5$  
- $C_6$  
- $D_3$  
- $D_4$  
- $D_5$  

| After the lesson pupils should be able to:  

1. explain the phenomenon of lightning flashes  
2. make a resume of Galvani's experiment with frogs  
3. interpret a text about the one-fluid theory of Alexandre Volta  
4. design an experiment in order to produce electric current  
5. implement the experiment designed  
6. define electric current  
7. give examples of other ways of producing electric current | According to this group if pupils are able to:  

1. they get a better understanding of the world and this helps them to develop $D_4$ and $D_5$  
2. they will be helped to develop $C_6$  
3. they will be helped to develop $D_3$ and $C_6$  
4. they will be helped to develop $C_6$ and $A_4$  
5. they will be helped to develop $C_5$  
6. they will be helped to develop $D_3$  
7. they will be helped to develop $D_3$ and $D_4$ through a better understanding of the world around them | a) (i) answering questions about:  

- explanations of the phenomenon of the lightning flash  
- what happened in Galvani's experiment with frogs  
- examples of other ways of producing electric current  

(ii) based on the text about Volta's experiment designing an experiment to produce electric current  

(iii) implementation of the designed experiment  

b) teacher description of Galvani's experiment with frogs  

- presentation of a text about Alexandre Volta  

- presentation of the material necessary for the experiment  

c) (not mentioned) |
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<tr>
<td>a) through answers to teacher's questions</td>
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<td>b) through observation of manipulation of materials</td>
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<tr>
<td>A. Statement of the aims of the lesson in terms of pupils' development of &quot;abilities&quot;</td>
<td>B. Statement of the objectives of the lesson in terms of pupils' learning</td>
<td>C. Analysis of the lesson aims and objectives to establish the link between them</td>
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<td>Through the contents of this lesson pupils could be helped to:</td>
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<tr>
<td>A₂</td>
<td>After the lesson pupils should be able to:</td>
<td>According to this group if pupils are able to:</td>
</tr>
<tr>
<td>A₃</td>
<td>(1) - interpret and summarize a text given by the teacher about episodes concerning the discovery of electric current</td>
<td>- (1) they will be helped to develop A₃ and C₆</td>
</tr>
<tr>
<td>A₅</td>
<td>(2) - design and implement experiments on electric current production</td>
<td>- (2) they will be helped to develop A₅, B₁, C₃ and C₅</td>
</tr>
<tr>
<td>B₁</td>
<td>(3) - describe the Volta cell</td>
<td>- (3) they will be helped to develop C₆ and D₃</td>
</tr>
<tr>
<td>C₃</td>
<td>(4) - identify electrodes and the electrolyte</td>
<td>- (4) they will be helped to develop C₆ and D₃</td>
</tr>
<tr>
<td>C₅</td>
<td>(5) - explain the practical application of the discovery of Volta</td>
<td>- (5) they will be helped to develop A₂, C₆ and D₃</td>
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<td>C₆</td>
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Table 4 (continuation)

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<th>the teacher presents the mate necessary for the experiments a worksheet</th>
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<td></td>
<td>c) the teacher goes from group to group helping, encouraging and stimulating every member of the group to involved in the work</td>
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<td>d) (not mentioned)</td>
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a text on the experiment of Volta was to be presented to pupils and they would be asked about its interpretation. Group B decided for an activity of team-work. The pupils should be arranged in two groups and be presented with two different texts; one group with a text reporting the experiment of Volta and the other with a text reporting the experiment of Galvani. Pupils should then be asked to draw conclusions from the texts.

The approach chosen by group B should, a priori, be more appropriate for the achievement of the aims selected. The nature of presentation decided upon by this group allows for constructivist learning whilst this is more difficult to achieve with the one stated by group A. It can provide opportunities for pupils to use language for sorting out and restructuring their own conceptions. The nature of presentation stated by group A could easily become a "presentation of teacher's science" rather than a "negotiation" of knowledge. It showed a more teacher centred approach than the one stated by group B.

c) While group A still did not mention the nature of feedback to be provided but considered a way of evaluation, group B showed a concern for the feedback to be provided whilst the evaluation was not mentioned. Although group A showed in its task analysis some progress in the analysis of the aims to be developed through the content, its decisions on the type of pupils' activities, the nature of presentation, etc., still shows a strong influence of the traditional approach. This, leads, as a consequence, to less difficulty in identifying ways of evaluation (in the traditional sense), but to greater difficulty in identifying ways of providing feedback. In contrast, the more constructivist approach, followed by group B, presents student teachers with an easier task concerning feedback but, to some extent, a harder task concerning the evaluation.

2.2 Interactive and evaluative phases

i) The lesson performed by S4

The simulation of the lesson performed by S4 did not really work for various reasons.

1) The student teacher S4, was very upset by not having pupils and having to perform the lesson with his peers acting as pupils. On the other hand, this episode revealed the S4's difficulty in coping with unexpected situations, a teaching skill a teacher should develop in order to handle a great variety of classroom situations.

2) S4 showed great difficulty in communicating and expressing his ideas.
In this respect I think it was good that this first experience was confined to his peers and did not involve children, because it provided a learning gradient sufficiently gentle to enable him to be aware of his difficulties. It also showed the lack of previous opportunities that he had had which could have helped him to develop this "ability".

3) His peers raised a lot of questions concerning scientific knowledge to which he was unable to answer. This helped him confront his poor scientific background.

4) He was unable to put into practice what he had stated in the task analysis of the lesson in the pre-active phase.

At least the experience may have helped him to an awareness of his weakness in some important aspects of his "abilities".

ii) The lesson performed by S_6

Before starting the lesson, S_6 divided the pupils into two groups and started the conversation by giving a brief account of the previous lesson. Then she presented each group with a text. The two texts were different, one reporting the experiment of Galvani with frogs and the other reporting the discovery of the Volta cell. She gave each group a few minutes to read and interpret the text and then asked one part of the group to tell the others what Galvani did in his experiment, what his conclusions were and what they thought about it. If well developed this activity could have been a very good way to develop pupils' capacities of team-work, critical-mindedness and the skill of communication. However, she did not make much of the opportunity because she neither gave enough time for the pupils in each group to exchange their views about the text nor did she stimulate this exchange. One boy summed up the text but she was unable to explore the situation.

The same happened with the other group, although with this group it worked a little better.

An extract of this part of the lesson can give a flavour of her performance.

Five to six minutes after having given the texts she asked the first group (3 girls and a boy).

"1 T - is anyone of you able to tell us what was the story about Galvani?"

"2 B - the main part?"
3 T - yes .. I want that you tell me what he did ... what conclusions did he draw from his experience ... and you must speak loudly so the other group can listen .. because they don't have that text ... right?

4 B - they were doing experiments and they have got frogs

5 T - who was doing experiments?

6 B - Galvani and his assistant ... and the assistant, by chance, touched the muscles of the frog with pincers and they were violently convulsed ... then ... after some observations he concluded that ... animals had energy..

7 T - energy?...

8 B - .... a characteristic electricity

9 G - after repeated many times the same experiment he drew that conclusion

10 T - was that what you read in the text?

11 Ps - yes it was

12 G - they repeated the experiments many times and then they drew the conclusions

13 T - and ... do you think that ... with that experiment the conclusions drawn by Galvani could be right?

14 Ps - ..... (silence)

15 G - yes they could .. but he should be sure of it .. and tried again to see if it was by chance ... or ...

16 T - yeah "

(She finished this without exploring it and turned to the other group)

"17 T - ... and .. about Volta's story .. who wants to tell us what happened ..

18 B - ... Volta put a series of plates

19 B - .. of different metals

20 Bs - and a piece of wet cloth between the plates

21 B - and he was making a pile with plate, cloth, plate ..

22 T - and what conclusion did he draw from it?

23 B - he drew the conclusion that after piling up a series of plates he could get a small electric shock .. and then he experimented .. and ... it gave electricity

24 T - thus Volta doing this was testing if electricity was due to animals or not ... was it?

25 B - yes and he proved that Galvani was wrong

26 T - ... yes ... and if we want to know if really it is like that ... if we want to make the same experiment that Volta did what should we do?

27 B - we should use the same method of Volta .. using different metals and some acid..

28 T - different metals and acid ... and anything more?
and we need a lamp or something like that to see if there is...

something that can detect electric current

... if Volta didn't make a pile with plates ... if he used only two different materials ... and a cloth wet by acid without being piled ... do you think that it wouldn't work?

I don't think so ... because they weren't in touch

they weren't in touch ... what do you mean?

if they were in touch it should work

were in touch ... what should be in touch?

the plates .. if they were in touch with the acid and with the other plate..

if I understand .... what you are saying is that ... if there was one plate in touch with the acid and then another plate of different metal it should work

in that way the electric current would be weaker

.. oh! yes ... so it should also work ... well tell me .... then what do we need to make an experiment similar to Volta's one?

er ... different materials
different metals

... acid .. a cloth wetted in acid ... and then .. piled them ... first ...

.. zinc for example then the cloth with acid and then
copper ... and ..

and if we want a stronger current we ....

we would put more .. right ... and if ... we put equal plates ... for instance you talked of zinc and cooper .. but if we try zinc and zinc

it doesn't work

how do you know that? ... suppose we are 200 years ago at the time where Volta lived ... he didn't know if two equal metals would work he had to try it first ... so what should we do?

we need to try all the metals .. to see which ones works better

yes ... that's for the metals ... and what about the solutions .... Volta used acid ... do you think it only works with acid?

he used various solutions ...

but the text says that Volta used acid

because it worked only with acids ..

... but if we can be sure that it works only with acid ... what should we do?

to experiment .... with acid and other solutions ...

.. but we must keep the same metals ...
One of the aims stated for the lesson was the development of the skill of communicating (C_Q). The analysis of this small extract, shows the student teacher's concern to achieve this through questioning and cueing, helping the pupils to perceive and complete their speeches. Utterances 5, 7, 33, 35 and 37 illustrate this point. The lesson continued with each group working on the activity. She approached each group and helped them. The three boys in group 2 worked very well together. There was not a leader. However, in the other group the boy took the leadership and the student teacher did not pay attention to that.

This activity is a good example of a simple experiment and here the word "simple" stands for a number of attributes:

(i) it is an experiment of a short duration, i.e., less than one class period. It allows the pupils to reach some conclusions during the class where the experiment is done, the data taken and analysed in the same class. It helps thus the development of the scientific attitudes of efficiency;

(ii) the apparatus and its manipulation do not pose unduly high demands on manual dexterity and the analysis of the results is also reasonably direct. It thus helps the development of some scientific process skills;

(iii) finally, in school systems where budgets for equipment are a problem, the cost of the apparatus has to be taken into account. The material for this experiment is very unsophisticated: some spare white glass bottles cut in half to make the glass jar, small plates of various metals, copper, zinc, lead, aluminum, a lemon, some solutions, water with sulfuric acid, glycerine, water and salt and some detector of current as for instance a small lamp 3.5 V, 0.2 A.

When the pupils finished the activity they were asked to give their results and draw their conclusions. The student teacher recorded them on the blackboard and she continued the lesson like this:

"1 T - well ... after this ... looking at the blackboard what conclusions can we draw?"
2 B - there is electric current when we have 2 plates of different metals
3 T - only that?
4 B - no ... we need acids and water
5 T - why? ... you have seen that with glycerine it didn't work ... so .. what must be the features of the solutions in order to get electric current
6 B - the acid must have something ... that can supply electric energy
7 B - ... and it must be in connection with different metals
8 T - ... to supply electric energy?
9 B - no ... I think ... there must be ... something that makes the connections between the two plates in order to complete the circuit and it can only be made through the solution
10 T - exactly ... but with two different plates in paraffin ... we didn't get current
11 B - .. because it isn't conducting
12 T - so what is the other condition?
13 G - the solution must be conducting
14 T - that's right ... now returning to the texts ... who was right Volta or Galvani?
15 B - Volta
16 T - yes Volta
17 B - although the conclusions drawn by Volta could only have been possible due to the experiments of Galvani ... if Galvani hadn't made those experiments ...
18 T - exactly ... the experiments done by Galvani had a great importance on the conclusion drawn by Volta".

This small extract illustrates the strategies used by Sg in her attempt to achieve some of the aims proposed for the lesson. Most of her interaction with pupils was in the form of questions aimed at leading pupils to draw the conclusions by themselves, (utterances 1, 3, 5, 10 and 12). In the last part of the lesson she gave information about the scientific names of the different elements of a simple cell and talked about the dry cell. Showing a battery cut in half, she asked pupils to identify the different constituents, through a comparison between the Volta cell and the dry cell. Through questioning she tried to make the link between the previous lesson, this lesson and everyday life. Thus she could evaluate to what extent the strategy used was suitable to achieve the objectives proposed.

On this occasion the post-mortem on the lesson was conducted differently. After watching the tape the student teachers were requested to write a short essay giving an analysis of the lesson. The purpose of this activity was to provide me with another way to evaluate the student teachers' abilities, as
for instance the skill of accurate observation, their capacity of critical analysis and their capacity to creatively plan other strategies to achieve the aims proposed for the lesson.

According to Sg's analysis, Cg (communicating) was the more developed skill, although, as expected, more in some pupils than in others. The capacity of work in a team was developed satisfactorily in the group of 3 boys, but not so well in the other group where the boy took the leadership and the teacher did not intervene. The same happening in the skill of manipulation. The skills of planning and designing experiments were not really developed because the teacher provided the worksheet with the table already constructed for recording data. According to her this could only be achieved if pupils were asked to make their own design and recordings. Also the development of critical-mindedness was not fully achieved because there was not exchange of ideas between the parts of the group and only the pupils who had the opportunity to interpret and expound the text to the other group could have developed this capacity. Sg also pointed out that she was unable to evaluate if the development of the skill of accurate observation was achieved because she did not pay attention to it during the lesson. According to her, the development of inquisitive-mindedness was achieved in almost all pupils. The two exceptions were the two girls who did not show much interest and took a very passive attitude. After analysing the lesson through the tape, Sg noticed that she did not pay much attention to them. She finished her analysis by commenting that if she were to teach the same lesson again she would not change the strategy very much, but she would stimulate the exchange of ideas between the parts of each group during the analysis of the texts; she would intervene during the experiments making sure that there was a balanced participation of each member of each group; and she would promote a discussion on planning the experiment and on recording the data before giving the pupils the worksheet.

The general comments made by her peers were very positive about the strategies used during the lesson. The main objections made were that all the aims proposed for the lesson could have been more achieved if the strategies had been explored better and if the teacher had been more relaxed.

In a next session we discussed the analysis made by each student teacher. This last activity enriched the feedback to a very high level. The conversation was audiorecorded and the transcription of some extracts can give a flavour of it. In this transcription T stands for myself as teacher responsible for the course.

"T - you stated some aims for this lesson ... such as developing capacities, skills ... etc. ... what do you think about the time span over which your pupils should achieve the aims which you set for them?"
S_2 - not in a lesson ...
S_5 - no .. not at all
S_3 - only by the end of a year ... we could achieve the aims ...

S_1 - I think these are small contributions ... these aims are long term aims .. but
we only can achieve them if in each lesson we are going to develop them ...
perhaps they will be fully achieved by the end of ...
I don't know ...
perhaps ...
through life

S_2 - .. but by the end of a year ...
we can evaluate if some have been achieved

S_8 - (all speaking at the same time)

S_3 - ... when a teacher at the beginning of the year proposes these aims ...
I think he tries to see them achieved by the end of the year ...

S_5 - .. by steps ...

S_4 - .. I think they must be evaluated by the end of a period ...
because if you only evaluate them by the end of the year ...
if you see that you haven't achieved them ...
you don't have time to change anything

S_6 - .. what's important is to contribute, in each lesson, to the development of
those capacities and attitudes ..... 

T - well S_5 proposed to develop critical-mindedness in pupils through the activity
of reading a text and reporting it to the other group ...
does this really mean developing critical-mindedness? What do you think about it?

S_2 - .. if they were interpreting it

S_1 - .... it depends

S_5 - .. the way it occurred in the lesson ...
perhaps only the ones who expounded
have understood it ...
and I should have prevented it by allowing them to discuss
it between them ...
this would help them to develop critical-mindedness .. 

T - ... but what do you mean by critical-mindedness S_5?

S_5 - it is the ability one may have to criticize what one has read or said

T - .. but to criticize in what way?

S_5 - .... well it is ...
saying that this is well or wrong for this or that reason

S_2 - .... not accepting things without questioning them

S_1 - therefore ...
to make a personal interpretation of what is read ...
and not only to expound ...
so a text can be ...
let's say ...
expounded by one pupils
to the others ...
without a critical mind ....
it may just be a verbal transcription
of what was read ...

S_2 - .... I think in this lesson the interpretation of the text wasn't requested ...
pupils were only asked to sum it up

S_5 - .. and so ...
critical-mindedness wasn't developed

T - thus do you think that just by the fact of interpreting the text the pupils
will develop critical-mindedness?
S1 - ... I think ... that it would help to develop .... critical thinking .... if for instance .... after having interpreted the two texts an opportunity for a discussion was provided ... and pupils were asked about which one of the scientists was right and why ... and there ... I believe ... that would help the development of a critical mind .... because it was forcing the pupil to develop ways of criticizing one text and another ... and that I think ... that would help the development of critical-mindedness

S5 - ... for me ... if I give some parameters for the interpretation ... this interpretation can develop critical-mindedness

S1 - but what parameters ..?

S2 - ... well if I say ... interpret the text justifying it ... criticizing it ... say if you agree or not ...

S1 - ah ... thus .. there are already two activities ... that is different ...

S3 - ... (all speaking)

S5 - ... I think ... an interpretation may very well be a critical interpretation ...

S1 - ... but there it isn't only interpretation ... it is interpretation and critical analysis ... to interpret is to understand the message

S6 - .... I think kids understood the message although they didn't criticize it ...

S1 - ... and it is important to stimulate ... or to develop in pupils this critical thinking ... it is important in order to help them to get solutions for their everyday problems ... if through physics I stimulate this thinking I'm opening their horizons ... changing certain mental frameworks which will allow them to find proper ways to overcome them, when confronted with real problems ...

T - well ... it is very important for you to perceive what you have to do in order to develop in pupils critical-mindedness ... but first you must understand very well what is meant by that ... and I was a bit surprised when you (S6) said that when pupils were interpreting the text they were developing critical thinking ...

S5 - ... I agree with you ... that wouldn't help

T - in your analysis (S1) ... you said that the aim most achieved was the development of the skill of manipulation ... neither of the others talked about this although one of the aims of the lesson was precisely this one ...

S1 - ... when I made the analysis ... when comparing the aims proposed for the lesson and the ones that I find were in some way achieved in the lesson ... it seemed to me that ... in a qualitative way .... the skill of manipulation ... the psychomotor skills .... would have been the most achieved ...

T - why?

S1 - because ... pupils were provided with the material ... they could manipulate that material ... they could do things with that material ... including ... what I call psychomotor skills ... a better reflex at the brain level of certain things ... for instance ... one group worked with an amperemeter to detect electric current ... pupils weren't taught ... how to connect ... the amperemeter in the circuit ... I agreed with that ... and that made the pupils find a practical way to do it

S5 - ... but it would be necessary to explore why they did it in that way
The conversation continued like that and it was very fruitful for clearing up ideas and for a search of better strategies to achieve the aims purposed. It can shown from the extract of the transcription that, through the activity of reflective analysis of the performance of the lessons, student teachers were getting a deeper understanding of the problems that could be encountered when approaching teaching in a constructivist way. It also helped them to elaborate new strategies to cope with them and to acquire a new perspective towards the "the profession of teaching".

3. Third lessons of groups A and B

The third lesson of each group took place a week later. At this time the same group of 5 boys who came for the first lesson of group A came again for the 3rd lesson of this group. The other pupils who came for the 1st and 2nd lessons of group B, brought with them two peers: one boy and one girl. This, per se, could be seen as an indication that they were enjoying the experience. Talking with them, when waiting outside the room, I confirmed this. All of them commented that they were enjoying the classes and that the way classes were running "it's quite different from what we are used to".

Due to technical problems the third lesson of group B could not be videorecorded, but was audiorecorded.

3.1 Pre-active phase

The general content chosen for the third lesson by each group was the following:

- **group A** - Electric current. It's conduction through metals. Electric current intensity;
- **group B** - Introduction to the topic "Electric current intensity".

By this time group A was still not functioning as a group. The reasons were various. One can be seen as derived from the student teachers heavy timetable. This stage of the course came at the same time as a period of tests and assignments for other courses. Thus they found some difficulties in finding time to work together. Notwithstanding, group B was able to overcome this difficulty. Another, and more probable reason, may be due to the heterogeneousness of the group, as already mentioned. The levels of competence of the individual members were
too different and this may have brought about some difficulties for the team-work. As a consequence of these facts the planning and the task analyses of the 3rd lesson of this group was made by S3 alone.

Tables 5 and 6, overleaf, present the task analysis of the third lesson of group A and B respectively.

The analysis of both documents revealed the following points.

a) The task analysis of group A, done by S3 alone, as mentioned above, was very incomplete and showed a great lack of reflection on the potentialities of the content concerning the development of "abilities" in pupils. When doing this activity, S3 kept asking me how she would do this and that, showing a total dependence on other's opinions. I gave her some suggestions, but she was unable to put them into practice. Taking a constructivist approach to the teaching of this course I should not inform anybody how to do things, how to plan, how to present, etc. My role was to provide opportunities for each one to construct her/his own way of doing, her/his own style of teaching through a process of planning, acting, observing and reflecting with the help of the feedback provided by peers, teacher and her/his own personal assessment.

b) The task analysis of group B showed that the student teachers of this group got ideas from the activity they had carried out and were able to adopt and put them into practice. The link between aims and objectives for the lesson was well made but the potentialities of the lesson content to develop other aims was poorly explored. The lesson was planned as a pupils-centered lesson, suggesting a constructivist approach to teaching. Although not explicitly mentioned, ways of evaluation were suggested through pupils' activities when answering questions posed by the teacher.

3.2 Interactive and evaluative phases

The lesson performed by S3

The performance of S3 was very weak. Maybe the weakest point was her faulty scientific preparation, her lack of understanding the basic principles of physics. If a solid basis of scientific knowledge is needed for teaching in a traditional approach to a high level a success, this need is still more essential for teaching in a constructivist approach. In her/his role as facilitator of the students development as scientists, the teacher should act as an adversary in the sense of a Socratic tutor and as a model of scientific thinking. In her/his adversarial role directed at the student's ideas (not at the student as a person) the teacher
### TABLE 5 - TASK ANALYSIS OF THE PRE-ACTIVE PHASE; 3rd LESSON. GROUP A

| A. Statement of the aims of the lesson in terms of pupils' development of "abilities" | B. Statement of the objectives of the lesson in terms of pupils' learning | C. Analysis of the lesson aims and objectives to establish the link between them | D. Decision on type of:  
  a) pupils activities  
  b) nature of presentation  
  c) nature of feedback to be provided  
  d) evaluation |
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<td>Through the contents of this lesson pupils could be helped to:</td>
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<tr>
<td>A2</td>
<td>After the lesson pupils should be able to:</td>
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<tr>
<td>A4</td>
<td>(1) - relate the metal structure to the flow of electric current</td>
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<tr>
<td>C6</td>
<td>(2) - make a distinction between a.c. and d.c. currents</td>
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<tr>
<td>D4</td>
<td>(3) - define current intensity</td>
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<tr>
<td>D5</td>
<td>(4) - give examples of apparatus to observe the flow of electric current</td>
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<td></td>
<td>(5) - identify the Ampere as the electric current's unit and the Coulomb as the unit of electric charge</td>
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<tr>
<td>(not mentioned)</td>
<td>a) pupils answer teacher's questions</td>
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<tr>
<td>(not mentioned)</td>
<td>b) (not mentioned)</td>
<td></td>
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<td>c) transparencies</td>
<td>d) (not mentioned)</td>
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### TABLE 6 - TASK ANALYSIS OF THE PRE-ACTIVE PHASE; 3rd LESSON. GROUP B

| A. Statement of the aims of the lesson in terms of pupils' development of "abilities" | B. Statement of the objectives of the lesson in terms of pupils' learning | C. Analysis of the lesson aims and objectives to establish the link between them | D. Decision on type of:  
a) pupils activities  
b) nature of presentation  
c) nature of feedback to be prov  
d) evaluation |
|---|---|---|---|
| Through the contents of this lesson pupils could be helped to:  
A₂  
A₅  
B₁  
C₆  | After the lesson pupils should be able to:  
(1) - explain in their own words, the phenomena that occur in a cell  
(2) - explain in their own words, the functioning of the lead-acid accumulator  
(3) - make simple electric circuits and explain what happens in them | According to this group if pupils are able to:  
- (1) they will be helped to develop C₆ and B₁  
- (2) they will be helped to develop C₆ and B₁  
- (3) they will be helped to develop A₂ and A₅ | a) pupils will be divided in three groups and each group will construct a simple cell  
observe what happens in the cell and answer questions posed by the teacher  
make a lead-acid accumulator and explain its functioning  
realize an exploratory activity with cells, lamps and wires  
b) the lesson will be based on pupil activities  
c) the teacher goes from group to group stimulating, appraising, helping and encouraging  
d) (not mentioned) |
relentlessly confronts the students with the problems arising from their process of conceptual change. To accomplish this role teachers need to have confidence in a solid scientific background that allows them to help students to change their intuitive ideas to more scientific ones. Also as a model of scientific thought, the teachers should insist on consistency among beliefs and between theory and empirical evidence. They should be sceptical of excessive "ad hocness" in theories, and should critically analyse empirical results in order to determine whether discrepancies between results may be in "reasonable agreement" with theory. In order to accomplish this, teachers should have a solid knowledge of the theories and a solid understanding of the basic concepts involved in the theories. All this implies that if the teacher lacks confidence in her/his capacity of mastering the subject matter it will be easier for her/his taking the role of a presenter of information (most of the time presented in a textbook), an explainer of solutions to problems (most of the time standard problems), a demonstrator of principles, a provider of laboratory exercises and a tester for recalling of facts and ability to apply knowledge to problems.

The student teacher $S_3$ seemed to feel very insecure when giving her lesson. One sign of this was her frequent glances at me or at her peers, appearing to be an attempt to ask for some help. When the lesson was finished she felt so frustrated about her performance that she did not wish the analysis of her lesson to be done straightaway. We respected her feelings and 3 days later we watched the tape and the student teachers were requested to write an essay on the analysis of the lesson. In general the comments made by her peers revealed a very accurate criticism and they all focused on the critical points of the lesson and presented alternative strategies to achieve the aims proposed. In her analysis, $S_3$ recognized that her performance was very weak but the points picked up by her were not especially relevant. When discussing what happened during the lesson, she was encouraged to analyse the problems which had arisen and was helped to explore imaginative ways of tackling them.

ii) The lesson performed by $S_5$

The third lesson of this group was performed by $S_5$. She started the lesson asking for a brief revision of the second lesson, thus making the link between the two lessons. Before dividing the pupils into groups she introduced the topic of the lesson in the following way:

"I T - so you say that in the last lesson you saw ways to produce electric current .... and based on those experiments that you did .... could you tell me what is needed to produce electric current?"
2 G - .... a conducting solution and two different metals

3 T - well ... did you observe what happened inside the solution?

4 P_s - ... (not audible)

5 T - well ... I have got here a simple cell as you see .. a jar with an acid solution ... two plates one of copper ... and another of zinc ... when I put these two plates into the solution what do you expect that will happen?

6 B - ... the lamp will light up

7 T - why?

8 G - because there will be a current

9 T - ... and in the solution what do you think will happen?

10 B - ... I think the solution will contain less ions

11 T - what? .... what did you observe when you did the experiment?

12 P_s - .... (silence)

13 T - .. well you didn't pay attention to that ... but I'm going to put the plates into the solution and you are going to observe very carefully what is going to happen in the solution

   (She connected the plates in series with a small lamp and put the plates into the solution contained in a transparent glass jar. The lamp lighted up)

14 P_s - (laughs) ... the lamp is lighting up

15 T - and inside the solution what do you observe?

16 G - there are bubbles of gas near the plates

17 B - less near one of the plates than near the other

18 T - yes .. near the zinc plate there is a stronger reaction ... and look what happened to the lamp?

19 B - the lamp went out

20 T - (removing the plates from the solution)

   you can see that this plate looks dirtier than the other ....

   (she could explore this situation but she did not)

   well .. so tell me why did the bulb light up when connected across the plates?

21 G - because there was a current flow through it

22 T - ... and what is needed for that?

23 B - ... it is needed a conductor ... and the two plates should be at different potentials

24 T - ... yes .. and tell me when the plates are out of the solution are they at different potentials?

25 B - outside no .. but in the solution they must be
26 T - so something must happen inside ... to get a potential difference between the zinc and the copper

With the aid of a transparency she tried to lead pupils to understand what happens in the solution, but she did not succeed very well.

27 T - you can see here the copper and the zinc plates ... do you understand these symbols .. of positive ions and of electrons?

28 Ps - (not audible)

29 T - in a metal ...

30 B - there are free electrons

31 T - what do you mean by that?

32 B - electrons that move easily through the metal

33 T - yes ... the ones that are not very stuck to the atoms ... then ......"

Obviously it was not easy for pupils to discover by themselves what happens in the solution. She had to give them the information although she was always asking for pupils' participation. Then she checked whether or not the pupils had understood that phenomenon. She asked one pupil to go the blackboard to explain in his own words with the help of his peers what happens.

An extract of this episode shows how it worked.

"1 B - (after having made a drawing of a simple cell)
    .. well here we have the two plates .. one of zinc and another of copper

2 T - well ... and when you put them into the solution what happens?

3 B - the zinc gives positive ions that go to the solution and ... it is left with a different potential from the copper .... and it gives electrons to the copper plate ... and the electrons that the copper plate has in excess are taken off to the solution ..

4 T - and thus the lamp goes out

5 B - yes

6 T - and if we wish that the lamp stays lighted up ... what is necessary?

7 B - .......

8 T - who can help?

9 G - .... it is necessary to supply more electrons to the zinc plate

10 T - and how can we do that?

11 Ps - (not audible)

12 T - do you find that this solves the problem?

13 B - it solves just for some time
Pupils were not able to explain what happens because they did not understand and she could not put it in another way. The lesson continued

14 T - ... do you know other ways to produce electric current?
15 B - ... a generator ....
16 T - look in a car ... what makes the lights to go up?
17 B - I never thought about it
18 G - neither did I
19 T - (showing a car battery) have you ever seen a thing like this?
20 P_s - it's a car battery
21 T - do you know how is it inside?
22 B - it has water ... sometimes it is needed to pour into it distilled water
23 T - do you know why?
24 G - it must be a conducting substance
25 G - to make the same effect of the solution
26 T - but distilled water isn't a good conductor ...
27 B - ... but perhaps it doesn't damage the battery
28 B - ... or ... may be ... in order that the metals ....
29 T - but do you think ... that the solution inside the battery is distilled water?
30 P_s - ........ (silence)
31 T - ... it's an acid also ... have you ever heard about charging and discharging batteries
32 P_s - yes
33 T - for instance .... when a car doesn't start ...
34 B - may be it has the battery discharged
35 T - yes .. and it needs to be charged .. and have you ever imagined how is that done ?
36 B - energy must be supplied to the battery
37 T - yes .. and .. then energy is accumulated into the battery
38 B - yes .. it is like the cell ... but only it must be charged
39 T - well it is not really like a cell
40 B - the function is also the samething
41 T - yes .. to produce electric current ... put in other way ... first the battery must be charged ... and it accumulates energy ... then .. when in order to make the motor work ...
it needs energy ... the battery supplies energy

yes ... that's right ... well a battery consists of a series of lead-acid accumulators ....

(she shows two plates of lead and a glass jar with an acid solution)

what will happen if I put them into the solution ... is there any electric current?

no because they are at the same potential

well ... so what should I do in order to charge the battery? ... as you said ... there isn't production of electric current ... if we connect the two plates with a wire and a lamp .... the lamp doesn't go up ... what shall we do in order to get production of electric current?

... we must supply energy to it

... we must charge the battery

... very well ... we need to charge the battery ... so let's do it ... we can do it through a cell ...

(she connects a dry cell between the two plates)

... let's see what happens ... observe very carefully ... you see here the negative pole of the cell ... and here the positive ... what is happening to the lead plate that is connected to the negative pole?

I see some bubbles coming up

and the other is getting dark

.... (all speaking at same time)

the cell is charging ... this piece of lead ... and the positive ions of lead go to the solution

... at the two plates?

no ... just at that ... there is a potential difference ...

well but I saw that when the two plates were into the solution there wasn't a potential difference ... they would not produce electric current

but now ... there is ... because now there are two different poles ... this plate is now accumulating energy ...

only this plate?...

both ... but different energies ... with different signals ...

two different reactions ... you see what here there are more gas bubbles ... and that one is getting darker ... is everyone seeing this?.... and now what should happen if I connect a lamp ..

now it will light up ... there is now a potential difference between the plates ... now it works ..... that's it ..... it lights up .. very bright .. now is getting less bright ..... and it goes out ...

why?
63 B - it is discharged again ... it needs to be charged ..
64 T - yes ... and this is what happens in a car battery
65 B - but ... it lasts longer ....
66 T - yes because in a car battery there are many plates inside ... if you weigh it you will see how heavy it is .... did you understand what was going on here?.....
67 P₃ - yes ...
68 T - ... well then you saw two different ways of producing electric current .... through chemical reactions .. you will understand it better after having studied chemistry ..... now we are going to do an activity with these materials
   (she gave each pupil a small light bulb a dry cell and a wire)
   can you light up that bulb with the cell and a wire?

After this moment all the pupils were involved in the activity. The student teacher gave them more bulbs, more dry cells, holders for bulbs, wires and, through asking for predictions, questioning and prompting she involved all the pupils in this very fruitfull activity. The pupils were requested to predict, to test their predictions, to imagine situations, to explain, to explicit their personal frameworks, to refute their own statements, to manipulate materials, to communicate between each other and with the student teacher. This activity took about 30 minutes. The pupils were very active and very interested.

The student teacher got the pupils to work in two groups. She went to each group, intervening only to stimulate the activity and introduce the scientific terminology and definitions when necessary, as for example resistance, current intensity, etc.. Once in a while she gave them some challenge such as, for instance: "can you make a circuit in which when one lamp is disconnected the others stay lightned up?". In the two groups the problem was solved by two different ways and a discussion about it took place between them.

When the student teacher decided that the activity should be ended (the pupils were so much interested that they would not end it by themselves), she tried to pass from the macroscopic approach to the microscopic. She used a transparency to help her in this task and through questioning she conducted the discussion. But by this time the pupils were already a bit tired and she decided to postpone this subject to the next class.

The analysis of the lesson was done immediately after the performance when the pupils had left. S₅ was the first to analyse her own performance. In general she enjoyed the lesson, but if she were to teach the same lesson again she felt that she would change the order of the activities. She would start the lesson with
the activity with bulbs, cells and wires where the pupils, working in groups, could get a better acquaintance with the phenomena that go on in an electric circuit and from there arrive to the understanding of the role of the solution in a simple cell. Through the main activity she realized that most of the pupils had "peculiar" frameworks about electric flow in a circuit and that it would be better if they had a prior opportunity to test them in previous experiences. She then realized that through this content she could help students to be aware of their intuitive ideas and confront them.

The comments of her peers were very positive. They got a good awareness of the importance of the pupils personal frameworks from these observations, as for instance the existence of the notion of two different energies (e.g. utterance 59, to which S5 did not pay any attention), the indifferenciation between concepts like energy, charge, electric flow and voltage. As they were watching their peer's performance carefully they were able to detect some problems which arose in the team-work. This enabled them to give feedback to their colleague as well as providing solutions to overcome those problems and to improve her next performance.

Almost all of them pointed out that S5 was content with a faint "yes" as a pupil's reply to her sort of rhetorical question "Did you understand?". In most of the other lessons already performed, that situation had occurred, but only now were the student teachers aware of it. It revealed an improvement in their abilities to observe, to criticize, to perceive what should be done in order to teach for understanding.

They also pointed out that what is going on in the solution, the reactions that take place in it, are too abstract for pupils to understand at this age. Other ways of tackling this particular problem should be found in order to clarify the role of the solution. We discussed some solutions that could only to be tested in their teaching practice in the next year.

Throughout the implementation of the trial stage all the student teachers found it difficult to evaluate the effects of their teaching on pupils' learning or non-learning. Due to the constraints of the situation (the short time of contact with pupils, with just one lesson performed by each student teacher) the assessment of pupils' learning is a difficult task.

Besides a continuous assessment that should be made in real classroom life, the student teacher should be able to design a test to evaluate if the aims stated were achieved. With this purpose both groups were asked to construct a test related to the topic "Electric current", to assess pupils' learning and develop-
ing of abilities. Both groups found great difficulty in constructing this kind of test. The traditional way of teaching physics implies a type of test very different from the one required here. Both tests, once constructed, were discussed by both groups and this provided an opportunity for a fruitful discussion. They became aware of the necessity for consistency between the aims proposed and the means for assessing them.

4. The lessons of the second cycle of the spiral of the action research process

The learning of a skill is a never-ending process and I think the learning of teaching skills is no exception to this rule. It is also a very slow process involving various steps, as for instance:

1. to perceive what to do in order to develop the capacity of developing in pupils the abilities stated at the beginning of the course;
2. to prepare and perform teaching activities;
3. to assess teaching activities in the pre-active, interactive and evaluative phases, as a means to improve the next teaching experience;
4. to prepare and perform teaching activities integrating solutions for improvement on the basis of previous assessment;
5. to receive feedback during the whole process of the development of the teaching skills;
6. to learn the teaching skills to teach according to the model of teaching chosen;
7. to analyse the problems and explore imaginative ways of tackling them.

In the second phase of the action research process another cycle of the spiral including, planning, acting, observing and reflecting took place. During this phase each student teacher worked individually when preparing the lesson that he/she would perform. Due to time constraints only the teaching activities of three student teachers $S_1$, $S_3$ and $S_5$ were analysed in detail in this second cycle. During the course on "Physics Didactics" student teachers must have teaching experiences with other grades, namely $10^{th}$ and $11^{th}$ grades. Student teachers $S_3$, $S_4$ and $S_5$ performed similar activities but involving content from these latter grades which were beyond the scope of this study. $S_1$, $S_3$ and $S_6$ worked with $10^{th}$ and $11^{th}$ grades during the span of time in which the first loop of action research concerning the $8^{th}$ and $9^{th}$ grade took place.
The purpose of this second cycle was to provide opportunities to student teachers to make improved decisions about the best way to teach according to the model they were trying to implement. Throughout this cycle, the student teachers prepared and performed teaching activities integrating solutions for improvement on the basis of the experiences, feedback, analyses and assessment of the first cycle.

The 9th grade topic selected for this second loop of the action research was "Light and its properties". It appears in the list of topics to be taught at the 9th grade in the following way: "Reflection and refraction of light. Laws of reflection and refraction".

As already pointed out in the preliminary study, (Chapter 2), the current physics curriculum at secondary school level is nothing but a list of topics to be taught. Teachers are confronted with this list whose paucity in detail could support good teaching and learning processes if teachers were aware of the problems involved in the learning of the topic. This situation could give teachers the opportunity to think of some important questions related to a topic and to find solutions to them. For instance:

(i) what are the children's intuitive ideas related to this concept, 'light'?  
(ii) from the results of question (1) what are the best strategies to help conceptual change? And what are the important topics to be taught?  
(iii) at what level should these topics to be taught according to the age, development and interest of the learners?  
(iv) what is important for normal citizens to understand about this topic?

All these questions require a high level of thought and investigation, either individually or in groups of teachers. Instead of this, the current practice is that the one who chooses what shall be taught, how it should be taught and to what level it shall be taught is the textbook writer. There isn't a great choice in Portuguese physics textbooks. Most of them are written by groups of secondary teachers, much of the time following a traditional structure, without taking into account the recent findings of research on science education. Usually teachers stick to the books, the easy way to handle the problem, without any concern about whom they are going to teach.

Before preparing their lessons on this subject matter the student teachers were individually presented with an instrument to help them to be aware of their personal frameworks on this topic. The instrument was constructed on the basis of studies made by Anderson and Kärqvist (1981), Tiberghien et al. (1977)
and Stead and Osborne (1977). As these studies focus on students with ages ranged between 10 and 16, some other questions related to a higher level of knowledge were introduced. This instrument is presented in Appendix 5.

A group discussion of the outcomes of this activity took place after each student teacher had completed it. Similarly to what happened after the activity with bulbs, batteries and wires, the student teachers had an opportunity to become aware of their personal and peers' frameworks related to this new topic. The outcomes showed that, despite their long schooling, some of the student teachers still didn't use the model "light exists and propagates in space" to explain optical phenomena. Some were also unable to use the concept of refraction in explaining more unusual situations. The impact that these findings had on the student teachers was to make them feel the necessities of revising their own conceptions and of designing a similar instrument to apply to a group of 9th grade pupils. The latter purpose was to gather information concerning the pupils' intuitive ideas, the selection of topics to be taught, the strategy to be used and what "abilities" could be developed through this subject matter.

To help the student teachers to get a grasp on the historical evolution of the interpretation of optical phenomena, and to compare the pupils' conceptions of these phenomena with the historical background, I provided them with a historical document based on Ronchi's "The Nature of Light", (Ronchi, 1970). Through this survey of the history of ideas on light, the student teachers could become aware of the difficulties mankind has had in arriving at the model of light used in geometrical optics. It took a long time for humanity to realize that light is something that exists in space, separate from sources and effects and to capable of explaining optical phenomena. The document helped the student teachers to appreciate that they can therefore hardly expect the pupils to succeed in reaching this fundamental understanding through their day-to-day experiences before the study of the optics units at school. They were also helped to be aware of the role of everyday language in the building of children's alternative conceptions about light. Usually the word light is not used to denote physical light, which is neither seen or felt. Instead, what we call light in colloquial speech is our experience of light, namely evidence of the interaction between physical light and our visual system, including the brain. The everyday concept of light is, accordingly, of a psychological nature. "The light is bad in here", "it's getting lighter", "it's light", are examples of how then the word is used in this sense. The word light may also denote a source of light, as in the everyday expression "switch on the light". It is, consequently, hardly surprising to find children who identify light with sources of light. But it must be surprising to find adults, after being taught physics, with
the same ideas.

As far as vision is concerned, there are many expressions indicating that eyes are active and send out something. For instance: "the man gave him a hard stare", "it looks quite warm", "her look makes us melt", "his look killed me", etc.. Thus, it is not surprising that children explain vision through rays that come from eyes and touch objects thus allowing vision.

Aware of this problem, the students teachers, helped by me, developed a test to be administered to the classroom population. The test was based on some questions related either to drawings or to very simple experiments performed in front of each pupil. Through direct contact with 9th grade pupils in one secondary school in Aveiro, I could arrange for 20 pupils to come at the University, to whom the student teachers administered the test.

The purposes of this activity were mainly fivefold:

1 - to help the student teachers to think of possible alternative conceptions related to light that could be held by pupils;
2 - to help the student teachers to develop an instrument for investigating pupils' ideas about light;
3 - to help the student teachers to use experiments and questioning to disclose pupils' ideas;
4 - to help the student teachers to analyse the results of the test;
5 - to help the student teachers to use the findings of the test in the planning of the unit on optics.

4.1 The first lesson on "light and its properties"

The first lesson on this topic was planned and performed by S6. The pupils were a very alert and uninhibited group of 4 girls and 4 boys of the 9th grade, enrolled in a secondary school of Aveiro. None of them belonged to the group to whom the questionnaire was administered at the University. Their age ranged between 14 and 17. Some of them had failed the 9th grade in the previous year. At the beginning, this group looked as if it would cause some discipline problems in the classroom. S6 was able to grasp this quickly and to accommodate her performance to the characteristics of the group she was addressing. This aspect is, in my opinion, one of the major difficulties facing microteaching. It is not very easy for student teachers to plan and perform in front of pupils they have not met before. They need to be very perspicacious to quickly, identify the characteristics of the group they are going to teach. Not all of them are able
to do this. Some years ago, one of my student teachers, almost gave up to perform a microlesson with 11th grade boys because as she said ". . . they are bigger than me! . . . they look so old!". She had had previous microteaching experiences with 8th grade children only.

The general content of the 1st lesson on "light and its properties" was based on the information gathered from the diagnostic test. It was stated by $S_6$ in the following way:

overall concept - the existence of light and its propagation in space;

subordinate concepts - the vision of objects; sources of light; beams and rays of light; transparent and opaque materials; light as a source of energy.

i) Pre-active phase

Table 7, overleaf, shows the task analysis of the pre-active phase.

The analysis of the document revealed the following points.

1) There was an improvement in the exploration of the potentialities of the content as concerning the development of scientific "abilities" in students, namely to identify pupils' intuitive ideas, helping them to be aware of their personal frameworks when interpreting optical phenomena.

2) Both the decisions on the pupils activities, the nature of presentation and the nature of feedback intended, revealed a shift in the role of the teacher from a transmitter of information to a facilitator of the pupil's construction of knowledge.

3) The strategy chosen gives, a priori, better conditions for the achievement of the aims stated for the lessons.

4) There was now a concern about the feedback to be provided and some suggestions for evaluation.

ii) Interactive and evaluative phases

After a short conversation between $S_6$ and the pupils in order to get acquainted, the student teacher began the lesson in the following way:

"1 T - . . . why we can see each other?

2 B - . . . because there is light

3 G - and we have got eyes
**TABLE 7 - TASK ANALYSIS OF THE PRE-ACTIVE PHASE; 1st LESSON ON "LIGHT AND ITS PROPERTIES". LESSON PERFORMED BY**

| A. Statement of the aims of the lesson in terms of pupils' development of "abilities" | B. Statement of the objectives of the lesson in terms of pupils' learning | C. Analysis of the lesson aims and objectives to establish the link between them | D. Decision on type of:  
| a) pupils activities  
| b) nature of presentation  
| c) nature of feedback to be provided  
| d) evaluation |

**Through the contents of this lesson pupils could be helped to:**

- **A3**
- **B1**
- **C3**
- **C6**
- **D1**
- **D2**
- **D5**

**A. Statement of the aims of the lesson in terms of pupils' development of "abilities"**

<table>
<thead>
<tr>
<th>Through the contents of this lesson pupils could be helped to:</th>
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<tbody>
<tr>
<td>A3</td>
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<tr>
<td>B1</td>
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<td>C3</td>
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<td>C6</td>
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<td>D1</td>
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<td>D2</td>
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<tr>
<td>D5</td>
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**B. Statement of the objectives of the lesson in terms of pupils' learning**

- After the lesson pupils should be able to:
  - (1) - use the model "light exists and propagates in space"
  - (2) - design experiments to com-
    prove the existence of light and that it travels in straight lines
  - (3) - make the distinction be-
    tween sources of light and light itself
    - give examples
  - (4) - explain the vision of objects
  - (5) - distinguish between trans-
    parent and opaque materials
    - give examples

**C. Analysis of the lesson aims and objectives to establish the link between them**

- According to S6 if pupils are able to:
  - (1), (3), (4) and (5) they will be helped to develop A3, C6, D1, D2 and D5
  - (2) they will be helped to de-
    velop C3 and B1

**D. Decision on type of:**

- **a)** (i) the pupils should draw conclus-
  ion by themselves about the inter-
  pretion of optical phenomena throu-
  gh discussion fostered by the teach-
  er.
  - (ii) imagine and design experi-
    ments to prove the existence of light
    that it travels in straight lines
- **b)** according to the adopted strat-
  egy the teacher will not give infor-
  mation, but through questioning, cue-
  and promoting discussions, pu-
  ils will draw conclusions about opti-
  mal phenomena.
  When possible for each conclu-
  sion, pupils will design and make ex-
  periments to test those conclusions

- **c)** (i) teacher gives encouragement
  to pupils in their efforts and contri-
  bution for the discussion
  - (ii) teacher provides a range
    of situations to help pupils to co-
    with new learning
Table 7 (continuation)

<table>
<thead>
<tr>
<th></th>
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<th>(iii) teacher will inform the learner in a verbal or non-verbal way if they are succeeding in their learning</th>
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<td></td>
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<td></td>
<td>d) presenting pupils with complete new examples, and ask them their interpretation</td>
</tr>
</tbody>
</table>
4 B - ... well ..... why can we see each other .... because we can .. that's all ...

5 B - ... we can see each other because there is brightness

6 G - .. and what is brightness? .. it is light don't you think so?

7 T - and what is light?

8 G - .. even if we switch off the light we still have brightness

9 B - ... the brightness comes from outside

10 T - so what is there outside?

11 G - there is light

12 B - .. there is the Sun

13 T - .. and what is the Sun?

14 Ps - ... (laughs)

15 T - could you write down on a piece of paper what is light for you? OK?

16 B - natural or artificial light?

17 T - well ... I would like to know what you mean by light ... if you want to make a difference between natural and artificial ...

(There was a bit of confusion and some pupils were talking loudly)

18 T - please ... listen me ... I asked for your own opinion .. so you shouldn't talk loudly ... because the others can be influenced ... OK? ... be honest ... I just want your own ideas ...

(After some moments of some confusion and laughing, each one wrote down his meaning for light).

19 T - let’s see what each of you wrote down .. could you start please ...

20 G - ... for me light is the visibility that we have and helps us to see ..

21 T - what do the others think about it?

22 Ps - (... everybody speaking at the same time)

23 T - please ... be calm .. one at a time .. do you agree with her idea about light?

24 G - .. visibility ....? .... I don't agree

25 B - .. the light is invisible

26 G - ... well it enables vision ...

27 T - so ... if light enables vision does it mean that it is visible?

28 G - no ... and it is because of that I don't agree that light is visibility

29 B - light is a thing that illuminates for us to see ...

30 G - look ... isn't light a set of colours ... that due to the speed gets white?
31 T - what ..? say it again please
32 G - a set of colours ... that is white
33 T - ... light is a set of colours and is white ... yes ... yes .... that is correct .... but what do you think about what your peer's idea ... is that right?
34 G - ... well she ... talked about day light ....
35 G - .... of course ... at night we can't see
36 B - ... light is a beam of rays
37 B - ... well for me light is something clear
38 B - generally it means visibility
39 P_s - (all speaking at the same time)
40 T - please once at a time ... what are you saying?
41 B - I'm saying that light is formed by rays that travel across the atmosphere at a certain speed ... and they are going to be reflected at the objects and enables vision ..
42 G - I think that light is related to colours
43 G - me too
44 B - I think it is related with optics
45 T - what is optics?
46 B - ... well optics is what is related with light ... and light ... is related with optics ..
47 T - do you think that answers the question?
48 B - no ... but .. it is difficult
49 T - tell us what you have written ..
50 B - light is a phenomenon that enables us to see and observe things which without it we couldn't see ..
51 T - so ... you agree that light is what enables us to see?
52 B - no .. I think what enables us to see are the eyes ..
53 P_s - ... (all speaking at same time)
54 T - please one at a time!
55 B - ... an object ... if we wish to see it but if it isn't illuminated by light we can't see it
56 T - even if you have your eyes open ... looking in its direction and you wouldn't be able to see it ..
57 P_s - (not audible)
58 T - well .. so you all agree that we can see because there is light .... I would like that you write down ... where do you think there is light in this room
59 P_s - (all speaking ....)
60 T - I don't want that you speak ... I want that you write down ... please be quiet ..

                        (They write down ... although some of them had already said "in every place").

61 T - well .. you there ... can you read what you wrote please

62 B - in every place

63 B - no ... I don't agree .. there is light ... at the lamps and outside

64 G - no ... it comes from lamps and from outside ... but here there is light in every place ... you can see everything ...

65 B - yes .. there is light every place where rays can strike

66 T - and is there .. here in this room .... any place where the rays don't strike?

67 B - yes ... inside drawers

68 T - ... yes ... but what can you tell your colleagues that are saying that light is only in lamps? ... can you imagine an experiment to prove that light exists not only in lamps but in every place?

69 G - we could switch on the television

70 T - and what would happen?

71 G - the TV would reflect light and it would give up brightness ... not in all the room but ..

72 B - what? ... I'm not following you ...

73 G - ... well I don't know how to explain

74 T - ... look but ... they could tell you that there was light only at the television ...

75 B - ... we could make this experiment ... with a lamp lighted up ... and a paper or something that could obstruct ... we could put it between the lamp and the paper ... we could see that there was light on the paper but behind the paper there wasn't ...

76 T - well ... let's make it and see what happens

                    (Using a torch and paper they did the experiment and a discussion took place because some of them still remained doubtful about what would exist between the torch and the paper. It is quite difficult to transcribe the discussion because there was an overlapping of voices and some tried hard to convince the others that it was evident that light existed between the lamp and the paper). Then one of the girls said:

77 G - well if the light was red ... we could be sure

78 T - did you say red light ? ... well we have got a red light here ...
she had brought a He-Ne laser and when she switched it on a red spot appeared on the wall of the room)

79 T - and you can see .. there .. on the wall a red spot .. right? .. and between this lamp and the wall what do you see?

80 B - there must be light between the source and the wall

81 T - how could you prove it?

82 G - how can we see the light going from here to there? .. I can't imagine ...

83 G - .. if we put a glass between ...

84 T - a glass? .. and what happened? ...

85 B - .. a mirror .. a mirror

86 B - .. no .. it wouldn't prove anything ...

87 P S - (they were thinking hardly ...)

88 T - haven't you ever observed .. when you have a dark room with the door just a little bit opened in a sunny day ....

89 B - yes ... we can see rays of Sun ...

90 G - .. because in the darkness what we see isn't light .. what we see is the object where the light strikes

91 T - and what kind of objects are those when we see the rays of Sun?

92 G - particles of dust

93 T - so ... if we try to throw some chalk powder between this lamp and the wall let's see what happens .... could you help here please ..

(doing the experiment)

94 P S - .. we can see it .. yes ... (laughs) ... very well ...

95 T - so is there light between the lamp and the wall?

96 P S - ... yes ... (laughs)

97 T - what conclusion can you draw from this experiment?

98 B - there is light at every point between the lamp and the wall ... and .... that we only can see it if there is dust ... (laugh)

99 G - ... the light strikes the particles of dust and they reflected it towards our eyes"
information obtained from the previous activity (the diagnostic test) to seek for opportunities during the discussion to identify pupils' ideas about the interpretation of optical phenomena. Nevertheless, due to some disorganized pupils' participation, which $S_6$ could not cope with easily, there were various situations in which pupils' ideas remained unclear and were not duly explored. Examples of these are illustrated by utterances 5, 6, 7, 8, 9 and 10. The distinction between light and brightness remained unclear and $S_6$ shift the conversation (15) without helping the students to express their own views related to these two concepts and discuss them. The same happens with the girl who insisted that "... light is related to colours", but who had not an opportunity to express clearly what she meant by that. Exchanges 62 and 63 give an example of two different concepts of light followed by an attempt (64) made by another student to clarify her peer's idea. In utterance 68, $S_6$ stimulated the student to help the clarification of peers's intuitive concepts about light with the help of an experiment's design. With the strategy used, she was providing opportunities to achieve the aims proposed for the lesson.

The first analysis was made just after the pupils left the room. As always, the student teacher who performed the lesson, $S_6$, was the first to assess her performance. According to her the lesson was a very fruitful experience because it made her believe that it was possible through the contents to achieve the aims stated and it was also much interesting to teach in that way.

The general comment made by her peers was that both the strategy used and her performance were good and appropriate for the achievement of the aims. They also commented that they felt that to observe this lesson was a very interesting experience for them.

Then we watched the videotape and analysed in detail the situations that could be improved. In this way feedback was provided for improvement of the next teaching activity.

4.2 The second lesson on "light and its properties"

The second lesson on "light and its properties" was planned and performed by $S_1$. The same group of pupils who had attended the first lesson came again and brought another boy with them. They commented that they have enjoyed the first lesson very much the first lesson and that they were happy to have the opportunity to come again.

The general content for this lesson was chosen by $S_1$ and stated as following: "Rays of light; light and energy; transparent and opaque bodies; eclipses".
i) Pre-active phase

Table 8, overleaf, shows my presentation of the task analysis of the pre-active phase made by Sj. It is a standard presentation so that comparisons may be made across others task analyses already presented. It was derived from documents provided by Sj.

The analysis of the document revealed the following points.

1) An improvement took place in the exploration of the objectives stated for the lesson.

2) The strategy chosen by Sj, based on questioning, cueing and class discussion was suitable for a constructivist approach to learning in which the information is created by pupils and not transmitted by the teacher.

3) All the decisions on types of pupil activities, the nature of presentation, the nature of feedback to be provided and evaluation, were taken with some degree of flexibility, revealing not a very structured plan but taking into account the possibility of promoting discussion between pupils.

4) The aim of helping pupils to be aware of their personal frameworks through the content of the lesson was clearly identified. The same thing was identified in the task analysis of the first lesson on "light and its properties" performed by S6. This showed that some student teachers were already aware of the problems concerning pupils' intuitive ideas and their implications for teaching and learning.

ii) Interactive and evaluative phases

Sj started the lesson by putting some questions to the pupils in order to assess the pupils' learning from the previous lesson. At the same time this allowed him to make the link between the content of the 1st and 2nd lessons.

Throughout the whole lesson, Sj was really concerned to make pupils think, to help them to explicate their thinking in a precise way and to involve all pupils in the discussion, giving opportunities for them to help each other to clarify ideas. He provided the necessary material for pupils to test their hypotheses whenever possible and necessary. The material used was very simple. Pupils were divided into two groups, two wooden boxes were provided inside which a torch could be put. One of the smaller walls of each box was replaced by a plate with a narrow slit, making a ray box.

Some extracts of the lesson give the flavour of it.
**TABLE 8 - TASK ANALYSIS OF THE PRE-ACTIVE PHASE; 2nd LESSON ON "LIGHT AND ITS PROPERTIES". LESSON PERFORMED BY**

| A. Statement of the aims of the lesson in terms of pupils' development of "abilities" | B. Statement of the objectives of the lesson in terms of pupils' learning | C. Analysis of the lesson aims and objectives to establish the link between them | D. Decision on type of:  
| a) pupils activities  
| b) nature of presentation  
| c) nature of feedback to be provided  
| d) evaluation |

| Through the contents of this lesson pupils could be helped to: | After the lesson pupils should be able to: | According to S1 if pupils are able to: | a) . (i) pupils answer questions posed by teacher  
| A3 | make explicit their meaning of "rays of light" | (1), (3), (4), (5) and (6) they will be helped to develop A6, C6, D1, D2, D4 and D5 | . (ii) pupils do experiments worked in group  
| A4 | criticize situations explored in fiction films | (2) they will be helped to develop A4 and C6 | . (iii) pupils explain their observations  
| A6 | identify light as a source of energy | | . (iv) pupils give examples that identify light as a source of energy  
| C5 | make a distinction between transparent and opaque objects | | . (v) pupils explain the phenomena of eclipses  
| C6 | explain shadow formation | | b) . teacher promotes discussion between pupils about the interpretation of situations related to optical phenomena  
| D1 | explain the eclipses of the Sun and Moon | | . teacher presents the material necessary for the experiments  
<p>| D2 | | | . teacher presents a transparency where the eclipse of Sun can be studied |</p>
<table>
<thead>
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<th></th>
<th></th>
<th>c) teacher's verbal and non-ver feedback</th>
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<tr>
<td></td>
<td></td>
<td>. teacher encourages pupils' participation</td>
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<td>. peers' feedback</td>
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<td></td>
<td>d) through careful observation class activities, involvement in work</td>
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<td></td>
<td></td>
<td>. through checking pupils' ability apply learning in new situation</td>
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<td></td>
<td></td>
<td>. through comparing success of pupils with the aims set for the lesson</td>
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</table>
"1 T - so .. you say that between this torch and the wall there is light ... yes
you had proved it last lesson ... now suppose I was outside and pointed
the torch toward Oporto ... suppose there wasn't any obstacles between
Aveiro and Oporto ... trees or houses ... or hills ... could a person in Oporto
see the light of this torch?

2 P_S - no ...

3 T - why?

4 G - well if the light of the torch was strong enough it would reach it

5 B - because it hasn't got sufficient range of vision

6 T - .. but does the light reach Oporto or no?

7 B - no .. because nobody could see it in Oporto

8 T - yes but ... if we say that light propagates in space .... and we know that
it exists between here and there (the torch and the wall) why is it not
seen in Oporto?

9 B - it finishes on the way to Oporto..

10 T - it finishes? .... what do you mean by that?

11 B - ... because the light is unable to reach that distance

12 T - why?

13 G - it hadn't enough intensity

14 P_S - (all speaking at the sometime)

15 T - please .. listen to your colleague .... could you repeat please

16 G - the light of the torch couldn't reach Oporto because it hadn't enough
intensity..

17 B - yes that's it ...

18 T - so ... you are saying that the distance between the source of light and
the point where we still can see it depends on the intensity of the source
.. is that so?

19 G - ... I think so ... the rays of light were so weak .... they couldn't reach Oporto

20 T - why?

21 B - maybe the wind

22 P_S - (laughs)

23 T - the wind? .... well blow up here (between the torch and the wall) and observe
if something happens at the spot on the wall

24 P_S - ... (laughs)

25 T - did we see anything?

26 B - no

27 T - .. so .... it isn't the wind ....

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28 B - ... may be the atmosphere ... the air doesn't let it go

29 T - well ... that's something ... let's see other example ... do you remember some moments ago we talked about fishes that live at the bottom of sea where there isn't light ... why is there no light at the bottom of the sea? ...... not only at the bottom .... after 170 to 200 meters of depth there is no light ....

30 B - ... the sun rays don't reach the bottom because of the water ..

31 T - that's true ... so as you say either the air .... in one case ... or the water .... don't let the rays to reach long distances .... they act as obstacles to the propagation of the light ....

32 B - so it means that the air isn't totally transparent ... it is also opaque

33 T - ... and what do you mean by opaque ... what is an opaque body?

34 B - it is a body that lets only some portion of light to pass through

35 T - yes ... that's right .... so it means that there are bodies more opaque than others?

36 P_s - yes ...

37 T - could you give an example of a body that isn't completely opaque ... but not completely transparent ..

38 B - .. the water

39 G - .. the air

40 B - .. the hand

41 B - .. the finger points .... switch on the torch ... look .. you see ... my fingers let the light go through".

Guiding the conversation in this way, S_1 was providing situations in which the pupils themselves brought to the discussion either the information and the interpretation of the contents he had chosen for the lesson. The sequence of utterances from 28 till 41, is an example that illustrates this point.

Later during the lesson he brought up the problem of the use of lasers in fiction films.

"42 T - ... when in these films the superman or the other figures fire off their guns .... what do you see in the films?

43 B - ... a coloured straight light coming out from guns ... but it isn't possible .. that is wrong ... we cannot see the light

44 T - yes ... alright .. and they are used on what purpose?

45 P_s - ... to kill ... to kill

46 G - ... to destroy .. to burn things

47 T - that's right ... and the laser is also a light .... and it is another example in which light is used to destroy ... to set a fire ...
just one thing ... (laugh) .... the poor old chaps ... our ancestors ... had such a difficulty to set a fire ... only with stones ... nowadays there are so many ways to set a fire ... (laugh)

(laughs)

well ... let's talk about rays of light ... the light from that lamp ... does it propagate in just one direction or in all directions?

... in all directions ...

yes ... and in each direction how does it travels?

... in straight lines ...

yes .. well each straight line is usually called a ray of light ... obviously ... that is a thing we cannot get really .. we only make an approximation of a ray of light .... now another thing when I'm looking at you .. why do I see you?

... because there is light ... because we have eyes

.... yes ... could you tell me if ... do the rays go from the eyes to the object or from the object to the eyes?

... from the eyes to the object

I don't agree with her..

... they go from the object to the eyes

yes ... that's it

... they go from the object to the eyes

... so ... there are two opinions

the eyes don't have rays of light ...

even if eyes had got rays of light ... they would strike me first ... and after that they would turn over ... and only after that you could see me

... well .... let's get things clear ... we have here two ideas

(all talking at the same time ... discussing the two possibilities ...)

you there ... what is your idea?

... I think they go from the object to the eyes ..

of course

why do you say so?

I don't know ..

... so .. if you say so .. you must know why?

... (laughs) ... because ..

it has more logic ..

please be quiet .. let him talk
76 B - ... well the light strikes the object and the object reflects it into the eyes ...

77 B - ... if there were rays going from the eyes we could see at night ...

78 T - ... could you imagine an experiment that enables us to decide between these two ideas?

79 P_s - (all speaking at the same time)

80 T - one at a time .... please

81 G - with a mirror ...

82 T - how could that work?

83 G - well if we are in front of a mirror and if we switch off the light ... if there were rays going from the eyes to the mirror we could see us in the mirror..

84 G - ... if rays would go from eyes to the object we could see the objects at darkness .. but ... we cannot see it ..."

It can be elicited from this extract of the lesson's transcript that S_1 conducted the conversation through questions aimed at disclosing pupils' intuitive ideas (e.g. utterance 56). He also fostered the discussion between pupils, allowing a sharing of ideas and at the same time providing opportunities in which pupils could help each others on the development of their own conceptions (e.g. the sequence of utterances from 76 to 84).

The lesson continued more or less in this way. By the end, with the aid of the transparency, the student teacher asked for an interpretation of the phenomena of eclipses, and to some extent he got it.

When the lesson ended S_1 gave his perception of it. This time he was much more conscious of his performance. He enjoyed the lesson although he felt that "... it is 'harder' to conduct the lesson in this way ... although more interesting".

His peers' general opinion was that the strategy had been good for the achievement of the aims stated. They had also enjoyed the lesson. They all pointed out the importance of having the information on pupils' ideas about the interpretation of optical phenomena.

Then we watched the tape and discussed in detail some particular situations either from the scientific or pedagogical points of view. The concept of 'opaque object' gave rise to a fruitful discussion. Some evaluation was made during the lesson by checking pupils' ability to apply learning to new situations and by comparing pupils' success with the aims set for the lesson.

There was a real improvement on S_1's performance compared with
the first one. He was able to integrate solutions for improvement on the basis of previous assessment. His teaching skills improved and he was more self-confident in his capacities for teaching according to the model he step up for his teaching.

4.3 The third lesson on "light and its properties"

The third lesson on "light and its properties" was planned and performed by S4. The same group of pupils came again. The fact that this group of 9 pupils come to the university to attend a lesson weekly during three weeks can be perceived as a sign that they were interested in the activity and didn't get bored on the previous lessons. This was, per se, a stimulating fact for the student teachers.

The general content for this lesson was chosen by S4 and was stated by him in the following way: "Reflection and Diffusion. Plane mirror. Laws of Reflection".

i) Pre-active phase

Table 9, overleaf, shows the task analysis of the pre-active phase made by S4. The same comments already made relating to the presentation are also valid here.

The analysis of the document revealed the following points.

1) This lesson being the third on this topic the decision on the type of pupils activities seemed highly appropriate. In the previous lessons pupils' intuitive ideas related to the concepts involved in the phenomena of reflection and diffusion were disclosed. The stage of "conceptual revolution", which would, hopefully, make the new conceptions more credible or at least tentatively accepted by the majority of students, had already take place. In this lesson the effort would be directed to interpret situations and to solve problems, according to the conceptual frameworks introduced before. Thus, S4 decided, correctly according to a constructivist perspective, on a session of practical work set against the background of a theoretical framework. During these type of activities not only were some of the scientific process skills developed but also the theoretical framework could be articulated and consolidated. Thus, a priori, the strategy chosen would be the right one to achieve the aims proposed for the lesson.

2) It was still apparent that S4 did not explore the potentialities of the activities proposed for the development of other "abilities" as for instance, A4 - cre-
TABLE 9 - TASK ANALYSIS OF THE PRE-ACTIVE PHASE; 3rd LESSON ON "LIGHT AND ITS PROPERTIES". LESSON PERFORMED BY

<table>
<thead>
<tr>
<th>A. Statement of the aims of the lesson in terms of pupils' development of &quot;abilities&quot;</th>
<th>B. Statement of the objectives of the lesson in terms of pupils' learning</th>
<th>C. Analysis of the lesson aims and objectives to establish the link between them</th>
<th>D. Decision on type of: a) pupils activities b) nature of presentation c) nature of feedback to be provided d) evaluation</th>
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<tbody>
<tr>
<td>Through the contents of this lesson pupils could be helped to: A5 C3 C5 C6 D2</td>
<td>After the lesson pupils should be able to: (1) - make a distinction between reflection and diffusion (2) - identify the characteristics of plane mirror (3) - design and realize an experiment to deduce the laws of refraction (4) - explain the formation of images in plane mirrors</td>
<td>According to S4 if pupils are able to: - (1), (2) and (4) they will be helped to develop C6 and D2 - (3) they will be helped to develop A5, C3, C5, C6 and D2</td>
<td>a) (i) pupils will work in two groups (ii) pupils will design and make experiments (iii) pupils explain the distinction between reflection and diffusion (iv) pupils will establish the law of refraction as a conclusion of the experiment b) teacher presents material for experiments (ray boxes, plane mirrors, torches, rules and protractors) c) teacher verbal and non-verbal feedback - peers' feedback d) based on answering to questions by the teacher</td>
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</table>
ative-mindedness, $A_6$ - self-confidence, $B_1$ - accuracy, $B_2$ - honesty, $B_3$ - consistency, $B_5$ - efficiency, $C_4$ - recording, organizing and interpreting data and $C_7$ - predicting. All these "abilities" can be developed in practical work if the teacher is aware of this possibility and acts during the activity in order to foster their development. If $S_4$ would had made a more carefully analysis of the lesson aims and objectives to establish the link between them he would more likely have acted during the interactive phase in order to achieve them. Of course, some content is more suitable for developing particular aims. My opinion is that the content of this lesson was, by its nature, likely to favour the development of these aims.

ii) Interactive and evaluative phases

$S_4$ showed a great difficulty in dealing with classroom discipline and management. His skills of communication had been developing at a very slow rate. These difficulties compromised his performance with a group of 9 pupils who were not very easy to cope with. And, as it is well known, once pupils are aware of the teacher's weak points, the latter has a great deal of trouble in carrying on with his job.

During the first part of the lesson he tried to distinguish between regular and irregular reflection. In order to accomplish this, pupils were divided into two groups and each group were provided with a ray box, a torch and two plates, one with a rough surface and another with a smooth one.

They were then asked to observe what happened when a narrow beam of light struck both surfaces.

A small extract of this part of the lesson can give an idea of how it went.

"1 T - well ... let's see ... what's the difference between the rough and the smooth surface?

2 Ps - .. (all speaking at the same time)
... on the smooth surface the light was reflected

3 G - ... in a straight line

4 B - ... in the same direction
.... (too much noise)

5 T - .. and in the other?

6 Ps - ... no ..... no

7 T - then .. that wall ... we can compare it with the rough surface
8 B - yeah!

9 T - ... so you may draw the conclusion that in the wall there is no reflection as you told me some moments ago

10 B - ... no ... there is a reflection on the wall if there wasn't I couldn't see it

11 T - yes ... but it is a special reflection ... in all the directions ... and when we have a smooth surface ...

12 P₃ - ... it's only in one direction ... it's only in a certain direction ... (not audible)

13 T - so ... this is known by what name?

14 B - ... smooth surface

15 B - ... a mirror

16 G - ... a polished surface

17 G - ... a mirror?

18 B - yes ... it also reflects ...

19 T - ... then ... say it ...

20 P₃ - ... (silence)

21 T - think a little ... you talked about smooth surface ... what is it?

22 B - a smooth surface?

23 G - ... (speaking to the others) ... I don't understand what he wants ...

24 T - what is a mirror for you?

25 P₃ - ... (they all speaking and laughing)

26 T - ... Paul ... what is a mirror to you?

27 B - a mirror is a surface ..... a surface ... (laughs) .... in which an image is reflected

28 T - that's right ... but what happens to the ray of light

29 B - it is reflected

30 G - ... in the same direction

31 G - ... it depends

32 T - in the same direction?

33 P₃ - (all speaking at the same time) ... it depends on the inclination ... (not audible)

34 T - it's right ... it's right ... so what is a mirror ... it is a smooth surface that reflects light in a regular way .."
This small extract illustrates two weak points of \( S_4 \)'s performance. He was unable to guide the participation in an organized and clear way. Sequence 2, 3, 4, 5, 6, 7 and 8 is an example in which just short and incomplete utterances were made by the pupils. A confusion of ideas and lack of precision can also be perceived through the sequence of utterance from 12 to 34. Utterance 28 is an example of what can be called "teachers' science" when, \( S_4 \), asked "what happens to the ray of light". He was using an abstract concept taking for granted that the pupils were following his speech.

\( S_4 \)'s difficulty in making the distinction between an idea and a name is also apparent. It can be perceived that his intention in utterance 13 was to get the term "diffusion" as an answer. Pupils could be guided to interpret the phenomena of diffusion but they could not name it, unless they already had that information. This is also apparent in exchanges 19, 20, 21, 22 and 23.

Another weak point is related to his lack of capability to listen to the pupils. He was more concerned to cover the topic of the lesson that to seize opportunities, during the lesson, to help pupils to express their ideas clearly. An example of this is the sequence of utterances 29, 30, 31, 32, 33 and 34.

Later in the lesson he asked pupils to design an experiment in order to deduce the relation between the angles of incidence and reflection. During the experiment no care was taken to make accurate measurements, some pupils did not understand what was going on, they joked a lot, but the teacher did not pay much attention. The strategy was quite good but he did not make as much of it as he might have.

When the lesson was ended we started to analyse it. \( S_4 \) was the first to realize that although the strategy was good, his performance was weak. He found great difficulties in dealing with most of the situations created during the lesson.

When watching the tape, we analysed in detailed some of these situations. Apart from the problem of classroom management, there were crucial points during the lesson that brought up very important issues. All the students agreed that the content "Laws of reflections" was a good vehicle through which the aims stated could be developed. In order to arrive at these laws, pupils should be encouraged to observe accurately what happens to a narrow beam of light when striking a mirror. Instead of following given instructions for the practical work, (\( S_4 \) did not give instructions), pupils should be encouraged to design and plan the experiment. But it would be certainly difficult, if not impossible, for pupils to deduce the laws if, for instance, the teacher doesn't first define the angles of
incidence and reflection. Once this was done pupils could solve the problem of inferring the relation by themselves. The teacher should help and guide them in their efforts, but should not give instructions. He should ensure that accurate measurements were done by pupils, and that recording data be done with honesty, consistence and efficiency. A non-example of this happened during the practical work, where both groups recorded data such as:

<table>
<thead>
<tr>
<th>Angle of incidence</th>
<th>20</th>
<th>45</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of reflection</td>
<td>20</td>
<td>45</td>
<td>30</td>
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</table>

Only when his peers and I pointed out these kind of situations, which reveal a lack of accuracy and/or honesty in measuring and reporting data, did $S_4$ realize that he had not paid attention to them. The discussion that took place while giving feedback to the student teacher who had performed the lesson was also a very fruitful process of clarification of what to do in order to act as a facilitator of the pupils' development instead of as a transmitter of information. Some alternative strategies were proposed to overcome some of the difficulties found during the lesson. It also gave me feedback on my own approach in helping student teachers to develop teaching skills in order to master a constructivist teaching approach.

6.3.3.2 By the second cohort

In the second year of Part A of the main study, each of the seven student teachers performed, in the first cycle of the spiral of the action research process, one lesson to two different groups of 8th grade pupils who came to the university on three consecutive weeks. The number of pupils in each group ranged between 6 and 9. As happened in the first year of the experiment, the student teachers chose the same topic "Electric current" for the lessons to be taught to the 8th grade. Nevertheless, in contrast to what happened in the first year, the pupils had not had any lessons in physics because, for this year, it was decided, in the official schools, to start the discipline of "Physics and Chemistry" with chemistry. Thus, the student teachers had to plan the teaching of this unit taking into account that the "Electrostatic" had not been taught previously.

The reasons that caused them to chose this unit were twofold. Firstly, the activity on bulbs and batteries, which they had performed during the implementation of the interest stage, gave them ideas of how to approach the topic and confidence in their first teaching experience. Secondly, as it is a general impression that usually pupils do not like electrostatics, probably due to the way
it is taught, the student teachers decided to try to change the usual sequence of the 8th grade syllabus to one they thought would improve learning. Aware of possible alternative frameworks concerning the concept of electric current, either from their own and peers' experience (when performing the activity on bulbs and batteries) or through the reading of the findings of research in science education relating to these issues, they planned this first set of lessons based on this information. The basic assumption was that if they could start this topic from pupil's own ideas it would be easier to guide the teaching process to help the pupils to build their own knowledge concerning either electric current or electrostatic. If pupils are self motivated to interpret their own conceptions they will ask for further information that would help them in that interpretation. According to this assumption, the student teachers, believed that after working on the unit "Electric current" pupils would feel the necessity of understanding the electrostatic phenomena as a means to a better understanding of the process of current flow.

As happened with the first cohort, the student teachers of this second cohort were divided into two groups for the planning of the lessons of the first cycle. The groups will be identified by A' and B'. Groups A' and B' were composed respectively by Sg, S^q and S^3 and S7, S9, S12 and S13.

Each group worked in the task analysis of the lessons to be performed weekly to the same group of pupils although each lesson was performed by an individual student teacher.

1. The first set of lessons (first cycle) and their analysis

In my own process of action research, the conduct of part A of the study in the second year of the experiment was, for me, a second twist up the spiral. The findings of the first year helped me to evaluate the action undertaken during the first year and served as a basis for improving the planning of the second year. It gave me a chance to learn; that is, to gather new general insights on the process of promoting the student teacher's perspective change toward a constructivist approach to teaching and helping them to develop appropriate teaching skills.

1.1 Pre-active phase

To some extent, a consequence of my own learning concerning the implementation of the two first stages was reflected in the pre-active phase of
the first teaching experience of both groups. My general impression of their task analyses was that there was a greater awareness of the potentialities of the content chosen on the development of scientific abilities in pupils, as well as a deeper perception of what should be done to achieve the aims stated. But, to know what should be done does not necessarily mean that student teachers, at least most of them, knew, a priori, how it should be done. To change one's own perspective, does not imply as a consequence a change in one's own behaviour. The process of changing behaviour can be, and usually is, a slower process than the one involving perspective change. It is easier "to say it" than "to do it".

The review of the task analyses of the pre-active phase of both groups in the first cycle of the spiral of the action research process was undertaken in a similar way to that presented earlier.

The analysis of the seven documents produced the following information.

1) The general content of both first lessons was stated as "An introduction to the concept of electric current". This was the overall concept common to both groups. Nevertheless, the statement of the subordinate concepts revealed, that, a priori, group A' had a more accurate perception of the span of time needed for a constructivist approach to teaching than group B'. After the experience of the first lessons in which some of the subordinate concepts, even the ones stated by group A', could not be addressed, group B stated the content for the next lesson without taking into account the experience of the previous lesson. Only in the planning of the third lesson did they use the feedback provided by the other two lessons and felt the necessity to return to the subordinate concepts stated in the first lesson.

Group B' was more congruent in its task analyses and showed a more awareness of the span of time that would be necessary for the learning of the different subordinate concepts.

2) Both groups presented a thorough analysis of the lessons aims and objectives to establish the link between them. Compared with the analyses made by the cohort of the first year, each one of the task analyses of the first cycle of this second year showed the same degree of accurateness and thoroughness showed by the task analyses made in the second cycle of the first year.

3) All but one of the task analyses revealed that the student teachers decided on pupils activities and a nature of presentation which showed a concern for the pupil as the meaning-maker. The chosen strategies would allow, at a preparatory
stage, for a raising of conceptual awareness of the pupils' alternative views. The strategies then provided opportunities for the introduction of anomalies in which, through experiments, demonstrations and questioning by the teacher, pupils should be requested to make some predictions, to test them and to infer from that testing. They allowed also for the fostering of critical, creative and inquisitive-mindedness.

An interesting situation, in which the approach was, to some extent, opposed to the one proposed by the other task analyses mentioned above, was the situation in which the contents to be taught related the microscopic aspect of the concept of electric current (a topic listed in the official 8th grade syllabus). When dealing with this the student teachers of group B' (group A' did not reach that point) decided on a more traditional approach to teaching. The nature of presentation was based on a teacher presentation of a OHP transparency illustrating electron flow in a metal. The teacher would, according to the task analysis, interpret the mechanism of the current flow in metals. After the lesson, pupils should be able to distinguish, at the structural level, conductors from insulators. This decision may indicate either one of two points; the difficulty that the student teachers found in adopting a constructivist approach to more complex subject matter, or the displacement of these issues in the context of the teaching and learning at this schooling level. This latter point could be discussed after the interactive phase of this particular lesson had taken place. It provided a good example for helping student teachers to become aware of the necessity of a critical analysis of the official syllabus.

4) Having decided on a nature of presentation and pupils activities which were more suitable to a constructivist approach to teaching and learning, the statement on the nature of feedback seemed not to be a problem in most of the task analyses ("teacher's verbal and non-verbal feedback, encouraging pupils to participate on the discussion either verbal or non-verbal reinforcement, a smile, a nod, or another gesture of approval"). The statement of forms of evaluation seemed to bring more difficulties and was to some extent more vague ("through comparing pupils' success with the aims set for the lesson").

1.2 Interactive and evaluative phases

The analyses of the lessons performed by the student teachers were made in the same way as was done in the first year of part A of the study. A general analysis was made immediately after the pupils had left, the student teacher who had performed that particular lesson being the first one to give her/his perceptions of the lesson. This was followed by a discussion in which each one of the
cohort, including myself, presented her/his own views of the lesson and the implication on the teaching of this or that behaviour, situation or strategies. Then we watched the videotape and analysed each bit of teaching regarding the aims and objectives stated for the lesson. These sessions were audiorecorded. The analysis of the videotapes of the lessons and transcripts of the audiotapes of the discussions produced the following information.

a) The first lessons of groups A' and B' were performed by S_{13} and S_{9} respectively. The group of pupils who came for the lesson performed by S_{13} consisted of six boys (13-14 years old). The other group consisted of four girls and two boys (13-14 years old). Both student teachers introduced the topic of the lessons by asking pupils to describe everyday life situations related to electricity. Then they both involved pupils in activities similar to the one they had used in the awareness stage i.e. bulbs and batteries. During these activities they circulated among the groups asking questions aimed at identifying pupils' ideas and providing situations to challenge these views. They both seemed aware of problems of team-work and acted adequately.

In the first lesson of each group, both student teachers were able to use in the teaching situation the feedback they got from their own experience in a similar activity. Nevertheless, S_{13} found some difficulties in helping some of the pupils because she was unable to discipline the encounter. The following episode illustrates this point. When talking with one of the groups she was asking what they would expect if she disconnected a wire in a certain circuit constructed by the pupils. After their prediction she asked them to test their prediction. Then, she asked, what would happen if the wire was connected to a point on the battery other than the pole. The pupils quickly replied that the lamp would go off and when she asked why, one answered "... because there must be a negative current and a positive current". At exactly that moment one pupil of another group called her. She left the group she was working with, without helping the pupil to explain his ideas about the two currents and providing situations that could help him to change his own conception of electric current to a more scientific one.

S_{9} did not find this kind of difficulty although he had some problems with expression. The student teachers are not used to talking with pupils of this age and sometimes they are not able to use accessible discourse.

b) Both lessons were of an exploratory nature. In both, pupils were actively involved in the activity of exploring different ways of making simple electric circuits, testing their predictions, making hypotheses to explain situations presented as anomalies and draw conclusions by themselves. There were plenty of opportunities
for inter-pupil discussion which sometimes were too lively, needing the intervention of the student teacher.

c) Throughout the lessons, both student teachers acted as facilitators of pupils awareness of their own frameworks when interpreting simple electric phenomena.

d) The general impression of their peers who observed the lessons was very positive. They all agreed with the strategies used, seeing them as approriate for the achievement of the aims stated for the lesson.

In a more deep analysis, when watching the videotape, each one pointed out relevant situations in which things did not worked so well and suggested alternative behaviours to cope with them.

e) The importance of this type of lesson for the introduction of a new topic was recognized by all student teachers. Not only for helping pupils to be aware of their own conceptions, but also for providing opportunities to the teacher to identify pupils' ideas related to the new topic and helping her/him to seek strategies that could help conceptual change in the pupils.

f) The second lessons of group A' and B' were performed respectively by S_8 and S_{11} and S_7. Due to time constraints the second lesson of group B' was shared between S_8 and S_{11}.

The group of pupils who came for the first lesson of group A' brought with them another pupil, this time a girl. The other group was the same.

Before the lessons started they commnented that they enjoyed the previous lessons very much and that they were happy to attend another.

There was a great difference between these three performances. S_8 followed the same line of action as his colleague who had performed the last lesson, although this time the nature of the lesson was not only exploratory. He introduced the scientific symbols for the elements of a circuit after asking pupils to make drawings representing the circuits they were building. Then he asked them to draw the same circuits again but in a scientific way.

Interesting problems were found with this approach relating to difficulties sometimes felt by pupils in the understanding of the scientific symbols. Constraints of time, space and scope of this study don't allow for a description and deep analysis of those difficulties here. Notwithstanding, they are mentioned here because they helped the student teachers to be aware of them and to introduce scientific symbols in their teaching with the due precautions.

An episode with the girl who had come for the first time provided
an opportunity for the student teachers to be aware of one of the implications of the current approach to teaching on the development of young people. In the previous lesson $S_{13}$ had already explored the observation of a bulb. In this lesson $S_8$, perceiving that the girl did not know how the bulb worked, asked her to describe it. This small extract of the lesson will illustrate the point on which I want to focus.

"T - look carefully, Helen, can you tell me what do you see in a bulb?

G - ... I see ... the coiled wire ...

T - yes ... and anything more? ... wait I will fetch a bigger one

(While the student teacher turned to fetch the lamp she turned quickly to her peers and whispering asked them)

G - what should I see ... what should I see ... tell me .. please!

Then the student teacher returned near her and, as he had heard, he told her

T - look, Helen, I'm sure you can tell me what you see by yourself ... observe carefully and you will be able to describe me what you see"

The episode continued and at last the girl was able to describe by herself every part of the lamp. The behaviour of the girl revealed that she was more concerned to tell the teacher what he was suppose to hear than to make an effort to observe and tell what she really saw.

These kinds of situations were accurately pointed out by the student teachers during the analysis of the lessons and provoked fruitful discussions.

$S_{11}$ performed the first half of the second lesson of group B'. Although this student teacher, during the analysis of the previous lessons, was able to point out, criticize and suggest alternative strategies to cope with some of the emerging problems in a constructivist approach, she showed great difficulty in performing herself within this approach. Although trying to involve the pupils in activities such as to identify conducting and non-conducting materials she showed difficulties in exploring the activity in order to help pupils to draw the conclusions for themselves. As a consequence, some pupils remained confused and unable to interpret and relate some of the situations they encountered in their attempt to distinguish between conductors and insulators.

During the analysis of the lesson, although her peers in their feedback pointed out some of the weakness of her performance, she accepted that only after watching the videotape. One of the criticism of her peers was, for instance, related to one of the aims stated for the lesson - to develop the scientific attitude
of efficiency. Throughout the lesson, there were situations in which some pupils abandoned a task, as for instance, in attempting to connect a circuit in which one lamp would burn more brightly than two others in the same circuit. While some pupils could do it, one group of two gave up the task without that fact being noted by the teacher. It was interesting to note that \(S_{11}\) realized that only when watching the tape. She had not perceived it during the lesson and did not accept her peers' criticism because, as she told us, "I'm sure they all did it".

The second half of this lesson was performed by \(S_{7}\). In a concern to follow the pre-planning for that lesson he introduced the difference between conductors and insulators at a structural level. As the background provided by pupils' own ideas did not allow them to understand the teacher's discourse, the lesson turned out into an example of "presentation of knowledge" by the teacher. The pupils took a passive attitude and \(S_{7}\) was unable to cope with this situation in which he, as he told us after the lesson, was feeling very uncomfortable because it was not what he wanted. Contrary to what happened with his colleague, he was the first to recognize the weakness of his performance. All the student teachers imparted the opinion that it seemed easier to teach in a constructivist approach in the stages of "raising of conceptual awareness" and "anomaly introduction" then in the stage of "theory presentation". During the lesson's analysis, a fruitful discussion took place relating to the teacher's role in this last stage as well as to the role of metaphors and analogies. They also draw the conclusion that the study of the microscopic aspect of the conduction in metals was misplaced at this educational level, although most of the textbooks, used in schools, mentioned it. I found this episode highly relevant to the student teachers' consciousness of the need for a reflective analysis by themselves on the content to be taught.

**g)** Immediate feedback to the second lesson was provided by the pupils. The ones attending the lesson performed by \(S_{8}\) commented that they enjoyed the lesson and found "these things very interesting". The ones who attended the lesson performed by \(S_{11}\) and \(S_{7}\) were not so happy and commented that the lesson was "a bit boring" and not so interesting as the first one (the one performed by \(S_{9}\)).

**h)** It was apparent during the third lessons of each group that the student teachers integrated solutions for improvement on the basis of their previous self-evaluations.

The third lesson of group \(A'\) was performed by \(S_{10}\). The third lesson of group \(B'\) was performed by \(S_{12}\).

\(S_{10}\) followed the sequence of the previous lesson and, through team-work on simple experiments, guided the pupils to draw conclusions related
to parallel and series circuits. Throughout the lesson opportunities were provided to help the pupils to develop the scientific capacities, attitudes and skills that were stated as aims for the lesson. He showed a great awareness of his role as a teacher working within a constructivist model of teaching. The lesson was a good example of how teaching can help the development of the learners in their 'scientific-like' aspects. All peers agreed in this point during the analysis. Improvement in some particular situations were suggested and discussed.

A feeling of a greater interest and enthusiasm towards this "new" approach to teaching was easily perceived throughout the development of the process.

The last one to perform in this first cycle was S₁₂. After the previous lesson of this group they decided to "go back" and give more time to the stage of "anomalies introduction" and to conduct the lesson in order to help pupils to construct their own knowledge slowly but effectively. Although the behaviour of S₁₂ was a bit passive it was felt that she had 'got the message' and, with practice, she would be able to act as a constructivist teacher.

2. The second set of lesson (second cycle) and their analysis

As happened in the first year of part A of the main study, during the second cycle of the spiral of the action research process each student teacher made her/his task analysis of the pre-active phase and performed one lesson with the 9th grade. To widen the range of topics to be approached it was decided that four student teachers would perform lessons on the unit of "Optics" to two different group of pupils (two lessons to each group) and three student teachers would perform lessons on the unit "Force and mass" to one group of pupils (three lessons to this last group).

Due to time constraints in the second year of this experiment, these student teachers did not apply any diagnostic test or used other process for investigating pupils' ideas about "light" or "force and mass". They used the information gathered by their fifth year colleagues who had applied diagnostic tests, related to these concepts, to their pupils on their teaching practice. The purposes of, and the information gathered from, these questionnaires on "light and its properties" and "force, mass and weight" are presented in Appendices 8 and 9.

The report on the case of the seven student teachers in the second cycle of the spiral of the action research process will be made in a different and more concise way than the report on the first cycle. Differently, because, as during
this phase the task analysis of each lesson was of the responsibility of each student teacher who performed it, it allows for a report on the individual progress. In a more concise way, because having in mind the background information on the procedures of collecting and analysing data described in the report on the first and second cycle of the first year and on the first cycle of the second year, I hope the reader will have no difficulty in understanding the report of this phase. A detailed description of it would overload the content of this chapter without adding relevant information.

The lessons on the unit "Force and mass" were performed by $S_{10}$ (the first one), $S_{13}$ (the second one) and $S_{12}$ (the third one). The group of pupils who came to the university for this set of lessons consisted of 9th grade eleven girls whose ages ranged between 14 and 16 years old. Some of them were repeaters which means that they had failed the 9th grade the year before and were repeating it in the year of the experiment.

Because the three lessons had to have a sequence the three student teachers worked together on the selection of the content for the lessons.

2.1 The lesson performed by $S_{10}$

Before planning his lesson $S_{10}$ was told that the group of pupils with whom he perform the lesson had already worked on the concept of force in their classes. Taking this information into account he decided to select for the content of his lesson the concepts of "mass" and "weight".

The analysis of his task analysis of the pre-active phase and the inter-active phase revealed the following points.

a) In his decision on the nature of presentation and pupils activities $S_{10}$ showed a great awareness of the implication of pupils' alternative frameworks concerning the understanding of the concepts to be introduced. Thus, his strategy for approaching this lesson was essentially based on questioning that aimed at disclosing those alternative frameworks. Although he was already informed, through the results of the diagnostic tests applied to a similar population, he decided that it was important to help the pupils, during this lesson, to be aware of their own alternative frameworks when interpreting scientific situations concerning these two concepts, "mass" and "weight". During this process he considered, in his task analysis of the pre-active phase, that it would be possible to help pupils to develop scientific "abilities" such as self-confidence, critical-mindedness, consistency and efficiency. This, as he stated, would be achieved through opportunities in
which the pupils could freely expound their ideas and discussed them with other peers. He saw his role as promoting and guiding the discussion, helping the pupils to be aware of their own consistency when refuting other arguments and their efficiency in pursuing the task of helping others in their conceptual change. He also stated that the strategy would help to develop in pupils their skills of communication, prediction and inferring as well as to help them to progress in their intellectual and cognitive development.

b) His behaviour during the interactive phase supported the general opinion on his capacity to embark in a constructivist approach to teaching expressed by his peers and myself after his first performance in the first cycle of the process of action research. His teaching skills for acting within this approach improved because he was able to articulate, in his teaching experience, solutions suggested during the assessment of the previous lessons.

Very interesting situations developed during his lesson which highlighted the inefficiency of the traditional approach. The following small extract of the lesson will exemplify this point. The class (there were 11 pupils) was discussing the difference between "mass" and "weight". One girl, who was a repeater, found great difficulty in understanding the difference between the two concepts. One of her peers was trying to help her in her problem.

"G_1 - ...look .. Mary ... you are here .. on earth .. you have a certain mass and a certain weight OK?

G_2 - (Mary) .. yes .. they are the same

G_1 - now suppose you are lucky .. and you go to the Moon ... your mass will be the same right? .... but your weight .. because you are in the Moon will be different ..

G_2 - no .. no I can't accept that .. I'm the same person here or on the Moon, my weight will be the same I can't see why should I be different!

G_3 - but don't you see that the weight has to do with the pulling of the planet in which you are?

G_2 - (Mary) .. but here on earth my mass is the same as my weight ..

G_1 - .. yes because ... or ... no ... the number is the same ... but one is mass and the other is force

G_4 - ... and the force depends on the attraction of the planet in which you are!!

The discussion went like this and, without teacher intervention. Mary understood, at least, the difference between the two concepts. The point I would like to focus on is Mary's reluctance to accept the fact that her weight on the Moon would be different ... "I'm the same person here or there!...". This shows how resistent her alternative concept of weight was and how it was untouched
Another point, related to this particular bit of the discussion, very much stressed by S11's peers in their lesson's analysis, was the fact that Mary developed her concepts of mass and weight helped by her peers and without the teacher's intervention. This provided good opportunities for other pupils to develop their capacities of communicating, self-confidence and consistency. This opportunity would be lost if the clarification between the two concepts had been made by the teacher.

The immediate feedback on S11's performance was given by the pupils who, after the end of the lesson, stayed in the room talking with the student teacher about some of the problems which had arisen during the lesson and expressing their enthusiasm for the way the topic was approached.

Once again this student teacher provided a good example of a lesson conducted in a constructivist approach. All her peers commented on that. They were also able to identify point situations that could be improved.

2.2 The lesson performed by S13

The same group of pupils came back a week after the lesson performed by S13. In co-ordination with the content taught in the pupils' class at their school, S13 selected the problem of mass and force measurement for the content of her lesson.

The review of her task analysis of the pre-active phase and the interactive phase produced the following information.

a) Her task analysis revealed a very deficient reflection on the analysis of the aims and objectives in order to establish a link between them, as well as a very weak exploration of the potentialities of the content for the development of some scientific process skills. In her decisions on pupils activities she planned activities in which pupils should make mass and force measurements using beam and spring balances, but the objectives of these activities were not clearly stated revealing that they had not been thoroughly thought out beforehand.

b) She started the lesson by questioning to consolidate the "new" conceptions. It was a kind of "conceptual articulation stage" in which the pupils participated actively. During this phase her performance was not bad at all. To some extent, she used the same strategy that she had used in her first performance. But, then, when the activity changed and she introduced the different apparatus of measure-
ment, she was unable to transfer to this situation the approach she had initially used. Using a OHP transparency showing a beam balance's diagram, she shifted her approach to a more traditional one, describing herself what was in the transparency and revealing great difficulties in her scientific background as well as in her capacity of communication. The awareness of her own difficulties made her act in a still more confused way and soon she got lost. She decided, then, to end the lesson more than 20 minutes before the due time. It was interesting to observe the reaction of the pupils when she changed the approach. While in the beginning they were participating actively in the lesson, they turned to passive receptors immediately after S13 has changed the approach. This was so evident that even S13 was able to detect it, which contributed to her confusion and her decision to end the lesson early.

c) Her confusion and her frustration were so apparent that it fostered sympathetic attitudes toward her in some of the pupils. These attitudes explicited by sentences like "it's alright", "don't be upset", "we understand this" are understandable within the context of the pupils' role in these sessions. They would be different surely if the pupils were in their normal classes at their schools. This aspect was already pointed out in Chapter 5, section 5.4.3.

d) The weakness of her performance was interpreted by her peers and by herself as being due mainly to two factors. First, her inability to make the transfer from teaching situations already experienced to a new one. Secondly, to her deficient subject matter mastery. Although high level physics was taught to her at the university, she still found difficulties in the interpretation of very basic principles and concepts.

e) The case of S13 is an interesting one, in the sense that although she changed her perspective on teaching she was unable to behave accordingly. Nevertheless she was well aware of her inability and felt herself in such an uncomfortable position that she decided to end the lesson. On commenting about what happened in this lesson, all the student teachers conveyed the feeling that it was easier to say what should be done and to point out what should not be done in a constructivist approach than actually to practice and act within it.

Notwithstanding, the discussion which arose during the analysis of the videotape of the lesson was very fruitful in suggestions of alternative ways to use the same content to achieve some of the aims proposed.
2.3 The lesson performed by $S_{12}$

A week later eight of the eleven girls came again for the lesson performed by $S_{12}$. It was said that the three girls who did not come were very busy with tests at their school and consequently were unable to come. It could also be interpreted as a loss of enthusiasm in consequence of the last session.

The content selected by $S_{12}$ for her lesson was "Hooke's Law".

The review of her task analysis of the pre-active phase and the interactive phase revealed the following points.

a) $S_{12}$ decided on an experimental approach to this topic. It was apparent from her task analysis that a deep reflection had taken place on the scientific "abilities" that could be developed through this content. It showed a concern to use these kind of experimental activities as a means to develop the learner in her/his 'scientific-like' aspects in contrast with its current use as a means to develop a "recipe following robot". Her task analysis revealed a very accurate view of what could be developed in situations like the one she proposed to provide.

b) An improvement in her teaching skills since her last performance was also apparent. She was able to articulate the feedback she got either from her own previous teaching experience or from her peers' experiences. At the beginning of the lesson she posed the problem. "What do you think it would happen to a spring like this one if we hung on a weight in its bottom?", "How could you know the relation between the extension and the load?", "Could you design and plan an experiment to find out that?", "What do you need?", "Make it and draw your conclusions".

She divided the pupils into groups of two and provided the material asked by the pupils. It was not difficult for her to realize beforehand what materials pupils would ask for.

No worksheets were provided. Her role was to circulate among groups, stimulating their work, helping in some more intricate situations, guiding some poorly planned attempts, but not saying what to do or not do. Each group worked on its own pace and by the end of the lesson only one group wasn't able to draw conclusions on its work.

Throughout the lesson opportunities were provided for the development of pupils' scientific "abilities" of critical-mindedness, self-confidence, team-work, consistency, efficiency, observing (accurate and systematic), designing, planning and performing experiments, recording, organizing and interpreting data, manipulating and communicating.
c) During the analysis of her lesson some doubts arose on the applicability of the same strategy to a normal class comprising in average of 30 pupils. This can be answered by each one of them only when they are practising it in their future real classroom situations.

2.4 The lesson performed by Sg

A different group of six girls came to the university for the lessons performed by Sg and S7. The lessons were spaced by one week. Optics was the topic selected for these two lessons.

The review of the task analysis of the pre-active phase and the interactive phase of the lesson performed by Sg produced the following information.

a) Sg chose three questions upon which the lesson would revolve: "How can we see objects", "How can we prove that light is energy?" and "How can we prove that light travels in straight lines?". Through questioning, class discussion and group-work he proposed to develop pupils capacities of critical, inquisitive and creative-mindedness, "abilities" of group-work, self-confidence, formulating experiments, manipulating and communicating. However his main purpose for the lesson, as he stated in his task analysis of the pre-active phase, was to help pupils to be aware of their alternative frameworks when interpreting optic phenomena, to progress in their intellectual and cognitive development and to appreciate physics as an activity of interest to everyone.

b) Aware of pupils' intuitive ideas about "light and its properties" through the information gathered by his colleagues in their teaching practice, Sg evolved a lesson based on that information. Through group discussion provoked by questioning he was able to elicit the alternative conceptions that these particular pupils held and to help them to an awareness of them. It was noted that an improvement in Sg's teaching skills to handle the problems emerging during the "raising of conceptual awareness" step of the teaching process took place. He felt more at ease, as he told us, than in his first performance. Opportunities were provided for the achievement of the aims proposed.

During the analysis of the lesson all the student teachers conveyed the feeling that they were getting self-confident in dealing with the problem of alternative conceptions providing that, in some way, they could know them beforehand.
2.5 The lesson performed by Sj

The content for this lesson was selected by Sj in co-ordination with the content selected for the previous lesson. The two student teachers Sg and Sj worked together on this issue.

The review of the task analysis of Sj's lesson and the interactive phase revealed the following points.

a) There was evidence in Sj's analysis of the pre-active phase of a concern to raise the conceptual awareness of pupils relating the concept of light. The influence on his planning, of information on pupil's ideas about concepts such as, source of light and light, luminous sources, illuminated objects and the mechanism of visualization. The strategy chosen for the approach to these themes was also based on class discussion and on the introduction of anomalies. The link between objectives and aims was well established for some of the aims stated.

b) Throughout the lesson it was apparent that there was difficulty met by Sj in conducting the lesson on a constructivist approach. Although some improvement on his teaching skills was evident comparing this performance with his last one, he still found it difficult to create a relationship between pupils and himself which allowed pupils to freely expound their own ideas. He was a very rigid person. His tendency to ask questions but not wait for answers was too strong to be easily abandoned. It was also evident that his deficient scientific background prevented him from facing the problems posed by pupils. In these circumstances it is safer to be the teacher doing the talking rather than the pupils. This point was considered in detail during the analysis of the lesson and all the student teachers stressed the importance of mastering the subject-matter before embarking on a constructivist approach to teaching. Not that it is not important for any teacher of any style to be expert in the subject-matter to be taught and learned, but the need for this expertness is raised to a high level in this kind of approach. In a traditional approach the teacher is the authority and s/he knows everything s/he says or at least s/he thinks s/he knows. Knowledge is not questionnable by pupils. There is no danger that the teacher's discourse will flow to scientific areas not well understood by the teacher. In a more constructivist approach lessons are not restrictive to the subject-matter prepared by the teacher. Lessons are not so closed and knowledge is being negotiated rather than a commodity being transfered.

This feeling was conveyed by all the student teachers and I am sure it was a very uncomfortable one. The words of one student teacher reflected the
feelings of his colleagues:

"Really .. I'm telling you ... it's sad but I'm realizing that if I want to teach physics in this way ... honestly I feel I need to start to learn physics from the very beginning".

2.6 The lesson performed by Sg

Another different group of 9th grade pupils came to the university to attend the lesson performed by Sg. This time the group comprised four boys and one girl. Three boys were repeaters and they took a very uncooperative attitude, not helping in the creation of a supportive atmosphere. This presented some difficulties to Sg, and also to S11 who performed the next lesson to the same group a week later.

Optics was also the topic selected for these two lessons. Knowing, a priori, that the class to which this group of pupils belonged had not started the learning of this unit, the student teachers Sg and S11 worked together on the selection of the topics to be approached.

The review of the task analysis of the pre-active phase and the interactive phase of the lesson performed by Sg revealed the following points.

a) This lesson being on introduction of a new topic, Sg planned it to be based on the information about pupils' intuitive ideas relating to the interpretation of optic phenomena. The source of this information was the diagnostic test applied to pupils by the group of student teachers doing their teaching practice at that time.

His task analysis showed a good reflection on the potentialities of these type of lessons for the development in pupils of some scientific "abilities" such as inquisitive, critical and creative-mindedness, consistency, efficiency, designing, planning and performing simple experiments to test their own ideas, manipulating, predicting and inferring whilst being helped to be aware of their own alternative frameworks.

Participation in class discussion, designing, planning and performing experiments in order to test their ideas were the main pupils' activities planned.

b) At the beginning of his performance, Sg was surprised by the reactions of the three boys who were repeaters. When he started to make open response questions aimed at disclosing pupils' ideas, he was faced with one of the five patterns of outcomes from the interaction of children's science and their teacher's
science identified by Gilbert et al. (1982). I'm referring to "the mixed outcome" in which the learners' views are a mixture or amalgam of children's science views and teachers' views. The three boys answered Sg's questions using scientific terms and a scientific discourse that hid their own ideas from the unaware student teacher. As Sg did not expect that, he started to get lost. During the first part of the lesson he showed some incapacity to cope with the situation. His mind was in some way blocked by it and he was not able the think of the best way to conduct the conversation. He spent too much time going around issues that were irrelevant to the purposes stated for the lesson. Only near the end of the lesson was he aware that at least 3 pupils did not hold the model that light is something that exists and propagates in space, apart from sources and effects. Not holding this model these pupils were unable to understand phenomena, such as, reflection and refraction on which, because of the first intervention of the repeaters, he spent most of the lesson time. Due to this fact there was not time to involve pupils in the designing and performance of experiences to test their own ideas.

The situation was a new one in respect of the whole set of teaching situations with which they had experimented. It had been already considered theoretically when the analysis of the research paper by Gilbert et al. (1982) was made, in the awareness stage, but it had never happened in practice. It provided a good opportunity for the student teachers to acquire a deeper understanding of its implication for teaching.

2.7 The lesson performed by S11

Evidence that the "raising of conceptual awareness step" of the instructional process had not been completed in the last lesson, was provided by its observation and analysis, made by all the student teachers. Despite this, S11 selected as content for her lesson "Laws of reflection".

The review of the task analysis of the pre-active phase and the interactive phase produced the following information.

a) S11 decided to approach the study of the laws of reflection based on experimental work. The pupils would be involved in group work and, according to her task analysis of the pre-active phase, the teacher's role would be to guide the experiments through questioning. She stated as aims for the lesson some of the scientific "abilities" which could, in principle, be developed through this kind of activity. No reference was made to any worksheet to help the planning and organization of data. Her task analysis of the pre-active phase seemed compatible with the perspective toward teaching she had been expressing during our discussions.
both during the awareness and interest stages and during the trial stage.

b) Her teaching behaviour during this lesson was inconsistent with the state-
ments of beliefs and perspective toward teaching she had made during our
discussions. She conducted the lesson by a traditional way of doing experiments.
Each pupil was given a worksheet describing all the steps of the experiment. The
two first year 9th grade pupils were actively involved in following the recipe but
were unable to draw any conclusions. The three repeaters made the experiment
and enunciated the law, not as result of the experiment but because they knew
it by rote. Near the end of the lesson she told them about the second law and
asked them if they had understood. They all said "yes" and she finished the lesson.

This lesson was such an "event" that I could not resist talking to the
pupils in front of $S_{11}$ and asked the repeaters if they had performed the same
experiment before. They said "yes, in the same way although with more sophisti-
cated apparatus". Then I asked them to explain me what they understood by "the
incident ray, the normal to the incident point and the reflected ray are in the
same plane". Neither of the pupils were able to explain what did that meant.

After pupils had left I asked $S_{11}$ for her perceptions on the lesson.
She told me that she did not understand why the pupils didn't learn, she found
the lesson interesting and was her conviction that they were performing the experi-
ment very well.

Then we heard the comments of her peers. They all were in complete
disagreement with the way she had conducted the lesson and the way she had
approached the study of the topic selected.

Of this cohort of seven student teachers, who participated in the
second year of part A of the main study, $S_{11}$ was the only one who did not show
improvement in her teaching skills during the course. Although her perspective
toward teaching did change (during the analyses of other performances she was
very critical, able to suggest alternative strategies toward a more constructivist
approach) her teaching behaviour was not an expression of her beliefs. Tabachnick
and Zeichner (1985) identify classroom behaviour as an expression of a teacher's
beliefs or implicit theories about teaching and learning. I agree with them when
teachers are working in a period that could parallel Kuhn's idea of "normal science".
In a period that could be called "perspective revolution" by analogy to Kuhn's
period of "scientific revolutions" it may happen that some inconsistencies or dis-
crepancies between teachers' new perspective and their behaviour in classroom
situation actually emerge. It is my belief, and some findings of this part of the
study supports it, that it is easier to change perspective than to change behaviour.
It is easier to say how it should be done than to do it. The case of S\textsubscript{11} is an example of this. Only when watching the videotape and discussing the weak points of a lesson, in the light of a constructivist perspective, did she recognize that the strategy used was not compatible with that perspective. Her case illustrates the difficulty faced by many teachers when they try to transfer innovative methods perceived by them as possible solutions to perceived problems. I see as sources of those difficulties to be the strength of tradition, habits, lack of time to undertake a reflective analysis on the best strategies to achieve desired aims and the consequent reliance on available textbooks. But, above all, I think that lack of creative power is the main source of difficulties. Creative power to design, plan and perform teaching situations in which the implicit theory held by the teacher, or student teacher, in a state of temporary level of psychological stress (equivalent to a state of crisis or state of change), could be put into practice. Student teachers, as well as teachers, need to be helped to develop this power. In the particular case of S\textsubscript{11} she received help through the opportunities provided, namely the reflective analysis and discussion of lessons. This means support by colleagues and supervisors, which is lacking in the case of most newly-qualified teachers launched alone into schools with packets of materials for the implementation of new curriculum.

6.3.4 The evaluation stage

As Rogers (1967) points out, the evaluation stage is probably the least distinct of the five adoption stages. Different types of evaluation occur at each stage in the adoption process, but the decision to adopt the new idea occurs, by definition, only at the evaluation stage. Rogers stresses the fact that the evaluation stage is empirically one of the most difficult about which to question respondents. An effective component of behaviour, a favourable or unfavourable feeling toward the "new" idea or perspective built throughout the previous stages, is evolved at the evaluation stage.

The main sources of data for the analysis of this stage in the individual adoption process of each student teacher were: (i) their responses to the questionnaire concerning their perception of the learning experience provided by me. The questionnaire is presented in Appendix 10. The reasons for the choice of this instrument of data gathering was already mentioned in Chapter 5, session 5.5. The data is presented in Appendix 11; (ii) their responses to a questionnaire concerning the perception of their own development of scientific "abilities". The questionnaire is presented in Appendix 12. The data is presented in Appendix 13; (iii) my own
observations and notes concerning the development of student teachers' perspectives toward teaching and the development of their teaching skills.

6.3.4.1 Each student teacher

1. Student teacher Sj

The analysis of the data relating to the evaluation stage of student teacher Sj produced the following information.

a) At the end of his learning experience Sj gave the following answer to the question "What does 'teaching physics' mean to you?"

"To foster enjoyment of physics. To develop and stimulate a certain number of "abilities" that we think are important. To help the pupils' integration in society. Specially to develop in them social habits, such as the skill of communicating. To contribute to a better understanding of the world and nature".

His second answer to the question initially put at the beginning of the course on "Physics Didactics", (the first is transcribed in sub-section 6.3.1 of this Chapter), revealed a broader reflection on the aims of physics teaching at general educational level. The role of teaching is seen in a social context. The approach to physics teaching is viewed in a social pedagogical aspect which, according to the findings of the preliminary study, can be seen as a more useful and valuable way of teaching physics at that level. The answer showed an awareness of the role of physics teaching in the development of the individual as a future citizen. Sj recognized his different perspectives on the physics teaching before and after his learning experience. Commenting on this he wrote:

"I'm convinced, now, that being a physics teacher can turned out to be an interesting profession. More important it is possible to lead pupils to the discovery of physics by themselves and therefore to help them to progress in their intellectual and cognitive development".

This statement conveyed the feeling that before this learning experience his perception of being a physics teacher was not very satisfactory to him. It is a widely spread feeling among youngsters, and newly enrolled students at the university, that to become a teacher is to enter a very boring and uninteresting occupation. This was also elicited by the analysis of the protocols of the interviews with pupils at the different levels of their schooling. Even among the student teachers interviewed, only a small number, at the beginning of their degrees, wanted to become teachers. For the majority of them circumstances "pushed them" into degrees leading to a teacher profession and they were, to some extent,
resigned to the idea of becoming teachers. This situation does not hold only in Portugal. Clarke (1968) reports on analysis of essays written by sixth-form science pupils in Britain about the possibilities of becoming teachers. A large proportion of pupils commented on the monotony of a teacher's work, and on the low salaries and poor promotion prospects of teachers. There were given as reasons for not becoming teachers. Thomaz (1980) through an enquiry involving 10th, 11th and 12th grade pupils from the areas of natural sciences and technology found the main reason for not becoming teachers to be the routine view they hold of the teaching profession.

In his statement Si revealed a shift on his perception of "being a physics teacher". After his learning experience he faced his future job with some interest. This was considered by me to be the achievement of an aim of the course.

b) The second statement in his answer, "it is possible to lead pupils to the discovery of physics by themselves and therefore to help them to progress in their intellectual and cognitive development", conveyed the idea of the pupil as being a contributing partner in his own learning. It revealed a concern to place the teacher's role in a more human and responsive one than the role of provider of information or "shaper of inert material" (Fox, 1983). It can be seen as a more constructivist view on science education. And it is when learning by herself/himself, being 'herself/himself the meaning-maker' that pupils progress in their intellectual and cognitive development.

c) As already stressed, Si was a very self-confident person. According to him there wasn't any development in his self-confidence during the course. When asked if he felt confidence in his capacity to develop scientific "abilities" in his future pupils he answered yes and quantified it as four on the five-point scale, showing a good degree of confidence (see Appendix 13). His view supported mine concerning his capacity for teaching within a constructivist approach to teaching. He did not show difficulties in progressing through the course, as he also reported in his answer to the questionnaire.

Si's answer concerning the relevance of his learning experience to his professional life also conveyed a constructivist perspective toward teaching. Explaining why he found it relevant he wrote:

"Because I got aware of my own difficulties although I feel I'm able to overcome them. Thus I'm sensitized to pupils own difficulties and I'm much more prepared to help them".

d) The analysis of his self-perception on his own development of scientific "abilities" revealed that he identified two main items in which he felt he had
achieved the greatest progress. The capacity of being aware of his personal frameworks in scientific observation and an appreciation of science as an activity of interest for the common person were both rated as four. These were followed by team-work, rated as three. As already pointed out, S1 showed a very good development of scientific "abilities" at the beginning of the course. Nevertheless his great distress was apparent when, through the opportunities provided, he realized that he was not aware of some intuitive ideas he still held which, after fifteen years of schooling, had remained unchanged. This discovery will, probably, help him to figure out situations, during his interaction with his future pupils, in which pupils' intuitive ideas can be elicited.

The development of his capacity for team-work let him to become aware of some crucial problems involved in this kind of activity. At the beginning he was a very commanding person, taking the leadership of the group. He was the person who had always the last and valid word. Throughout the group sessions, either with the whole group or when working with his group (S1, S3 and S4) his behaviour changed, partly due to the open climate of the group discussions, (where people could feel the necessity for critical analyse of situations and the need to express their own views consciously, with honesty and respect for other's views), partly due to peers' feedback, and also partly to his capacity for the critical analyse of his own attitudes once aware of them. A shift in his behaviour was apparent by the end of the course. His capacity of team-work improved. He was then able to listening to others, respecting others' ideas, using others work and so on. Of course, this change was also reflected on his performance as a teacher, as elicited from the analysis of his performances. At first he acted as a traditional teacher. He was the authority, the only one who talked to a passive audience of pupils. The analysis of his second lesson showed a great improvement in his teaching skills for the conduct of a class discussion in which every pupil could actively participate.

An interesting point relates to his perception of progress in his capacity to appreciate physics as an activity of interest for the common person. Although at the beginning of the course he already held positive attitudes toward physics, he did not feel that the common person should or could see interest in physics. This is a common feeling among both physics students and physicists. Usually physics is a subject matter considered to be accessible, or of interest only, to a selective group of individuals. This is one of the reasons, if not the reason, for starting physics teaching only at the 8th grade. In some way this view reflects the "cultural transmission" perspective on physics teaching. When looking at it
in a different perspective, when using physics content to develop common people's scientific "abilities", i.e., developing their 'scientist-like' aspects, one can then appreciate physics as an activity of interest for everyone.

2. Student teacher S2

The analysis of the data relating to the evaluation stage of student teacher S2 revealed the following points.

a) The answer given by S2 at the end of the course to the question "What does 'physics teaching' mean to you?" although a very succinct one "it is to help in the understanding of the world around us leading us to the causes of events"

revealed a more determined view about the meaning of teaching physics than the one expressed at the beginning of the course (transcribed in sub-section 6.3.1 of this Chapter). In her explanation of the differences between the two views she stressed one of the feature of her new perspective towards physics teaching

"Before the course, 'to teach physics' was, for me, to convey knowledge which we can get in books without seeing the link between that knowledge and the reality around us, memorized knowledge, formulas and definitions. Now I can see that link".

Reflecting on this S2's statement a why-type question emerged. Why did S2 say that only after the course she could see the link between teaching contents and the reality around us? Why did she change her view of teaching in such a short period of time (less than five months) in which she was involved in this educational practice? What made her change her view? It seems to me that the approach given to this course might have contributed to the change. There was not either a body of knowledge to be transmitted or rules or norms for acting to be acquired. Through a process of awareness, interest, trial and evaluation student teachers were construing for themselves a new model of teaching based on assumptions different from the ones underlying the traditional one. Throughout the process student teachers became aware of the necessity of developing in themselves the scientific "abilities" they considered important to develop in their future pupils. It is interesting to note that although I did not "teach physics", S2 could see, as she said, through her teaching experiences, the link between teaching and what is going on around us. This point supports my beliefs that a constructivist approach toward physics teaching is a more valuable and useful one. If teachers are concerned with the development in their pupils of scientific "abilities" through physics content, the content itself will be more easily understood and assimilated. The learning situation will be easier and more enriched.
b) S2 was one of the four student teachers who express a lower degree of confidence in being able to achieve the aims proposed for their teaching. A possible interpretation of her feeling can be the following. She was the first of the second group to perform a lesson to 8th grade pupils. Due to time constraints she didn't perform later to 9th grade pupils. Although she had performed a lesson to 10th grade pupils at the earlier part of the teaching activities, her last teaching experience was in a simulation situation in which her peers acted as pupils. As I have already stressed in Chapter 3, section 3.3, this technique can raise very disturbing situations for student teachers. This was, to some extent, the case of S2. Thus, at the end of the course, she really did not feel a great confidence in her teaching skills. Notwithstanding this she was very participative in the analysis of her peers' performance, suggesting alternative strategies to achieve the aims stated for the lessons, being able to pinpoint the appropriate teaching skills for a constructivist approach to teaching. Unfortunately she did not have a chance to perform a teaching activity in which she could integrate solutions for improvement on the basis of previous assessment. Her case supports the claim that the approach used in this methods course can only be taken if the number of student teachers enrolled is small or the number of hours per week spent in the course is larger.

c) S2 thought the main cause of her difficulty in progressing through the course was her faulty scientific preparation. Teaching/learning situations in which pupils are stimulated to criticize statements, elaborate hypothesis, be creative, freely express their own ideas and the like, call for a strong scientific background in the teacher.

d) Her statement that what she learned during the course would be relevant to her professional life "because it will help me to teach in a more efficient way", revealed that she progressed through all the stages of the model of change without permanent rejection and that she had reached the adoption stage.

e) Looking at the histogram (Appendix 13) showing S2 self-perception on the development of "abilities" it is apparent that she perceived that these "abilities" were developed during her learning experience in the course. It is interesting to note that the items in which she perceived more development were C6 - communicating, D1 - be aware of personal frameworks in scientific observations, D4 - to get positive attitudes towards physics and D5 - to appreciate science as an activity of interest for the common person.
3. Student teacher S3

The analysis of the data relating to the evaluation stage of student teacher S3 provided the following information.

a) When comparing the answers given by S3 before and after the course it was interesting to note that, to some extent, the second one complements the first one. At first she wrote that

"teaching physics is intended to get pupils aware of physics phenomena, helping them to understand those same phenomena, so that pupils can explain them by themselves".

This statement conveyed the idea that she was stuck in a teaching's perspective centered on exterior phenomena, whereas her second answer, at the end of the course, revealed a more concern for the individual:

"... it must be a way of developing in pupils capacities, attitudes and skills, which allow them to have a better understanding and a better integration in the world!".

This latter view conveyed a more humanistic view of the teaching/learning process. Notwithstanding this, S3 did not show improvement in appropriate teaching skills, as can be elicited from the analysis of the activities that took place during the course. Why? The answer to this question is given, in some way, in her own answer when she was asked to compare her views before and after the course:

"I feel that it is very difficult to explain, since the change took place slowly, so it looks as if at this moment I'm unable to compare, although I find differences".

She was unable to critically analyse and explicit the differences she found. The answer given indicated, once more, some of her characteristics - her lack of inquisitive mind and lack of consistency. She was unable to point out the differences although she found there were some. It shows that if she was unable to identify the differences she was not really aware of them and consequently she could not perform accordingly to her last perspective.

Once more this behaviour supports my stance that, in order to teach within an approach aimed at the development in pupils scientific "abilities", one must have them fully developed in oneself.

b) S3 was the student teacher who rated lowest her degree of confidence in her capacity to teach within a constructivist approach. At least, in this evaluation she was consistent with her behaviour during the course.
c) The reason pointed out by S_3 for the difficulty she found in progressing through the course was her faulty scientific preparation. In my opinion it was not only that reason, but mainly her deficient development of the "abilities" she wanted to develop in their future pupils through her teaching.

d) The explanation given by S_3 in item 5.1 of the questionnaire, 'why did she think that what she had learned during the course would be relevant to her professional life', once more expressed her lack of critical and creative thinking. She wrote

"Although I feel it is more difficult to teach according to this model, and the results only can be seen after a long period, what I learned will have influence on my professional life".

According to her, the results of teaching within this approach can only be seen after a long period. This wouldn't happen if she possessed the creative power for developing adequate situations and design adequate instruments to assess teaching. Why and how what she learned will influence her professional life, is hard to say.

e) The histogram showing S_3 self-perception on the development of "abilities" showed that although she saw some progress mainly in A_2 - inquisitive mind and D_1 - be aware of her personal frameworks in scientific observations, she did not recognize any improvement in her capacity for team-work - A_5. In my interpretation, this fact was due to three factors. First, her first group did not work well, as already stressed, mainly due to S_1's initial behaviour. In that group she really did not find an environment favourable for the development of this capacity. Secondly, even when integrated in the whole group, due to her total dependence on her peers, these took a paternalistic attitude toward her which did not help the development of her capacity for team-work. A third factor was, probably, my behaviour as teacher who did not provide adequate conditions for that development and did not pay enough attention to it. I did not know them before the course and that did not facilitate my intervention in the formation of the group. I recognize, however, that before developing the capacity for team-work one should already have developed capacities of critical-mindness and self-confidence. This was not so in her case.

f) During the first four stages of the adoption process, S_3 did not reject the innovation at any stage. Nevertheless, it seems to me that she reached the adoption stage in a mental state not favourable to a successful adoption. Although she passed the awareness, and interest stage showing a great motivation, judging the utility of the innovation for the improvement of physics education and deciding that the advantages of the innovations outweighed the disadvantages, during the
trial stage something went wrong. She was not able to grasp what she should do in order to put the innovation into practice. Although some improvement could be perceived in her teaching skills, she needs strong support in her first years of teaching to fully adopt the innovation. This is a point that will be discussed in Chapter 9.

**Student teacher S₄**

The analysis the data relating to the evaluation stage of student teacher S₄, revealed the following points.

**a)** Comparing his view on "what is teaching physics" before and after this learning experience S₄ wrote:

"At the beginning I had a very traditional view of teaching. I mean, for me, teaching was only the transmission of content. The task of the teacher was to "give" the subject matter". Indeed this view is conveyed by his answer to the same question at the beginning the course

"teaching physics is to transmit a series of knowledge and to explicit concepts".

At the end of the course his new answer conveyed a different view

"It is to help pupils to understand the world around them and to develop in pupils capacities, attitudes and skills".

It revealed a shift in the focus of teaching from knowledge itself to the learner. According to his new perspective teaching must be more concerned with the pupils herself/himself than with the content itself. He recognized the relevance of what he learned during the course to his professional life because

"it changed my perspective toward teaching".

**b)** In his general comment on his learning experience he wrote:

"I think that my learning experience in this course was positive and now I know the way I want to teach. It gave me confidence concerning my future activity".

Nevertheless all of his performances were very weak and he recognized that. The main reasons for that were his lack of scientific knowledge and his great difficulty in communicating. He was very active during the pre-active phase; he carefully chose the strategies that, according to the content of the lesson, would more likely achieve the aims stated; he made reasonable complete task analyses; he went, with care, through all the stages of the pre-active phase, pre-
paring materials, testing experiments when needed, etc. Notwithstanding that, when faced with pupils, something was missing, namely scientific knowledge and the capacity of communicating.

c) He did not find difficulty in progressing through the course although according to the histogram of his self-perception on the development of abilities he did not recognize great progress.

d) He reached the adoption stage although, in my opinion, his teaching skills within a constructivist approach need a great deal of improvement.

5. Student teacher S5

The analysis of the data relating to the evaluation stage of student teacher S5 produced the following information.

a) At the beginning of the course S5 stressed that she did not know what "teaching physics" was. She only knew what teaching physics should not be and that was the way she had been taught. Her statement contained in itself a critical judgement on the traditional way of teaching, for she considered it as "not teaching". After the course "teaching physics" meant something different to her:

"In a broad sense it is to help pupils to develop all the capacities and skills we believe are important for them and possible to achieve through physics teaching. In a strict sense it is to help pupils to understand the world around them and to adopt personal stances on the technological progress and on its social and philosophical consequences!".

Her meaning for "teaching physics" reflects a concern with the individual; a way of helping pupils to become effective members of a democratic society. Not only preparing them to function intelligently and productively in the modern technical society.

When asked to compare her views before and after this learning experience her answer revealed a very determined stance and a very confident conviction, "... now I know what it (physics teaching) must be".

b) According to S5, what she learned during the course will be relevant to her professional life

"because this approach to physics teaching is much more interesting and I feel this is the way that it's worth while teaching".

After many years of being taught physics she found a more interesting way of teaching physics, the way she now feels worthwhile. This gives a good start to her professional career. If, as a result of a reflective activity, a teacher
arrives to a model of teaching s/he feels worthwhile teaching it is more likely that her/his pupils will enjoy the learning of the discipline.

c) She showed a high degree of confidence in her capacities to approach teaching within the "new" perspective rating it as four on a five-point scale. She progressed through the course, revealing a great improvement in her teaching skills in her last performance. This was recognized by her, her peers and myself. Also some comments made by the pupils at the end of her second performance add evidence of that improvement.

Student teacher S5, definitively reached the adoption stage with the adequate prerequisites for a sucessful adoption of the innovation.

d) Looking at the histogram showing S5 self-perception of the development of abilities, it can be noted that she felt that during the course, almost all the "abilities" considered suffered a great improvement. The ability considered to be less developed was C5 - manipulating. Due to the selection of contents for her lessons and time constraints, there were not many opportunities in which she could develop that scientific process skill.

6. Student teacher S6

The analysis of the data relating to the evaluation stage of student teacher S6 produced the following information.

a) The model of teaching she held at the beginning of the course, comparing with her peers', was a more developed one in Fox's sense (Fox, 1983). Teaching physics meant for her

"... to develop in pupils capacities which lead them to understand physical phenomena ... but how? ... I don't know".

Her statement revealed a certain anxiety and a consciousness of a lack of knowledge on how to achieve that aim. In her second answer, after the course she wrote:

".. it is to make easy the understanding of physical phenomena, helping pupils to develop their mental structure in order to do their own thinking".

In this statement she expressed a constructivist view on knowledge when she recognizes the relevance of pupils' own thinking to the understanding of physical phenomena.

When analysing her comparison between her view on "what is teaching physics" before and after the course it could be perceived that she did not have
a very precise idea of what kind of capacities she was talking about in her first answer. In his answer to item 2 in the questionnaire she wrote:

"Before the course I had never thought that through physics one could achieve aims such as, scientific thinking, creativity, critical thinking and many more. Now I know that this is possible and very possible!".

This statement conveys a feeling of self-confidence and a very deep conviction arising from her own experience.

b) Once more the cause of the difficulty found by S6 in her progress through the course was "faulty scientific preparation". This was a recurrent point focussed on by the majority of the student teachers.

c) The analysis of the histogram (see Appendix 13) of S6's self-perception on the development of "abilities" revealed that she felt, in general, a great personal self-improvement.

This improvement was really apparent throughout the course. An episode occurred during a lesson illustrates her capacity for self-confidence. S6 showed at the beginning of the course, a great lack of self-confidence. It seemed that she was afraid of giving her opinions. She was not confident in her capacity of handling the problems she was faced with. Somewhere in the middle of the course, when she was planning the lesson she was going to perform, she stopped working saying that she would give up, she was not able to carry on with the work, she could not do it, she was unable to perform the lesson and she did not feel any confidence on herself. I let her talk and when she finished, we, her peers and myself, tried to analyse with her, her reasons for acting like that. After some talk she overcame her problems and decided to carry on with the task. Some days after she performed the lesson. It was the first lesson on "optics". It really was a good performance in the sense that she used the strategies chosen to achieve the aims she stated for the lesson. After the lesson, her face showed her feelings. She was really pleased and full of self-confidence. When analysing her lesson she commented in a very convincing way .. "It is worthwhile to teach in this way".

d) S6 reached the adoption stage with good prospects of successfully implement the "new" model of teaching.

7. Student teacher S7

The analysis of the data relating to the evaluation stage of student teacher S7 revealed the following points.

a) In his second answer to the question "what does 'teaching physics' mean
"... it is to give opportunities to pupils in order to foster their interest for learning physics, helping them in their learning and research".

A comparison between this last statement and his first answer to the same question revealed a changed perspective on teaching and on the teachers' role. He, himself, recognized this when explained the difference between the two statements:

"I think that, concerning our expectations on 'teaching physics', something has changed after the course. We understand, at last, that 'teaching physics' isn't a matter of transmitting or explaining physics knowledge, but, it is a matter of stimulating, guiding and helping pupils' evolution in their physics learning".

b) Although he said he was confident in his capacity to implement the "new" model of teaching he was one of the student teachers who rated his degree of confidence lower. Actually the analysis of his performances revealed his deficiency in teaching skills needed to implement the model.

c) He found difficulty in progressing through the course, the main causes being "faulty scientific preparation", "faulty knowledge of theory of learning and teaching" and "insufficient time for preparation".

d) In his attempt to explain why what he learned during the course was relevant to his professional life he focussed on an interesting point. He wrote:

"Because I think this learning experience gave us something which was missing throughout the previous years of the degree: the interest for teaching physics and its practice".

The subject matter of this course being the teaching of physics, and by adopting a constructivist approach to the teaching of this course, one of the main aims stated for the course was to achieve "increased interest in teaching physics". This supports my belief that teaching physics within a constructivist approach helps the rising of interest toward the discipline.

e) The analysis of the histogram showing S7 self-perception on the development of abilities added evidence on the issue focussed above. D4 - to get positive attitudes towards physics and D5 - to appreciate science as an activity of interest for the common person, were the items in which he felt to have suffered a greater development.

f) S7 reached the adoption stage although I perceived that at the trial stage he was sometimes about to reject the innovation. It seemed to me that what made him progress through the adoption process was more in his peers' teaching experi-
ences than his own teaching experiences. In such cases it is more likely that a rejection will take place in a later, adoption, stage if enough support is not provided.

8. Student teacher Sg

The analysis of the data relating to the evaluation stage of student teacher Sg produced the following observations.

a) After his learning experience, Sg expressed his view on "teaching physics" as following:

"(it) is providing pupils with situations which help their development as a whole through physics content. For me this development as a whole implies the development of scientific "abilities" as much as possible."

On commenting on the difference of his views on 'teaching physics' before and after the course he wrote:

"the idea I got, after the experience provided by this course, is that instead of speaking of teachers it would be more correct to speak of supervisors. My concept of 'teacher' is of one who teaches centred in himself and by supervisor I mean the one who teaches starting from the learner's knowledge, by helping him."

Both statements revealed a shift in his perspective toward teaching from a traditional one to a more constructivist one. The last statement gives an interesting example of concept formation. The concept of teacher that he held due to his interaction with teachers during his own schooling entered into conflict with his new concept of teaching. Thus, the new concept of teacher was named "supervisor" which expressed his new perspective on teaching.

Since the beginning of the trial stage he showed a good grasp at the implication of the "new" model of teaching for teacher's behaviour in classrooms. He easily perceived what to do in the different situations in the lessons and was able to explore them in order to achieve the aims proposed. He entered the adoption stage with every intentions of implementing the innovation.

b) The main hindrance to full performance within a constructivist approach seems to have been a certain lack of confidence in his scientific preparation. This was identified by him when seeking causes for his difficulties in progressing through the course.

c) He recognized the relevance of what he learned during the course because, in his own words,

"Due to opportunities for reflecting first, I was helped to see teaching as something different. Thus, a priori, I'm aware of problems I never thought could emerge during teaching".
Lurking behind this statement is the importance of using, in this kind of course, educational research papers as sources of information.

d) The histogram showing Sg's self-perception on the development of "abilities", (see Appendix 13), revealed that, in general, he felt a great development in all of them, the lesser rated being the capacity for team-work. This is consistent to what happened during the course and already stressed at the sub-section 6.3.

9. Student teacher Sg

The analysis of the data relating to the evaluation stage of student teacher Sg revealed the following points.

a) A shift in Sg's perspective towards teaching could be elicited through the comparison of the two answers to the same question put before and after the course. In his second answer Sg wrote:

"For me 'teaching physics' is to help the development in pupils of scientific "abilities" (e.g. communicating, predicting, etc.). It is to start teaching from ideas pupils already hold, helping them to clarify them and if necessary helping them to develop those ideas to more scientific one."

Then he tried to explain the difference between those two views;

"Before the course I conceived 'teaching physics' in the same way that I had been taught. Now I understand it in the way I mentioned above. I think that through physics teaching the scientific "abilities" we considered important can be developed in pupils if we teach within the same approach that we have been trying to experiment with."

b) Although, of the student teachers who found difficult in progressing through the course, Sg was the one who rated lowest item 5.1 in the questionnaire (why he thought that what he learned during the course would be relevant to his professional life). This also reflected the implications of faulty scientific preparation on the implementation of a constructivist approach. In his answer he wrote:

"It will be relevant because not only it helped me to face teaching in a new perspective, but it will also made me aware of some of my own deficiencies concerning scientific knowledge and the way I express myself. I think that all of us need to work hard in this field in order to acquire confidence to teach within this approach."

This was also a recurrent point focussed on by all the student teachers throughout our sessions of reflective analysis on the situations which emerged during the course.

c) In general he felt a great improvement in his "abilities" to have occurred
by the end of the course. This is shown through his histogram. Nevertheless, in
my perception, I did not think that his skill of communicating improve that much.
This point was discussed between us and he recognized the necessity of making
an effort on this point.

d) In his general comment on his learning experience he focussed on a point
that supports my belief in one of the advantages of a constructivist approach
to teaching. He wrote,

"I think this experience was very useful because it helped me to re-acquire
my self-confidence I think it happened not only with me but also with my
colleagues, I think this self-confidence has been reduced by the way we
have been taught, In this course I learned (I think) to view physics teaching
in a new perspective. It made me rethink my own way of learning, my own
way of interpreting phenomena. Not only to study for passing exams but
to study for understanding the basic concepts, to progress in my cognitive
development and to get enough confidence in my scientific background
in order to teach within this new approach. The course allowed me to become
acquainted with other teaching methods, different from the traditional
one and to look at pupils in a different way, looking at them as beings in
development".

This emphasis placed on the process of "personal development" is
central to the constructivist approach to teaching. It is my belief that, by working
within this approach, teachers support the development in their pupils of scientific
"abilities" such as, for instance, self-confidence.

e) As can be seen from the earlier analyses of the progress of this student
teacher through the four first stages of the adoption process, he reached the
adoption stage in a state of great awareness of the difficulties that he needed
to overcome.

10. Student teacher $S_{10}$

The analysis of the data relating to the evaluation stage of student
teacher $S_{10}$ produced the following information.

a) The identification made by $S_{10}$ of the difference between his two views
on "what is teaching physics" before and after the course brought up a very impor-
tant issue in physics education. In most teacher training programs the emphasis
is on "what to teach" and "how to teach". If, before embarking on a teaching situ-
ation one asks himself "why to teach", the "what" and "how" to teach follow as
a consequence of the underlying assumptions of the answer to the first question.
In S10 own words, "until this learning experience I didn't know 'why' to teach physics. Now I think I know it. Now I see teaching as a means to help the development of the pupils".

While in his first answer, given before the course, he showed a self-centered perspective on teaching, the second one, although revealing a self-concern with his scientific preparation, conveyed the idea of teaching as a necessity for helping pupils' development. In his second answer he wrote:

"For me teaching physics' is to be sure and confident in scientific knowledge, mastering it in order to be able to help pupils to develop the scientific 'abilities' which I consider important".

b) A latent concern with his faulty scientific preparation was conveyed through all his answers. This concern is apparent lurking behind the explanation he gave of the relevance of his learning experience to his professional life. In his statement he wrote, "Because it 'opened my eyes' to certain problems, already mentioned, that I wasn't still aware of".

c) By looking at his histogram in general S10 perceived improvement in all his "abilities" after the course.

d) The philosophy underlying the conduct of this course on "Physics Didactics" demanded the creation of situations which enabled the individual student teacher to take over control of her/his own "development", at the same time achieving an increased effectiveness in her/his teaching strategies. To some extent, the general comment made by S10 at the end of the questionnaire supported this philosophy. He wrote:

"Despite being a short experience I enjoyed it because I identified myself with the aims proposed at the beginning of the course. On the other hand, I got a awareness of the responsibility of teaching others, the effort teachers are asked of either in the scientific or pedagogical area. I consider this experience highly positive, the most important of my school life, this because it was here that I identify myself with this way of teaching. Summing up, it was in this experience that I knew what physics teaching is about".

e) S10 progressed through the adoption process to the adoption stage led to the acquisition of teaching skills appropriate for a successful implementation of the innovation.

11. Student teacher S11

The analysis of the data relating to the evaluation stage of student teacher S11 revealed the following points.
a) The comparison of the two answers on "what does teaching mean to you" given before and after the course showed the shift in S11's perspective toward teaching. In her second answer,

"Teaching physics is to help pupils to understand the surrounding world in a better way, developing in them abilities which will help them to act in their future life in a more scientific way"

she touched, in my opinion, on a very important aim for science education. Not only should pupils be helped to understand the surrounding world but they should be helped to develop "abilities" which allow them to act in life in a more scientific way - helped them to deal with change.

The difference between her two perspectives toward teaching was expressed by her as follows, "Now I have become conscious of the importance of teaching". It conveyed her feeling that "... trying to help pupils learn basic concepts of science..." (in her first answer) wasn't as important as "... to help (pupils) to act in life in a more scientific way" (in her second answer).

b) Although she rated her confidence in her capacity to develop in her future pupils scientific "abilities" to a high degree her performance did not reflect that confidence. As already pointed out, although this student teacher had heard the message conveyed by the innovation she showed great difficulty in implementing it in practice. When asked to make a general comment on her learning experience, she imparted the idea that the "new" perspective could be, perhaps, more theoretical than practical. She wrote;

"I think this course helped me to be aware of what physics teaching should be about. Now I see teaching in a different way, although it seems to me that the teaching experience I had is a bit unreal".

c) The main causes of the difficulty she found in progressing through the course were pointed out by her as being: faulty scientific preparation and insufficient time for preparation.

d) She perceived, as is shown by her histogram, a great improvement in the development of her own "abilities".

e) S11 did not improve her teaching skills to an appropriate level to make the adoption of the innovation successful unless she got strong support from others, including supervisors and/or colleagues during her teaching practice and first years of professional life.
12. Student teacher $S_{12}$

The analysis of the data relating to the evaluation stage of student teacher $S_{12}$ produced the following information.

a) The comparison of the two answers given by $S_{12}$ to the question "what does teaching physics mean to you" revealed an important aspect of her change in perspective. Her first answer imparted a traditional perspective toward teaching, "to make the pupils understand the world around us". In her second answer, the same thing is viewed as a means to help the development of the learner. In her second answer she wrote,

".. (teaching physics) is to help the development in pupils of scientific capacities through the interpretation of everyday phenomena. It is also providing pupils with opportunities to disclose their ideas, their doubts and their problems, leading then to progress in their intellectual and cognitive development".

A shift from content- to a learner- development oriented teaching can be elicited from the comparison of the two statements. The last part of the latter statement reflects a concern on the process of personal development starting from what is relevant for the learner, from what ideas s/he already knows.

The same idea is reinforced by her statement about the differences she perceived between the two perspectives,

"Throughout the course I discovered a much more interesting and stimulating way of teaching physics that the one I had been taught. I discovered that it is always possible to relate physics content to everyday phenomena. Maybe it is more difficult, but I got the idea that pupils will be more interested in learning if teaching is centered on them and not seen as a transmission of knowledge".

b) She felt confident in her capacity to develop in her future pupils scientific "abilities", rating her confidence highly. This confidence is also expressed when she explained why she found what she learned during the course relevant for her professional life. In her own words this was, "Because it (the learning experience) helped me to discover a more interesting way of teaching physics which will make me feel more stimulated to teach and confident because I think I will be able to do it".

c) Faulty preparation in knowledge of theory of learning and teaching and faulty preparation in scientific knowledge were the two reasons pointed out for her difficulty in progressing through the course.

d) All her "abilities" were felt to be developed throughout the course, the highest rated being: the capacities of creative-mindedness, team-work and self-con-
fidence. The development of the last one was certainly perceived by me through her change of behaviour during the group discussions on lessons analyses.

e) This student teacher reached the adoption stage with appropriate teaching skills in a good state of development.

13. Student teacher $S_{13}$

The analysis of the data relating the evaluation stage of student teacher $S_{13}$ revealed the following points.

a) During the course $S_{13}$'s meaning for "teaching physics" changed from "... to transmit basic concepts to pupils ..." to "... to help pupils to develop abilities' which are important not only for the development of pupils in a scientific way, but, also and more important, for their development as human beings". This idea is reinforced by her statement about the differences between the two views. According to her,

"the difference is that before the course I saw physics teaching concerned only with the teaching of the physics content, but now I see it not only as a means to help pupils to understand it but also to help them to develop as people".

b) She pointed out the causes for her difficulty in progressing through the course as: her faulty scientific preparation and insufficient time for preparation. The analysis of her last performance revealed to what extent her deficient scientific background blocked progress in her lesson.

c) She believed that the experience she got from the course would be of great importance in her professional life because,

".. even during the short period it took, it help us a great deal to be aware of our role as teachers in the development of our pupils".

In her general comment on her learning experience she stated:

"I think this course was very useful. Despite the weakness of my performances, I think it helped me to be conscious of my own difficulties as well as why and how I should teach in my future life..".

d) The histogram of $S_{13}$'s self-perception of the development of her "abilities" showed that she perceived a good improvement in almost every of them.
6.4 Difficulties encountered

Some difficulties were experienced during Part A of the main Study. They can be put together in four ways, relating to: i) coordination; ii) student teachers; iii) time constraints; iv) language.

i) By difficulties relating to coordination aspects I mean the problems I had to face in getting the right pupils at the right time for the sessions of microteaching. The heavy timetables of both pupils and student teachers, the topics in the official syllabus already covered in the pupils classrooms, and the selection of the topics for the microteaching sessions, the information about pupils' alternative conceptions relating to the concepts selected, the use of the heavily booked TV studio, were some of the variables that had to be coordinated.

ii) The problems relating to the student teachers were mainly derived from their deficient scientific preparation. Their competence in the understanding of basic concepts and principles affected their performances and their morale. Also, in the majority of cases, their poor cultural background inhibited them from freely exploring situations which emerged during the lessons. This situation is a reflection of the lack of attraction that the teaching profession presents. In the majority of the cases the most competent people do not chose to take teacher training degrees. Of course, in the present case, different degrees of competence were held by the different student teachers, but, with just one exception, they presented this kind of difficulty. Nevertheless, their interest and enthusiasm during the course was apparent as well as the effort they made to overcome their difficulties. They regretted that they could not dedicate more time to the course. Their timetables were too heavy (26 class hours per week). This was particularly felt during the trial stage, because part of this stage came at a time of tests and assignments for other courses. Commenting on this situation, one of the student teachers said,

"I realized that this course needs more time for preparation than any other. I never spent so many hours of preparation with other courses as with this one".

This situation relates to another aspect - time constraints.

iii) Seven hours per week during 14 to 15 weeks is a short period for conducting the course within the approach chosen. With 6 to 7 student teachers it is only possible at best to accomplish two simple cycles of the spiral of the action research. It would be advisable to have a longer period for such a methods course or a small number of student teachers enrolled.
Another problem encountered concerns the difficulty I had to face in translating the Portuguese classroom normal discourse into English discourse. Sometimes the report of studies conducted turned out to be a very hard task. A concern to not alter the meaning given in Portuguese discourse when translating it into English is a very time consuming and hard task. Problems of translation validity were dealt with by submitting the translations to two colleagues who are well acquainted with both languages.

6.5 Findings emerging from Part A of the Main Study

Given the exploratory feature of this study in an area which is still very much unexplored - the teaching of teaching skills appropriate for a constructivist approach to teaching - the findings must be interpreted with great care. The few case studies and the descriptive nature of the research methodology must be kept in mind. Designed to be exploratory, the conclusion of this study must not be taken as definitive answers to the problems studied.

The analysis of the thirteen case studies in the four first stages of the implementation of the scheme produced findings that seem to give support to the following conclusions:

1. the scheme designed, and the way it was implemented during the four first stages, seem to be useful for the achievement of the aims proposed;

2. the results of the implementation of the four first stages of the scheme seem to indicate that a radical change from a "cultural transmission" to a "constructivist" perspective toward physics teaching held by student teachers is possible in a relatively short period of time as a semester;

3. consequently, an attitudinal change toward the "act of teaching" is evidenced by the enhancement in the enthusiasm with which the activity was faced;

4. improvement in teaching skills relating to the stated aims in particular lessons was achieved during the trial stage although the constraints of time and situation (simulation of real classroom situations) do not allow for a more firm conclusion;

5. some evidence of improvement in the student teachers' development of scientific "abilities" was also obtained;
6. supervisor - student teacher and student teacher - student teacher interpersonal relationships seems to be a very important part in the development of the four first stages of the adoption process in each individual. This relationship should be based on the qualities of congruence, where the person is being 'himself' in interactions with others and can be seen as a real person; empathic understanding, where the person has the ability to understand another's reactions from the other person's point of view; and unconditionality of positive regard, which means an individual accepts the other person as a separate person with permission for him to have his own feelings and experiences and to find meaning in them;

7. the use of videorecording facilities was highly useful to the extent that it helped to sharpen the student teachers' perceptions of their strengths and weaknesses;

8. the approach to microteaching used during the course, treating many teaching skills simultaneously and integratively with subject matter content seems to be a more useful one to support transfer to real classroom situations. It also allows a link to be made between student teacher's performances with her/his underlying assumptions;

9. practice teaching based on the reflective analysis of the link between stated aims and objectives and the teaching skills which tend to facilitate the achievement of those, was perceived as a very relevant learning experience;

10. the use of the knowledge of the alternative conceptions held by pupils before being taught a physics topic as starting points in teaching was perceived as the cornerstone for the improvement of physics teaching;

11. the lack of scientific competence relating to basic concepts in physics emerged as being the main difficulty in the implementation of a constructivist approach to teaching. Strong evidence of great difficulty in transferring scientific knowledge acquired at university level to secondary level was obtained;

12. the lack of interdisciplinary knowledge, showing a very individualized subject matter teaching at all levels of schooling seems to be another stumbling block to the implementation of a Personal Construct Psychology approach to physics teaching.
6.6 Summary

In the first part of this chapter, the activities taking place in the different stages of the scheme designed for promoting the change on student teachers' perspectives on physics teaching from a traditional to a constructivist one, as well as for developing in them appropriate teaching skills, were described.

Data relating to the awareness, interest and evaluation stages were presented and analysed concurrently for both cohorts of student teachers from the two years of Part A of Main Study.

Data relating to the trial stage of the two cohorts were presented differently for both groups. The implementation of the trial stage of the first cohort was reported in great detail. The intention was to give a thorough picture of the whole process as well as providing a clear description of the procedures for collecting and analysing data. The implementation of the same stage of the second cohort, studied in depth, was presented in the form of summaries. These summaries were in the form of condensed versions of the case studies, mainly omitting in-depth descriptions since these would excessively lengthen this report.

Some difficulties encountered during the implementation of the four first stages of the scheme were reported as well as the findings emerging from Part A of this study.
TOWARDS A CONSTRUCTIVIST MODEL FOR

SCIENCE TEACHER EDUCATION

© Marília Duarte Canhão da Silva Pereira Fernandes Thomaz

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SUMMARY

The study reported in this thesis is of an attempt to get some insight into two under-explored areas - the practice of a constructivist approach in science teacher education and in the teaching of science.

An overview of the Portuguese Educational System is presented with the purpose of identifying the context within which this study was conducted.

A preliminary study aimed at investigating reasons accounting for pupils' attitudes towards "physics" and "physics teaching and learning" is reported. From it, evidence is obtained supporting the view that a "cultural transmission" perspective underlies current physics teaching.

A constructivist approach to physics education is proposed as a fruitful alternative to the prevalent practice. It is argued that the approach is compatible with current philosophies of science as those of Popper, Kuhn, Lakatos and Feyerabend.

Aims for physics teaching in general education were derived within the psychological perspective of George Kelly and his constructivist view of knowledge.

Rogers' developmental model of the adoption process of an innovation was used as a framework for designing a scheme to promote change in student teacher's perspectives in the direction of constructivism and for developing teaching skills appropriate for teaching within this latter perspective.

The choice of a research methodology compatible with the assumptions underlying this study was justified by analysing the two main methodological approaches used in educational research.

The main study reported in the thesis was aimed at investigating the applicability and effectiveness of the scheme designed within three contexts: i) the course of "Physics Didactics" given by the author to thirteen student teachers in two consecutive years at the university of Aveiro (Part A); ii) the year of teaching practice of five of these student teachers (Part B); iii) the first year of professional life of three of the student teachers, (Part C).

In Part A of the main study an investigation is reported into the implementation of the four stages (awareness, interest, trial and evaluation) of the adoption process of the innovation with thirteen student teachers.
In Part B, five case studies are presented based on the implementation of the adoption stage by student teachers in their teaching practice.

The implementation of the adoption stage in the first year of professional life of three of the student teachers is presented in Part C of the main study. Despite different institutional contexts during their teaching practice and first year of professional life, the three novice teachers were able to maintain a constructivist perspective in their schools.

Difficulties encountered in the implementation of the scheme in the three contexts are reported as well as some possible ways for overcoming these difficulties.

In the last chapter of the thesis conclusions are drawn concerning the effectiveness of the scheme designed, the research methodology followed and the adoption of a constructivist approach to Science Teacher Education. Recommendations and suggestions for further research are also presented in this last chapter.
To my husband Manuel and
my children

Manuel Maria
Diogo Miguel
Sônia
Pedro Maria
Filipe Nuno
and
Tiago Maria

... they know why!
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THE MAIN STUDY: PART B - TEACHING PRACTICE

7.1 Introduction

As already mentioned in Chapter 5, section 5.3, the first part of the study on the implementation of the adoption stage of the scheme took place during the teaching practice of five of the six student teachers who participated in Part A of the main study during the first year. The five student teachers, S1, S2, S4, S5 and S6, had finished the fourth year of their integrated teacher training degree and entered the fifth and last year. After this fifth year they would become teachers. The student teacher S3 failed the fourth year and thus she was unable to enter her teaching practice.

The findings of Part A of the study showed that these student teachers had reached the adoption stage. This means that, as a consequence of the results of the trial stage, they had decided to continue to make full use of the innovation, first in their teaching practice and then in their future life, unless they subsequently decided to discontinue the innovation. As already stressed, an innovation may be rejected at any stage in the adoption process. If rejection occurs after adoption, this behaviour is called a "discontinuance". A "discontinuance" is, then, a decision to cease use of an innovation previously adopted.

During the trial stage, the student teachers used the innovation in a small scale, with a small class size, for two or three lessons, without having full responsibility of the classes. During teaching practice, the context in which they used the innovation, was quite different. Here they used it in real classroom situations and, although adopted, the implementation of the innovation in the new context could bring about "discontinuance" by some of the student teachers.

The purpose of Part B of the Main Study was to investigate:

i) the implementation of the adoption stage concerning each individual student teacher's behaviour within the context of their teaching practice;

ii) the effectiveness of the scheme, used as the framework for the teaching of the course on "Physics Didactics", on the development of the student teachers' teaching skills to teach within a constructivist approach;

iii) pupils' reaction to this approach to teaching.

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7.2 The setting of the teaching practice

The five student teachers were all allocated to the same school in Aveiro by the Ministry of Education. The characteristics of the school have been already described, in Chapter 5, section 5.3.

Although in Portugal the school year starts at the beginning of October, by the middle of September the student teachers started planning the school work for the year in collaboration with their supervisor at the school. At that time they had made initial contact with the school; finding out about classrooms, labs, existing materials and the group of teachers teaching physics and chemistry at the different schooling levels.

7.3 Group discussion at the beginning of the adoption stage. Analysis of the data

Before starting work with pupils, the student teachers were asked to come to the university for a group session. The purposes of this session were stated in Chapter 5, section 5.5. The session was audiorecorded and the analysis of the transcript produced the following information.

In general, their views had not changed from the ones they held at the end of the course on "Physics Didactics" (the course finished in February and they started their teaching practice in the following September). All of them had decided to carry on with the implementation, during teaching practice, of the model of teaching based on constructivist theory. Nevertheless, the individual attitudes to this decision and the problems foreseen by each were characteristically different.

When asked about his ideas about how he was going to approach teaching, S1 answered as follows:

"Well .... I was never happy with the model of teaching and learning I had .... in spite of having had one which was not a very bad one .... I had quite a lot of experiments ... etc. ... but .... anyway ... when the new model became clear for me ... I adhered to it .... because I thought that any way out should be better ... even if it was bad ..... fortunately it wasn't bad at all ... I could feel that when it was put into practice ... at least in that situation ... and I'm really decided to carry on with it ... but I have the same problems that the majority of my colleagues also have .... you know ... they are thirty pupils ..... I'm afraid that things won't go so well with such a number of pupils ... there are deficiencies at all levels ... I'm not referring to handling materials ... but mainly the school space .... and it worries me .. because for .. team-work .. it's very bad .... the class time also worries me .. because .. we have only forty useful minutes of class ... and I think that this is a big problem ... it should be very difficult to start and end some work properly
in forty minutes ... but ... anyway .. we have already started to plan according to the model ... well .. I think it is possible to imagine that it is going to work ... at least better than it would result with the traditional one ... and this is already a good thing ..".

His answer revealed his awareness of some specific problems for the implementation of the model, namely class time and the type of classrooms being not adapted for team-work. Both variables fitted in within a traditional way of teaching which, in the short term, was not and is not possible to change. This is a real problem that a teacher has to face if s/he wants to introduce any innovation into the educational system. A way to overcome it is to sort out ways to adapt those variables to the new model. This is also a challenge to the student teachers as expressed by S1 when talking about his expectations

"... my expectations .... well ... obviously we are going to face an unknown thing .... and ... although I like challenges .... I'm always a bit afraid of them .. as everyone is .... I think .... but I like challenges and I'm convinced that it is going to be a very interesting experience".

Although expressing her decision to teach according to the model, S2 saw the main problem she was going to face as being her faulty scientific preparation, mainly in what concerned hands-on work. She verbalized this point in the following way:

"... in all my schooling .... at primary and secondary level I never did experiments ... and I have great difficulty in thinking about experiments concerning this or that topic .... now .... I need to work with things ... apparatus and so on .. which I'm not acquainted with .... and I must use them .... and present them ... for the first time .... I'm worried because I see a very short time for all these things ... the time constraints are worrying me quite a lot".

This difficulty she pointed out was a very real one, not only for her, but also for the others. Their lack of familiarity with materials, apparatus and possible experiments was a clear consequence of the way they had been taught. At the university they did lab work but at a different level to the one they needed to use with children. Only during the course on "Physics Didactics" had they worked at this level, but only then in relation to a small range of subjects. During teaching practice, student teachers are usually faced with a complexity of new problems and they are pressed by time limits. If they do not feel very motivated, encouraged and helped by supervisors to sort out ways to overcome these problems, they are more likely to give up and follow in the tracks of their own former teachers. Unfortunately the year of teaching practice was, for most of the student teachers, the last one during which they can be helped in their efforts to implement innovations. In the following year they would become full teachers working alone
in a school somewhere in the country. Unfortunately there are few schools where there is a group of teachers working in a team and trying pedagogical innovations. Even in schools like the one where this teaching practice took place, this does not happen. This point was stressed by the student teachers during the conversation. The following extract illustrates this.

(The symbol R stands for myself acting in my role of researcher during the conversation).

"R - ... and what about you (S5) .. what were your impressions of your first contact with the school?

S5 - .. my first contact with the school .... to tell the truth .. it disappointed me quite a lot.

R - why?

S5 - we had a meeting with the teachers of our area .... a plan for the school activities for this year was made ... and .... I found ...... the persons aren't motivated .... I think they got used to that routine ..... to go there ... to give lessons and go away .... and nothing else .... they don't show a minimal motivation for doing new things ... things which could be done in order ... for instance to integrate the pupil in the school .... to humanize the school .... and so on ...... I can foresee my problems if want collaboration from others! ..".

Similar comments were made by S1 during the conversation. He remarked

"... concerning the group of teachers with whom I had already had opportunity to contact .... well ..... to be honest .... I didn't like it ... I know there must be there ..... persons with ideas ... I want to believe that .... but what I saw was ..... a great inaptitude .... a complete disorganization .... mainly in the form of reasoning .... they look like persons who haven't reasoned for a long time ... (laughing) ... well .... may be I'm being a bit cruel .... but ... they are very committed to their lives ... I mean their private lives ... outside school ... you know ... may be they have their reasons .... but really at school ...... it's a complete 'let it go!'.... they don't have new ideas ... or perhaps they do have but they don't want to give them because probably they foresee a series of troubles and don't see any reasons for having them ...... honestly I didn't like my first contact with my future colleagues ..".

In the preliminary study, during the interviews with secondary school teachers, I came across the same feelings held by some teachers. A teacher, in our educational system, does not have any incentives to implement pedagogical innovations. Usually, s/he does not get help from other colleagues and normally teachers do not work in groups. Moreover, if someone comes with new ideas, wanting to put them into practice, s/he is looked as a boring person who wants to show off. There are obviously exceptions, but unfortunately there are not many. It is important for student teachers to be aware of this situation and be encouraged to fight it. For this they need to have a great enthusiasm for teaching and be
strongly convinced of their ideas. With our educational system this is not very easily achieved. Usually persons do not feel the necessity for pedagogical innovations. A comment made by \textit{S}_1 during our conversation illustrates in some way, this aspect. He remarked:

"I'm convinced that many people don't believe in this way of teaching ..... unless a person has opportunities to put it into practice .... I believe that the majority of persons don't believe in it .... some days ago I was talking to a colleague of mine ... from other area .. telling him about the approach we want to give to our teaching and he laughed at me ... saying 'well that is only for the course on "Physics Didactics" .... you know ... that isn't to be put into practice' ..."

The difficulties felt by \textit{S}_4 were of other kinds. They were more centered on himself as can be elicited from this extract of the transcript of our conversation.

"\textit{S}_4 - I foresee problems with discipline and communication ..... I'm concerned ..... what will pupils' reaction be ... when I see them in front of me .... how shall I interact with them? ... I'm very worried about it ..."

He was perfectly aware of his great difficulty in communicating, from which problems of discipline can be a consequence. He looked very anxious after his first contact with the school. Another extract of the transcript gives an account of his reaction to his first contact with the school.

"\textit{S}_4 - ... I think the school is too big ...  
\textit{R} - in what sense?  
\textit{S}_4 - is too big .... too many people  
\textit{R} - and in what way does it affect you?  
\textit{S}_4 - .. it doesn't have a family touch ..... we can't be acquainted with other people .... we pass other persons in the corridors .... really they are my colleagues but I don't know them .... they are strangers ... and I have a feeling .... that this is going to happen till the end of the year .... the school has too many people .... if ...... on the contrary it was a small school ..... we could get to know and talk to every pupil and teacher and .... this I think would be more suitable for working".

Also \textit{S}_5 focussed on this problem of a certain inhumanity in the school environment. She commented,

"... there are so many people ... so many pupils ... we can't get to know each pupil individually ..... we don't get in touch with their parents .. we don't know what kind of problems pupils bring to classrooms ..... their family's environment ... I think this is important for our interaction with pupils ..... we only see the pupils three hours per week ... and among thirty others .... well these are not good conditions for working ...... I feel that .... the greatest problem to be faced in this kind of approach ... is the class size .... to be able to follow each pupil .... to provide team-work .. to try to
develop those abilities in pupils ..... well .. I think it won't be easy ... but anyway .. I have hope I can overcome all these problems".

The same feeling was also expressed by the other student teachers. They felt themselves lost in a school of such dimensions. The transition from a situation in which they usually worked with a few people, (they were six peers and their teaching experiences involved only six to ten or eleven pupils), to a new one in a school with three thousand pupils and hundreds of teachers was really a great change. They saw it as an obstacle that would have some influence on their performance, at least initially. This aspect of their first contact with the school, surely had some impact on their feelings and their ideas about the way they were deciding to teach. It was a negative impact in the sense that the obstacles and difficulties foreseen by the student teachers were not very supportive of the implementation of a constructivist model of teaching. Notwithstanding all of them expressed their interest and willingness to initiate the innovation. This can also be elicited from the answer given by Sg.

"Sg - .. my feelings on the way I want to teach remained the same as I had at the end of the course ... nevertheless ... I see some problems .. mainly concerning time

R - why?

Sg - to teach within this model needs more time available .... because .. if I was going to teach within the traditional model I could follow the textbook straightaway ... doing the experiments mentioned in the book and so on .... but in the way we all want to do ... we can't do that ... we need to think hard about our lessons .... in all the things we have done during the course .... oh! ... that's quite different ..... but ... well I think .. it is possible to go along with it".

During the last part of our conversation we talked about their course on "Physics Didactics". Some additional comments made by the student teachers are worth mentioning. They perceived it as an important contribution to their new attitude towards teaching physics, as well as towards chemistry. According to them, the opportunities to put theory into practice during the course before applying it in the classroom - "the real world" - were extremely positive and encouraging. They regretted that, due to time constraints, more opportunities had not been provided. This idea was summarized by S1

".. I think .. what may be a lack in the course is the possibility of each student teacher performing more times ..... giving more lessons .... stumbling more times ..... loosing more nights sleep (laughing) .. feeling uneasy during more nights thinking about the mistakes one made ..... but .... then having time to analyse not one or two lessons but having the possibility to try again ... to perform again .... I think this is very important for believing in the model ... to try it .. to put it into practice ... to make a trial ..".
They also pointed out the necessity and importance of an earlier contact with the schools for students who are going to become teachers. This would enable them to be aware of the real problems in school before they are already involved in it.

**Summing up:** the analysis of the transcription of the group session produced the following informations:

i) their attitudes toward the implementation of the model of teaching on which they worked during the course on "Physics Didactics" remained the same as held at the end of the course. They were definitively at the beginning of the adoption stage;

ii) their first contact with the school was not very happy and not at all stimulating. Instead of a positive setting for innovation in which they should be encouraged and helped to put into practice their ideas about teaching, it was perceived as a hostile and, to some extent, threatening one;

iii) the main problems foreseen were concerned with class size, time limitations, traditional by designed classrooms and lack of the enthusiasm and collaboration from other teachers;

iv) the opportunities to put theory into practice, provided during the course, were perceived as highly relevant to the adoption process through which each individual student teacher passed from first experiencing the innovation to its final adoption;

v) earlier contacts with schools were seen as a potential fruitful opportunity for the enhancement of student teachers' awareness of the real problems before being involved in them.

7.4 Case studies of the adoption stage of student teachers $S_1$, $S_2$, $S_4$, $S_5$ and $S_6$

The following sub-sections consist of the presentation of five case studies centered on the adoption stage of each one of the five student teachers, $S_1$, $S_2$, $S_4$, $S_5$ and $S_6$. Individual progress during the year of teaching practice is presented and analysed.

As already mentioned in Chapter 5, sub-section 5.4.2, during the year of their teaching practice each student teacher had full responsibility of two classes, one of the 8th grade and one of the 9th grade. They were also required to give some lessons to a 10th grade class where the supervisor from the school was in charge.
In the present study only the student teachers' interaction with the 8th and 9th grade concerning physics teaching was considered. As already mentioned in Chapter 1 the physics teaching at the 8th, 9th, 10th and 11th grades takes place within the context of a subject called "Physics and Chemistry". As a rule in the school where the teaching practice took place, all 9th grade classes started this subject with the study of physics and all 8th grade classes started it by the study of chemistry. Thus, during approximately the first half of the school year, the five student teachers were followed in their interaction with their 9th grade classes and during, approximately the second half they were followed in their interaction with the 8th grade classes.

Throughout the year the student teachers worked together in the planning of units, the design of diagnostic tests to be used before the introduction of the different units, assessment tests, worksheets and other kinds of material used during teaching.

In consequence of their reflection on the research findings about pupils' alternative conceptions, the student teachers were aware of the implications for teaching and learning of the various concept understandings that pupils bring to physics classrooms. Having adopted a constructivist approach to teaching, they felt it necessary to obtain information about their pupils' views concerning the basic concepts included in each unit.

Several techniques for investigating concept understanding have been proposed by researchers: i) clinical interviews with individual pupils (Pines et al., 1978; Lybeck, 1979; Erickson, 1977; Gilbert and Osborne, 1980b; Trowbridge and McDermott, 1980); ii) word-association and word-sorting tasks (Preece, 1978; Shavelson, 1974; Schaefer, 1979); iii) asking learners to write definitions (Schaefer, 1979), or to chose a preferred statement from several correct ones (Kempa and Hodgson, 1976); iv) tasks which involve bipolar dimensions on which an idea is rated (Osgood et al., 1957); v) multiple choice test (Johnstone and Mughol, 1978; Helm, 1978; Watts and Zylbersztajn, 1981; Shipstone, 1982; Erikson, 1980; Fredette and Lochead, 1980).

Gilbert (1983) pointed out that for researchers who see knowledge as a personal construction, interviews must play a central role. Nevertheless, for a teacher who also shares the same perspective, this technique is not practical, since no teacher is likely to have time for 28 to 30 clinical interviews in each of her/his classes. Therefore the diagnostic procedures used by the teacher at the beginning of each unit should be relatively brief although allowing for an useful
insight into her/his class pupils' dominant thought patterns. Pupils' prior knowledge may vary across classes, so that the approach taken to the teaching of the topic needs to be different depending on the class to which it will be taught. This implies that, in spite of the importance of teacher's knowledge of the research findings concerning a specific concept, it is far more important that teachers gather information about their own pupils using a technique compatible with the context in which they are working.

Based on these assumptions the student teachers decided at the beginning of the year, to apply a diagnostic questionnaire to each of their own classes before starting a new unit. And here they found a difficulty. Although a great amount of research on this field has been carried out, physics educators have not produced diagnostic tests to be used by teachers in classrooms, or at least made them available.

In my role as their supervisor I helped the student teachers in the design of two questionnaires about the concepts of "light" and "force, mass and weight". The questionnaires, their purposes and main difficulties found are presented in Appendices 12 and 13. The questionnaire about "Light and its properties" was designed based on the works of Anderson and Kärrqvist (1981), Tiberghien et al. (1977), Stead and Osborne (1979) and on the questionnaire designed in the previous year at the course on "Physics Didactics".

The last two questions of the questionnaire about "Force, mass and weight" were based on the work of Watts and Zylbersztajn (1981). The other questions were based on my own experience over several years as a teaching practice supervisor, in which I had identified some of the interactions between 'teachers' science' and 'children's science' related to this topic.

Pupils were asked not to put their names on the questionnaires so they would feel more free to express their ideas.

Besides gathering information about pupils' intuitive ideas, another purpose of these questionnaires was to rise curiosity in the topic to be taught. While answering the questionnaire pupils were becoming aware of their personal frameworks in 'scientific observation' and this fostered their curiosity in the topic to be learned. Evidence of this was provided either through the lessons transcripts or by comments made by some pupils before the beginning of the lessons and annotated by me during my observations. The following extract of a conversation between pupils, and annotated by me, at the beginning of the first lesson on optics (the questionnaire had been administered during the lesson before) illustrates this point.
"P_1 - what did you answer about 'what is light'?

P_2 - I had never thought about it! ... did you?

P_1 - well .. I said light is very important for our lives .... isn't it?

P_2 - I said light is energy

P_1 - Is it?

In another group:

"P_3 - I'm telling you .. cat's eyes have light inside

P_4 - come on! .. I don't believe that! ..

P_3 - Really .. you will see"

Another comment:

"P - .. well .. after that test ... today we are going to talk about light ... that's nice!"

Due to time constraints it was impossible to design other questionnaires related to the units of "work", "heat" and "electrostatics". In these cases each student teacher used different procedures, either oral questions to the whole class or some written questions. In both cases the questions were based on research findings and on results of our conversations about some difficulties that could probably be found related to those topics.

An activity similar to the one perfomed in the course on "Physics Didactics", relating to the concept of "Electric current", was provided by each of the student teachers at the beginning of this unit. Nevertheless they all agreed that their earlier procedures could not provide enough information either on each individual pupil or on other possible pupils' intuitive ideas. This fact supports the necessity of the production, by physics educators, of questionnaires aimed at investigating pupils' alternative conceptions concerning all the basic physics concepts.

The planning and conduct of the first lessons on each unit were, in the majority of the cases, based on the information gathered through the different procedures used to investigate pupils' alternative ideas about the concepts involved.

7.4.1 Case study 1 - S.T. S_1

7.4.1.1 Class description

The two classes of student teacher S_1 had completely different characteristics. His 9th grade class was composed of 19 boys and 10 girls being on average
16 years old. Eight of the pupils were repeaters (the ones who failed the 9\textsuperscript{th} grade the previous year and were repeating the same grade). This class was what usually is called a "difficult" class. Pupils were from a mixed socioeconomic background, mostly upper class, but some from economically poorer homes. There were seven very disruptive individuals, provoking an atmosphere of indiscipline which demanded the frequent intervention of the teacher in order to control the situation. Throughout the year $S_1$ tried hardly to have a good relationship and not to take authoritarian attitudes with these individuals and with the whole class. This was sometimes very difficult and presented very disturbing situations for him. It became such a problem that, as $S_1$ told me, he used to dream at night that he was fighting with some of the pupils of that group.

The 8\textsuperscript{th} class consisted of 7 boys and 20 girls. The class average age was 15 years. These pupils were also from a mixed socioeconomic background but mostly from the middle class. This was a very interested class, with very participative behaviour that fulfilled all the expectations of $S_1$ relating to the relationship between teacher and pupils and between pupils.

Throughout the first four months of the school year I observed, on average, two lessons per week given to this 9\textsuperscript{th} grade class. The same happened with the lessons given by the other student teachers. All the lessons observed on optics were audiorecorded in the way described in Chapter 5, section 5.5. The lessons observed on the other units of the 9\textsuperscript{th} grade were either audiorecorded or could be reconstructed from notes taken during the lessons.

During the last four months of the school year the classes observed were the 8\textsuperscript{th} grade classes of each student teacher. On average, two classes of each student teacher were observed per week. All the observed lessons on "electric current" and some on "electrostatics" were audiorecorded. The remaining lessons were reconstructed from my notes taken during the lessons.

\subsection*{7.4.1.2 Data from, and interpretation of, classroom observations}

Throughout the first four months of $S_1$ interaction with his 9\textsuperscript{th} grade he showed a strong commitment to teaching within a constructivist approach.

His tenacity in going along with his decision demanded a great effort of him both physical and psychological. During that period he suffered periods of great depression because the class was not responding to his effort, by showing disinterest but mainly due to the disruptive behaviour of some of the pupils. This caused him sometimes to interact exclusively with that group of pupils to control
them. His awareness of that fact made him very unhappy because he felt unable to overcome the problem. Notwithstanding, he never gave up and in each lesson he tried again to improve the situation.

I started my observations at the end of the first unit. The first lessons on optics were based on the information he gathered through the diagnostic test. It means that he started the approach to the topic from pupils' intuitive ideas and then, by promoting discussion and guiding between them, he helped pupils towards conceptual change. The greatest difficulty he found was the disorganized participation of that group of troublemakers which was always interrupting other people's speech, asking questions out of the lesson's context, joking and laughing. After some lessons, when the content of the lesson was appropriate for team-work, he discovered that this type of lessons was the most suitable for that particular class in the sense that, when the pupils were busy and involved in their work, the atmosphere of the class provided more opportunities for the teacher to interact with all the pupils, helping each one to develop the "abilities" he aimed for in the lesson. Through this type of lessons he was, slowly, helping pupils to change their behaviour, to think more seriously about the problems that they were presented with, to design experiments to test hypotheses presented by the teacher. In a later stage, they were able to make their own hypotheses and design and perform experiments to test them.

The story of the evolution of this class is a very interesting one. Although being a class which was always difficult to manage, pupils' behaviour changed with time, starting to respond to the teacher's style of teaching. During the months of the practice some progress was apparent, which gave S1 courage and enthusiasm to carry on with his style of teaching.

The third unit "Force, mass and weight" was also started from pupils' ideas which he investigated through a diagnostic test. By that time the class was reacting better to the approach to teaching that S1 was taking. Also his teaching skills were improving and he did not miss opportunities to achieve the aims stated for each particular lesson.

Before each lesson observed by me I was given the task analysis of the lesson which allowed me to analyse it in terms of its purposes. Slowly but surely S1 lead his interaction with the class so as to help the pupils to develop their "scientist-like aspects". He was aware of this and one day at the end of the lesson he told me:

".. at last they are cooperating ... don't you think so? .... after all even with this type of classes it is possible and rewarding to teach according to this model ..".

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Throughout the lessons his constant concern to help pupils to think by themselves, to construct knowledge by themselves, was apparent. It was not an easy task. On the contrary it had it's very hard moments but, slowly, he achieved what he proposed to do with his teaching.

An extract of the 36th lesson, at the middle of the unit "Force, mass and weight" illustrates this point. The content of the lesson was Newton's third law and some of the aims stated were to help pupils to develop scientific process skills such as observing, formulating hypotheses, designing and performing experiments to test hypotheses and predicting. He started the lesson by asking pupils to observe carefully what he was going to do. Then he held two equal magnets separated by a certain distance and released them. The class was quiet and interested in what was going on. Then he asked one of the pupils.

"T - What did you observe Christina?
G - the two magnets attracted each other
T - did both move or just one?
G - well .... I think I saw both moving
T - so .. can you draw any conclusions about what happened to each one of the magnets?
G - each one was acted on by a force
T - come to the blackboard and represent those forces".

The girl went to the blackboard and made the following drawing

"T - could you explain what you have drawn?
G - well the force of magnet A on the magnet B

is this one

B - oh! .. that's wrong ... so .... isn't a force always represented upsidedown?
T - what do you mean by that?
B - .. a force is always represented by ↓

During the previous lesson they had been talking about and representing weights. The comment of this boy made S1 spend some time helping him to clarify his doubt. Then he returned to the girl standing on the blackboard.
"T - why did you draw the arrow with its extremity in A?
G - because magnet A is the one which is responsible for the force on B
B - but the length of the arrow has nothing to do with that!
T - yes .. what information is given by the length of the arrow?
B - it gives the intensity of the force ... for instance .. if the force is 5 N we can use a certain length .. but if it is 10 N the length is doubled ..
T - yes .. so how would you draw it?

The boy went to the blackboard and drew

A


The girl at the blackboard looked at it and commented:

"G - .. but like that .. the intensity wasn't enough for B to reach A! ..
T - why?
G - because the arrow doesn't touch A! ..

Pupils have a recurrent difficulty in understanding the meaning of the scientific symbols. Because S1 was more interested in knowing pupils' understanding than in giving information he was able to provide opportunities to disclose this type of difficulty. He involved other pupils in the discussion helping them to clarify their peer's ideas.

After this episode he put the following question to the whole class:

"T - so .. you said that A attracts B with a force and B attracts A with another force .. right? .. and what about their intensities? .. should they be equal or different?
Ps - they are equal!
T - are they? .. how could you say that right away? .. can you prove it?
The class kept silent for some seconds and then some pupils started talking at the same time

"T - just one .. please .. you Carlos can you imagine an experiment to test the hypothesis that the forces are equal?
B - yes .. I think so .. can I go to the blackboard?"

He went to the blackboard and made the following drawing

O

A

B - suppose these (O) are the two magnets .. I put them in this line and mark this point here (A) .. at the middle of this distance between the two magnets .. then I released the magnets at the same time .. if they reach the point A at the same time .. it was because the forces on each one should be equal .. right?
T - (to the whole class) what do you think?
P_1 - right
P_2 - I think that would prove it...
P_3 - it only could prove it if the magnets were equal!
T - do you think so?
B - can I try it ... can I try it
T - yes ... try it please

The boy made the necessary arrangement on the teacher's desk and did the experiment. The whole class was watching, showing a great interest in what was going on. Using this type of strategy S_1 helped to raise the interest of the pupils, to perceive the importance of their own contribution to the construction of knowledge.

After the experiment, that went very well, S_1 asked the class:
"T - and what do you think would happen if we put a piece of plasticine between the two magnets ?
P - I think the plasticine would isolate them
T - let's try it

The episode continued. It would be impossible to transcribe all the verbal interaction that took place but I think the small extract above gives the constructivist flavour of his way of teaching.

During the second half of the school year, after the study of physics has finished in the 9th grade class and has started in the 8th grade class, I started my observations on the latter class. As already mentioned, this class was very different from the other one in discipline matters. It was a class of average academic ability with a group of highly motivated pupils. S_1 was very pleased with it because as he pointed out

".. I have been able to work with them, implementing the model of teaching very easily. They have been reacting externally well, and I have been able to achieve the aims I proposed to achieve. These ones .... (the pupils of the 8th grade class) ... they really made me feel happy with teaching".

In informal talks with his pupils before the lessons I grasped the pupils' views about their lessons either in chemistry (during the first part of the academic year) or in physics. Generally they enjoyed the lessons because, as they said ".. he made us to look at things with new eyes ..", ".. I like ... (the lessons) because they are interesting ..".
The analyses of some of the lessons either in the 9th or in the 8th grade were made in a similar way to the analyses of lessons given by S2, S5 and S6 and are presented in Appendices 14, 15 and 16. These analyses of these lessons and associated notes revealed the following recurrent points.

a) The task analysis of the lessons revealed a great concern to use the physics content to develop the scientific "abilities" of the pupils. The decision on the nature of the presentation and on the pupils' activities stated in the task analyses revealed a concern to involve pupils in the construction of knowledge. The nature of presentation was usually based either on class discussion or team-work.

b) A development in S1's capability to teach within a constructivist approach was apparent throughout the school year. The main hindrance to his progress was S1's personality. As can be elicited from previous descriptions reported in this study, S1's tendency to impose his point of views was too strong to be easily abandoned. He was well aware of this and tried to 'go against' it. Many times at the end of the lessons, when I was reaching his desk having come from the back of the classroom where I was observing, he smiled at me saying

"I known .. I know what you are going to say .. I talked too much .. I know that .. I need to let them do the talking ... but ... I tried ... and sometimes I get it .. others ..... well but it's better isn't it?".

c) During the period of my observations of the 9th grade I noted that, with time, S1 was able to establish a working relationship with the class. The improvement in this aspect was a consequence of his endeavour to implement the chosen model of teaching.

At the end of my observations the impressions gained were that:

- there was always present a concern to use physics content for the development of the 'scientist-like aspects' of the pupils;
- pupils were responding slowly but definitively to the teacher's efforts. During the last lesson observed, their participation in the group discussion was active and organized. They freely expressed their views and were able to argue them in a scientific way;
- throughout the sequence of lessons an increase of interest for the discipline was conveyed by the way pupils related it to their everyday life experiences. They brought their problems, doubts and instances of physical situations to the classes.

d) The relationship between S1 and his 8th grade class was extremely friendly and relaxed by the time I started my observations. This allowed for a class atmos-
phere in which plenty of opportunities for the development of all the "abilities" stated for each lesson could be provided. $S_1$ remarked that since the beginning of the year it had become easier to establish this climate with this class than with the 9th grade class.

e) During the period of my observations it was noted that generally:

- the lessons involved the imparting of very little information from the student teacher to the pupils;
- the pupils were encouraged to participate actively in discussion aimed at the construction of knowledge by themselves;
- the pupils showed themselves at ease when expressing their ideas. No signs of disinterest or disruptive behaviour were detected;
- it was apparent that there was a constant concern to promote discussion between pupils in which all of them could contribute to the clarification of the problems proposed by either the student teacher or any of the pupils;
- it could also be noted that, with this class, $S_1$ was able to encourage and enthuse pupils to do small research projects, as for example one related to "pollution and its effects". This led to very interesting work and to results which contributed to an acceptance of observing the world in a more scientific way;
- practical work was conducted every time that the contents of the lessons were compatible with this type of activity. In some of these cases pupils were asked to design and plan the experiments that could test hypotheses elaborated by the teacher or by the pupils. In other cases the practical work was based on worksheets. These last, in contrast with the traditional worksheets for experimental work, contained the statement of the problem to be investigated and just some useful suggestions to conduct the experiment, but not in the traditional form of "recipe".

7.4.1.3 Analysis of the data from the interview

The analysis of the transcript of the interview conducted with $S_1$ at the very end of his teaching practice revealed the following points.

a) When asked if he was able to put into practice, in real classroom situations, what he had expected at the beginning of the year, he answered
"I think I achieved that reasonably ... at least in the 8th grade and 10th grade classes ... with some difficulty at the beginning but then ... I was seeing how it could be done ... with the 9th grade I felt much more difficulty in implementing the model due mainly to the characteristics of the class ... it was a very disturbed class!"

b) According to his experience, the main difficulty a teacher can find in implementing a constructivist model of teaching is concerned with discipline problems. He stressed that

"... it doesn't matter if the class is of low ability ... my 8th grade was considered by the other teachers a class with low school rating in their subjects ... it didn't happen in my discipline .... but anyway it wasn't a class of high ability ... and I didn't feel difficulties in implementing this approach to teaching ... what is essential is to have is discipline."

c) The causes perceived by S1 for the behaviour of the 9th grade class were:

- the experience of these pupils in the previous year. They were considered as a "tough" class and there had been serious problems of discipline during that year;
- the pupils' attitude towards physics. A priori the majority of the pupils did not like physics;
- the great gap between the sociocultural background of two groups of pupils;
- the serious family problems that some of the most disturbed individuals of the class had.

The complexity of the interaction between these variables made communication between teacher and pupils and between pupils extremely difficult.

d) According to S1, the pupils of his 8th grade class reacted very well to the model of teaching. Better than he had expected, which made him very happy. S1 pointed out some sources from which he had gathered this information; i) feedback from some parents who, talking to the teacher in charge of relation with the parents of that particular class, commented that they thought that something different was happening in the physics and chemistry subject and that they found what was being made very interesting; ii) the work developed by the pupils during the year. A large amount of interesting work, some of which was not suggested or asked for by him, were done by the pupils either in group or individually. This fact was seen by S1 as a good criterion for judging about pupils' interest and enthusiasm for the learning experience; iii) repeaters who had failed or had had bad marks in this discipline in the previous year, and did not enjoy it, became very participative during the year. By the end of the year talking with S1, some of them expressed their satisfaction with the subject and their decision to follow a scientific
The relationship between himself and these pupils. According to him this relationship was extremely positive, which allowed for a constructivist approach to teaching.

e) Throughout the year he had established a good relationship with some of the other colleagues in the group of the teachers who were teaching the same subject. He discussed some of the strategies he used with them, as well as some of the tests he and his peers had developed and which were very different from the traditional ones. In his experience, he found a great receptivity in some of his colleagues to the innovative ideas he presented them with. The negative impression he had got during the first contacts with them changed drastically, at least in relation to some of them, along the year in which they worked together on some tasks.

f) The "abilities" of critical and creative-mindedness, self-confidence, formulating hypotheses, planning experiments and communicating were seen as the ones which he considered to have been best developed in pupils during the interaction.

g) The teaching practice situation was seen as one that could present some difficulties to the implementation of any educational innovation unless all the supervisors share the same perspectives towards teaching or have a considerable capacity of open-mindedness to innovations. Otherwise the implementation will be very difficult and could bring "discontinuance" behaviour in some student teachers.

h) When asked which types of strategies he used more frequently for the achievement of the aims stated, he stressed that, for him, the most important task when initiating any new topic was to identify pupils' ideas through either a diagnostic test or any other procedures that could give that information. Then to start the teaching of that particular topic from that information. Once this was done, the strategies could vary according to the content to be approached. When possible he used experiments planned by the pupils, an activity which he found was always welcome by the pupils. The discussion on the interpretations of the results of experiments was seen as a fruitful strategy to develop some of the scientific "abilities" stated as aims for the teaching.

Another strategy which, according to S1, was very fruitful for the achievement of some of the aims was the use of some themes, sometimes not related to the topic under study, as small research projects with the purpose of developing in pupils some of the "abilities" which are not so easy to be developed with the contents of the official syllabus. This work was usually conducted in
for a constructivist approach to teaching.

e) Throughout the year he had established a good relationship with some of the other colleagues in the group of the teachers who were teaching the same subject. He discussed some of the strategies he used with them, as well as some of the tests he and his peers had developed and which were very different from the traditional ones. In his experience, he found a great receptivity in some of his colleagues to the innovative ideas he presented them with. The negative impression he had got during the first contacts with them changed drastically, at least in relation to some of them, along the year in which they worked together on some tasks.

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Another strategy which, according to S1, was very fruitful for the achievement of some of the aims was the use of some themes, sometimes not related to the topic under study, as small research projects with the purpose of developing in pupils some of the "abilities" which are not so easy to be developed with the contents of the official syllabus. This work was usually conducted in
groups, outside the classroom and were of different natures (e.g. interviews to
the population, observation of some events occurring in town, etc.). He pointed
out that the purpose of these activities was to help pupils to become conscious
of the place where they live, its problems and possible ways to solve them.

i) From his experience during the year he drew the conclusion that it was
possible to implement a constructivist model of teaching, although not very easily.
In the 'teaching practice' situation there is a complexity of new variables to cope
with, and the "innovator" is always under an evaluation by other teachers.

Another source of difficulty to the implementation of the innovation,
as seen by $S_1$, was the organization of the educational system. Commenting on
this, he said:

"I foresee great difficulties in working within this approach when one has
to perform five lessons in five different classes, one after another .... because
while using a traditional model the teacher prepares one lesson ... s/he
is preparing all the other four ... this is not possible when working within
this model .... each class has its own pace ... its own solutions ... thus it
is five times one lesson ... I think .. it would be extremely difficult ....
not because the teacher doesn't believe in the approach but ... because
physically it would be extremely difficult to stand it".

As a solution to this state of things he advanced three alternatives:
i) the teacher gets enough training in this type of approach to overcome these
problems; ii) the number of classes in her/his charge is smaller; iii) the group of
teachers working within this perspective increases quickly. The last solution would
foster a new mentality in pupils which would facilitate the use of this approach
to teaching. This last alternative was seen by $S_1$ as the most fruitful and more
realistic one. According to him it can only be achieved not by informing teachers
about the "new" perspective but showing by its results and by helping them to
put it into practice.

7.4.2 Case study 2 - S.T. $S_2$

7.4.2.1 Class description

In contrast of what happened with student teacher $S_1$, the two
classes, from the 8th and 9th grades, which $S_2$ had were similar.

From the start, both classes did not present any disciplinary problems.
The pupils were apparently interested and willing to participate. The total number
of pupils in the 9th grade class was thirty comprising eighteen girls and twelve
boys. Their ages ranged from 14 to 17 years, eight of them being repeaters. When I started my observations of this class, at the sixth lesson of the year, the pupils seemed relaxed, ready to participate, showing a good relationship with S2 and there were no signs of disruptive behaviour and little, if any, indication of disinterest.

As it will be described in the next section, this situation changed along the year and the behaviour of this class was completely different by the middle of the unit of "Force, mass and weight", the third unit to be covered at the 9th grade.

The 8th grade class contained twenty six pupils, twelve boys and fourteen girls. Only two were repeaters. The pupils ranged in age from just 13 to 15 years old. During the first half of the year, in which I did not observe it, S2 said that she did not have disciplinary problems and that the class was very quiet but also very passive. She had difficulty in getting their participation.

I started my observations of this class in the second half of the school year when the study of physics started. My general impression of the class agreed with what S2 told to me beforehand. Although the pupils answered the questions put by the student teacher they did not seem, generally, actively involved in what was going on during the lessons. Nevertheless no signs of disruptive behaviour were observed.

7.4.2.2 Data from, and interpretation of, classroom observations

As happened with the other student teachers, I started observing her lessons in the last lesson of the unit of "Energy" (the first unit of the official syllabus of the 9th grade). The audiorecording of the lessons started with the first lesson on optics. During the lesson before this one S2 applied the diagnostic test aimed at investigating the intuitive concepts pupils already hold on "light and its properties". The approach given to the teaching of the unit of optics was based on the information she got from that diagnostic test. Thus she approached the teaching of this topic starting from the pupils' own knowledge and interest in the subject. The three steps on the instructional process, "raising of conceptual awareness", "anomaly introduction" and "construction of theory" could be identified during my observations and throughout the in-depth analysis of the transcript of some of the lessons.

Her task analysis of the pre-active phase of most of the lessons on optics revealed a concern to establish the link between the aims and objectives
stated for the lesson. Both the nature of the presentation and the pupils' activities stated were in agreement with a constructivist approach to teaching.

The pupils' reaction to her style of teaching was highly positive in the sense that they were actively involved either in group discussions or when working on experiments planned to explore their ideas and test them. S2 was, to some extent, able to help the development in her pupils in what she had stated for each lesson. Pupils' participation was organized and interested, they put questions of their own, they discussed their own ideas with peers and reached conclusion by themselves with S2's help. Her relationship with the pupils was very good and their enjoyment of the lessons and for the teacher's style of teaching was apparent. This information was gathered through my observations and informal talks with some of the pupils. An episode that occurred during one of the practical work classes can illustrate this point. During these lessons pupils worked in groups, normally six groups containing five or six pupils each. As it was very difficult to audiorecord what was going on in each group, I used to ask permission to one group to put the tape-recorder on its table. I observed it, as well as other groups working nearby, and took my own notes. As time passed the group taperecorded during this type of lessons forgot the presence of the tape-recorder and the observer, and was talked freely. During one of these situations, in which pupils were finding out the characteristics of the image given by a plane mirror, I heard their conversation after they had finished their task. In their conversation they made some comments about their choice of subjects for the next year and some added comments on their present teachers. These last ones were not very favourable to most of their teachers but when referring to the physics teacher all agreed that they liked her. In one pupils' own words "... although she is very young she is a 'good' teacher ... I like her".

Throughout the lessons on optics it could be elicited by the analyses of her lessons that she was trying to implement, with some success, the model of teaching she purposed herself to implement. In some way this was facilitated by the class' behaviour and its interest in the topic to be learned.

After finishing the unit of optics she started the unit of "Force, mass and weight". Here something happened that changed the picture completely. Although she had applied the diagnostic questionnaire on this topic, she approached its teaching without taking the information she got from it into account. When I commented on this she said to me that she had already made the plan of the unit according to the textbook before having applied the questionnaire. Actually she stuck to the textbook and it was apparent that her concern was more to cover
the topic than to use it to help the development of her pupils. Simultaneously
her teacher's role changed drastically from a facilitator to a transmitter one.
This can be elicited from the analysis of one of her lessons on this topic presented
in Appendix 14. The lesson was selected because firstly it is an examplar of $S_2$
sty le during that period. Secondly because it was possible to record, at the same
time as the student teacher was talking, a parallel conversation between two
pupils. That conversation gives evidence of the inefficiency of that style of teaching
in pupils' conceptual change and learning.

An interesting and significant change in the class' behaviour took
place during that period. From a class without discipline problems, it changed
to a class with multiple problems not only regarding to its behaviour during lessons
(lack of interest, no participation, joking, talking, not paying attention to the
teacher) but also regarding its relationship with the student teacher. The attitude
toward her by most of the pupils became hostile and aggressive. One thing come
after the other and the situation evolved badly. The stress experienced by $S_2$
when attempting to handle the situation pushed her to perform more and more in a
traditional way. She tried to survive by adopting teaching methods such as lecturing,
whereby she had a central role and could control the whole class. Progressively
her task analyses of the pre-active phase started being done without any statement
of the aims or even objectives.

In an attempt to interpret the situation I talked to her and asked
her why was she acting like that. Her answer was:

".. you know ... I'm doing this deliberately .. they (the pupils) are being
so naughty ... the other day I had to send one out of the class .. I don't know
why they are behaving like this ... they don't show any interest in this subject
... they don't pay any attention .. I decided to try this method by now ....
really I'm not concerned to develop their 'abilities' by now ... I will cover
the unit and that's all .... I want to try this .. to see if it works better".

Some days later I went to another of her lessons. The lesson was audio-
recorded and in the next hour we listened to the tape together. She was astonished
because she had not realized how noisy the lesson had been. She had to speak louder
and louder in order to overcome pupils' noise. She spoke so quickly that we could
hardly catch her words from the tape. She realized then how boring the lesson
had been.

By the end of the unit the pupils were asked to take a test and the
results were very poor. After receiving the results of the test the pupils' attitude
toward her was very aggressive. She was very shocked and talking to me she com-
mented:

".. I'm really unhappy with this .. I feel I'm in a bad mood .... I don't like
the way I have been teaching .... it really doesn't work .. I ought to change it".

From there on she did try to approach teaching more in the line she had followed during the previous unit, but as one important component was already missed - a good rapport with the class - , she was unable to be as successful as she had been in the earlier period.

The observations, analyses of some task analyses of the pre-active phases and respective lessons' transcriptions as well as associated notes, revealed the following points.

a) Relating to the 9th grade class, the lessons on optics had a constructivist flavour. She based her lessons on the information she got from the diagnostic test on pupils' intuitive ideas about the basic concepts of the unit. Then, she provided opportunities for pupils to design, plan and perform simple experiments either to test their hypotheses for interpreting optical phenomena or to draw conclusions about some relations between optical variables (e.g. laws of reflection). Experiments were used to develop in pupils scientific process skills rather than to use them in the traditional way of following the steps described on a worksheet.

The teaching of this unit was worked out during the course on "Physics Didactics".

b) During that period pupils reacted positively to the approach chosen and the relationship between teacher and pupils was friendly and relaxed. With very few exceptions pupils showed interest and were actively involved in whatever was going on in the lessons.

c) It was apparent that S2 was unable to make the transfer of the innovation to other subject matter not focussed on during the course on "Physics Didactics". Some reasons for this fact were advanced by her during the interview. This will be reported in the next sub-section.

d) The consequence of her lack of ability to transfer skills was really apparent from the change in pupils' behaviour either concerning their participation during lessons or concerning their attitudes toward S2.

e) Psychologically S2 suffered a very depressing period which did not help her to analyse the situation clearly and calmly. Only later on, as I found out from her in the following year, very disturbing problems occurred within her family circle during that period.

During that period she conducted lessons in a traditional way which
made her feeling unhappy and demotivated because, as she said, "that isn't my perspective on what teaching should be".

f) When she realized that she had to change her behaviour concerning her teaching she started to make the task analysis of the pre-active phase in the same way that she had followed during the teaching of the unit on optics.

Notwithstanding this she was unable to perform the interactive phase in the same way and she acquired a certain animosity towards her 9th grade class.

g) By the time I started my observations (in the second half of the school year) the relationship between S2 and her 8th grade class was much more friendly than with her 9th grade class. Although the task analysis of the pre-active phase of the lessons observed revealed a concern with the establishment of the links between the lessons' content and the development of some of the "abilities" stated for the lessons, her difficulty in conducting the lessons in a constructivist approach was apparent. This was more evident in lessons whose content had not been focussed on during the course on "Physics Didactics". Nevertheless an attempt to improve her teaching skills and an awareness of her difficulties was always evidenced either during her performances or when discussing with me the problems emerged during the lessons.

7.4.2.3 Analysis of the data from the interview

The analysis of the transcription of the interview conducted with S2 at the very end of her teaching practice produced the following information.

a) When asked if she felt she had been able to put into practice, during the teaching practice, the model of teaching she was interested to implement at the beginning of the year she answered

".. I'm very aware that I didn't achieve that ... at least at the 10th grade ... there ... I felt that one was more concerned to 'give' content ... because pupils were going to be assessed on that at the end of the year ... more than other things .... as you know we weren't in charge of that class and its assessment wasn't our responsibility ... at the 9th and 8th .... well ... sometimes I did ... sometimes I didn't .... well ... really .. I recognize that most of the time I was unable ... I don't know why ... may be ... it was my fault ... or the classes or other personal problems .... I don't know".

b) According to her the main difficulties she found in the implementation of the model were: i) her lack of practice either in this model or in the traditional one. As it was her first experience in real classroom settings, she felt that she was faced with a complexity of situations which inhibited her from making a re-
flective analysis, either during the pre-active phase or at the evaluative phase; ii) because pupils were not used to this style of teaching they did not react positively to it and they needed time for adaptation. Most of the time pupils were pressing her to tell them what they should know. They were more interested to memorize than to understand. Pupils' past experience acted as a stumbling block for the implementation of a constructivist approach to teaching. According to her she had more difficulties with the 9th than with the 8th grade class. She interpreted this as a consequence of pupils' shorter experience with the study of science, none having been in "Physics and Chemistry". $S_2$ pointed out as another reason for the difficulty found with the 9th grade class, the climate of tension created within this class made the communication between the pupils and herself difficult. She disliked the class and did not feel motivated to work with it.

c) Notwithstanding her experience during the year of teaching practice $S_2$ stressed that

"... it is possible and important to use physics and chemistry content to help the development of the learner ... it is possible because even with the large classes that we had ... this was achieved to some extent ... at least by some of us ... and it is important because if pupils are going to forget everything they learned or memorized ... I think it is far more important to prepare them to act in life ... to make them think by themselves".

This statement revealed that she had already adopted the model although recognizing her deficiencies in putting it into practice.

d) Process skills were the "abilities" she perceived to have been more developed in pupils during the year. Also self-confidence was seen, by her, as one "ability" she helped to develop in the 8th grade class pupils. According to her this did not happen with the 9th grade class because she did not feel interested and motivated to do that with those particular pupils.

e) Only during the teaching of optics had she talked with some of other colleagues in the group of the teachers, teaching the same subject, about the strategies she was using. She commented that they showed some interest, mainly concerning the diagnostic test and its results. Besides this, she did not talk with them because she was not very motivated and interested to share experiences with others.

f) According to her it was through practical work that she could, more easily, achieved the aims stated, mainly the development of scientific process skills. It was in this type of lessons that she could have a less directive role, providing opportunities to pupils in which they could design, plan, perform, interpret and draw conclusions by themselves.
Although \( S_2 \) intended to carry on her attempt to implement this model of teaching in the future, she conveyed her fear of more difficulties when working in a school within a group of teachers with a different perspective on teaching. In her own words

"... it is not probable to find teachers working within this model and I'm afraid I will not be able to work alone in this line .... but I want to try it and to improve my teaching skills which I think will be easier .. mainly due to my experience of this year .. I'm afraid this year I didn't make a great deal of improvement ..."

7.4.3 Case study 3 - S.T. \( S_4 \)

7.4.3.1 Class description

\( S_4 \) faced a similar situation to the one faced by \( S_1 \), in respect of the characteristics of the 9th and 8th grade classes. The differences between them were even more than the classes of \( S_1 \), although in different aspects. His 9th grade class was composed of sixteen boys and fifteen girls ten of them being repeaters. The average age of the class was 16, which means that a great number of pupils were much older than the average pupil of a 9th grade class. Although only ten of them were repeating the 9th grade, some must have failed in earlier grades. The general impression of the class was that the majority of the pupils were not at all interested in learning something or in making any effort to pay attention whatever the subject matter was. They seemed to be of very low academic ability and in some way they showed signs of a certain frustration of being still in school. This aspect was displayed by a certain aggressiveness toward the teacher.

Completely opposed to this case, the 8th grade class was composed of a group highly interested and motivated pupils. The class comprised fifteen boys and fourteen girls, who ranged in age from 14 to 15 years. There were two repeaters only.

7.4.3.2 Data from, and interpretation of, classroom observations

When I started my observations on \( S_4 \)'s 9th grade class the relationship between the student teacher and the pupils was already a very bad one. Also, although in his task analyses of the first lessons on optics a concern was apparent to "raise conceptual awareness" and "introduction of anomaly", he was unable to achieve the aims he had stated for the lessons during the interactive phase. This situation was due, mainly, to aspects that can be considered into two categories.
of difficulties: one intrinsic and another extrinsic. By intrinsic aspects I mean the ones related to the individual student teacher, his personality, his scientific competence and the development of her/his scientific "abilities". By extrinsic aspects I mean the ones related to the characteristics of the class, the school environment and the situation of the teaching practice. Although considered separately these two categories of difficulties were in some way intertwined in the sense that the way S4 dealt with the extrinsic difficulties was dependent on the intrinsic ones. When talking with S4 about the difficulties he was facing during the interactive phase of the teaching his claims were, most of the time, related to the extrinsic difficulties. In my opinion the intrinsic ones were the ones which most contributed to the state of the situation.

To transcribe his lessons from the tapes was a very difficult sometimes even impossible task because most of the time the pupils were too noisy.

His first class that I observed was the one that followed the diagnostic test on "light and its properties". He was unable to start the lesson during the first 10 minutes because the pupils were not settled down, talking, shouting and laughing, completely ignoring the teacher. He took the register but was not able to call out the names as there was too much noise and he spent a considerable time looking to see who was there. Then he started the lesson using the answers given by the pupils to the questionnaire as a source for discussion. His inaptitude to conduct the discussion in order to help pupils to conceptual change was apparent. He emphasised the intuitive ideas disclosed by some pupils too much without providing situations in which those ideas could be in conflict. At the end the majority of the pupils were still more confused than when they started. This situation fostered, in pupils, aggressive attitudes toward S4. He was unable to control the situation and some days after (approximately 5 weeks after the beginning of the school year) he said to me:

"you know .. I had to give up .... I'm going to teach them in an expositing way because it is impossible to make them think ... be interested or work by themselves ... they don't want to study ... they don't even want to listen to what I'm saying ..... they are always joking and behaving disruptively".

When I asked why did he think that had happened he replied

".. well you see the great percentage of them are repeaters and they are here only because their parents want them to be in school .. they aren't really interested in studying .... they don't want to make any effort to think .... they are always asking me to dictate definitions .. so .... I decided to teach them like that ... I can't do any group work .. or practical work .. they do nothing ... they only play and make jokes".

Although this class was a very difficult one to deal with due to its
features, the personality, scientific competence and development of scientific "abilities" of student teacher \( S_4 \) were the factors that most contributed to his "discontinuance" on the implementation of the innovation. They had also a great implication for the class' behaviour. His lack of confidence in his scientific competence (which was very well grounded) was a kind of stumbling block which inhibited him from embarking on an approach to teaching in which pupils should be encouraged to put questions and rise problems. This approach requires a deep understanding of the subject matter and a strong scientific background from the teacher.

When pupils discovered this weak point in \( S_4 \) they lost confidence in him and took attitudes which did not foster a friendly and cooperative atmosphere in \( S_4 \)'s lessons. In one of the lessons observed, when he was explaining some thing on the blackboard one pupil in a very aggressive way said to her neighbour

".. better not take any notes ... he is always making mistakes .. we don't learn anything with him".

Hearing this kind of comments made him still more confused, nervous and unable to think. Talking to me he commented on this saying

".. you know .. in this class I can't think ... it's like being in hell .... they are awful .... some lessons ago I send one out and he didn't go .... I couldn't put him out ... and now I'm afraid to get into a similar situation ... thus .. I can't send anybody out anymore .... and they are aware of this .... what I'm doing now is to find ways to keep them always busy ... as for instance to give worksheets and asked them to fill in".

His relationship with the 8th grade class was much better. The intrinsic difficulties found in the implementation of the innovation during the interaction with the 9th grade class were not so strongly in evidence here. Nevertheless, as they remained the same, \( S_4 \) showed great inaptitude in using the model even with this group of pupils. Although he did not reject the innovation, the way he behaved during the interactive phase of the lessons hardly helped the achievement of the aims stated. He found great difficulties in helping pupils to be aware of their alternative framworks and he acted in a very confused way when participating in class discussions and when interacting with groups involved in practical work. His "abilities" of communicating and decision-making were the ones which most inhibited the implementation of the innovation. Nevertheless, during his interaction with the 8th grade class some small improvement of his teaching skills was apparent.

It was interesting to note that the 8th grade pupils' attitudes to him and to his style of teaching. Although they recognized \( S_4 \)'s difficulties in conducting the lessons, as they told me in informal talks, in general they enjoyed them. When I asked them why, they mentioned the fact that most of the physics lessons were practical related to electric current in which they could work by themselves with

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very simple materials and which made them feel that they were playing. S4 based
the study of the electric current on the activity he had performed during the course
on "Physics Didactics".

7.4.3.3 Analysis of the data from the interview

The analysis of the transcript of the interview conducted with S4 at the end of his teaching practice revealed the following points.

a) According to S4, he was able to put the model of teaching he intended
at the beginning of the school year to implement into practice, but only with his 8th grade class. Nevertheless he recognized that even there he had met great
difficulties. In his own words

"... sometimes I felt I confused the pupils ... when questioning them ...
I put too many questions at the same time ... which made them feel lost ...
although as they were in general good learners it didn't affect them very much".

In his opinion, it would be practically impossible to implement the
model in classes with disciplinary problems.

b) His experience with the 8th grade class was very positive for him. The
feedback he got from these pupils encouraged him to carry on with the approach
used with that class. The pupils enjoyed the lessons because, as they told him,
those were the only lessons where they could participate.

c) Some of the reasons pointed out by S4 for the difficulties in implementing
the innovation in the 9th grade were: i) the insubordination of the class; ii) the
demotivation of the majority of the pupils; iii) the average age level of the class.
In his opinion this model of teaching was not perhaps the most appropriate for
that range of ages; iv) the subject matter was not the most motivating for that
group of pupils.

d) Paradoxically one of the "abilities" he considered to have been best de­
veloped in the 8th grade pupils was the process skill - communicating. He could
perceive that because, according to him, by the end of the year pupils were better
able to express their ideas. He saw this as a result of a great number of opportuni­
ties provided in which each pupil was encouraged to participate and give her/his
opinions.

e) S4 felt that trying to implement a "new" model of teaching in a teaching
practice situation requires greater effort than teaching in a traditional way. Ac­
cording to him it would be easier to follow a conventional approach in both classes
than trying to implement a new one and "... probably I would get better results in terms of my own final evaluation! ...".

f) Nevertheless he expressed his feeling that

"... it is afterall more attractive to teach in the new approach ..., because we feel that the pupils are trying to find explanations for everything ..., and sometimes they come up with some solutions! ... the teacher would never think of them!".

Although recognizing his great difficulties in teaching within a constructivist model he conveyed his intentions to carry on with his efforts in that direction.

7.4.4 Case study 4 - S.T. S5

7.4.4.1 Class description

The 9th grade class of S5 contained 29 pupils (19 boys and 10 girls) who ranged in age from 14 to 17 years old. There were 17 repeaters. Pupils were from a mixed socioeconomic background, mostly middle class. This class also was not an easy one as regards class management. There was a group of boys who were difficult to control: sometimes hostile, disruptive and displaying behaviours (joking, laughing and talking among themselves on topics that had nothing to do with the lessons). Although S5 had discipline problems with this class she was able to achieve a good rapport with all the pupils and in her own words

"... even though they gave me .. so much trouble .. I like them .... I enjoy being with them .. more than with the 8th grade class".

Her 8th grade class also contained 29 pupils (13 boys and 16 girls). There were only two repeaters. The average age of the class was 13. The majority of pupils were from a low socioeconomic background. The class was very quiet. S5 told me that she found great difficulty in encouraging its participation during the first months of the school year. When she first met with the class she faced a very passive group of pupils who were not very interested in cooperating and being involved in class work.

7.4.4.2 Data from, and interpretation of, classroom observations

My observations of S5's lessons started at her fifth lesson to the 9th grade class. It was the last lesson on the first unit of the 9th grade and it covered
the topic of "Energy". In the 6th lesson she applied the diagnostic questionnaire about "light and its properties". The audiorecording of the lessons started at the 7th lesson. The task analysis of the pre-active phase and the analysis of the interactive phase of this lesson is presented in Appendix 15. The lesson was selected for presentation firstly because it is an exemplar of her attempt to implement the model of teaching she already had adopted and secondly because the difficulties she faced during her interaction with this particular class, can be elicited from the analysis of the transcript of the lesson.

As already mentioned in Chapter 5, section 5.6, the main question which was addressed in the analysis of the lessons observed was: "how did the student teacher guide the interaction taking place in the lesson toward the achievement of the stated objectives and aims?". Two aspects of the interaction were considered in an attempt to find out from the analysis of the transcripts of the lessons answers to that question; the nature and the content of interactions.

a) The nature of the interactions.

In order to introduce the unit of optics the nature of the presentation chosen by the student teacher was in the form of a class discussion based on the information gathered from the diagnostic questionnaire.

The main type of verbal interaction made by S5 was in the form of questioning. It was apparent through the lesson transcript that the main concern of S5 was to lead pupils to the construction of knowledge. With this purpose the first questions were aimed at looking for evidence that could lead pupils to draw the conclusion that "light is a source of energy" (see utterances 1, 14, 17, 23, 25, 40, 56, 97, 137 and 146 in Appendix 15).

Two main difficulties emerged concerning this type of interaction:

i) it was apparent from the transcript of the lesson and from the observations of the non-verbal behaviours of the pupils that they weren't used to this form of interaction. Their participation was very disorganized. Generally they were unable to express their ideas clearly and revealed a great deficiency in linguistic skills. It was also apparent that they had difficulty in making a synthesis of what was being said and in drawing conclusions based on evidence.

Another aspect, very important as it was one of the aims for teaching is the development of the scientific capacity of team-work, was the difficulty showed by pupils in listening to others. All wanted to give their ideas, their opinions, but they hardly ever listened to their peers.
This area of difficulties challenges teachers who see their role as facilitators of the development of their pupils either in a scientific or social context;

ii) the other main difficulty was directly related to the student teachers themselves. This form of interaction is not very "confortable" to the student teachers. S5 revealed great difficulty in handling pupils' answers and assertions and in controlling their participation. She was unable to avoid a mass shouting-out of answers and unable to lead pupils to draw conclusions for themselves.

She also felt uneasy when interdisciplinary knowledge was called upon. The same happened with the majority of the student teachers. This problem reflects, in my opinion, a very important aspect deserving a deep consideration. Through their schooling the teaching of specific subjects had been too individualized and not enough attention had been payed to the integration of knowledge. In my point of view, if this aspect of teaching does not represent a highly important problem when students of other degrees are concerned, for teaching degrees it requires great care and reflection. My own observations, and the comments made by the student teachers, provide evidence that the lack of interdisciplinarity of knowledge is one important aspect inhibiting the implementation of a constructivist approach to teaching.

Other questions were put to push pupils to clarify their statements, helping them to develop their skills of communication. As is illustrated in the transcript, pupils revealed great difficulties in expressing their own ideas. One function of group discussion was the development of pupils' confidence in the use of the language not only for the process of thinking but also within the social context. It shouldn't be thought that a pupil was developing intellectually or socially if much of her/his speech was monosyllabic or produced in incomplete sentences. Notwithstanding evidence from research (Rowe, 1974; Hornsey, 1982; Zylbersztajn, 1983; Brown and Edmondson, 1984) which has pointed out that most of the "legitimate" talk in classrooms is by the teacher, who asks a great number of questions many of which require pupils only to recall information and which involve pupils' answers consisting mostly of very short sentences.

Some other questions were aimed at disclosing pupils' ideas and challenging their views (see utterances 177, 181, 312, 331 in Appendix 15).

The lesson could not be considered to have been performed traditionally in the sense that there was not a pure transmission of knowledge but rather a concern to lead pupils to construct knowledge. Some syntheses of what had been
said during the lesson were made by S5. Plenty of opportunities were also provided for inter-pupil discussion although the difficulty experienced by S5 in exerting disciplinary control over the group in order to fully capitalize the flow of ideas that occurred during the lesson was apparent. This was illustrated by the episode with the girl who was distracted (see utterance 342 in Appendix 15). Most of the pupils were very participative but the conversation was very often disorganized and the student teacher was unable to cope with the situation. After the lesson she commented on the difficulty she felt in controlling pupils' participation in the discussion in order to help each one to express ideas in a correct and clear way. She felt that various ideas had been put forward but were not clarified. This made her feel the necessity of returning to them in the next lesson. Nevertheless she enjoyed the lesson and felt the pupils were interested.

In a class of 29 pupils, high percentage of them being highly participative, it is very difficult for an unexperienced teacher (dealing with a strong flow of participation), to detect some less active pupils. As an observer I was in a privileged position to perceive that. Those pupils who were not so active showed signs of disinterest because there were too many questions without clear answers. Nevertheless she was able to identify one of these situations and tried to involve the pupil in the discussion (see episode 333 to 357 in Appendix 15).

Communicating and interpreting seemed to have been the aims on which S5 placed most emphasis. No situations were provided for the development of the process skill - predicting (one of the stated aims). But, as S5 commented at the end of the lesson,

"... with this type of lessons it's difficult to fulfill the plan we made for the lesson .... it is in someway unpredictable what the lesson is going to be ... it depends very much on the ideas set up by pupils".

b) The content of the interactions.

Because the approach to the topic was based on information gathered through the diagnostic questionnaire, the issues raised during the lesson were not considered either in the official syllabus or in the textbooks available. The latter are commonly written by secondary school teachers who are not usually familiar with recent findings concerning problems encountered in science education. One of these problems, the intuitive or alternative conceptions pupils bring to classrooms, has considerable implications for the teaching and learning of concepts in physics. Starting from the knowledge pupils had before formal teaching in optics, the lesson evolved from the interpretations and discussion of the different pupils' ideas about optical phenomena. This type of approach stimulates the de-
development of pupils' curiosity, criticism, communication, observation, self-confidence, consistency and interest for the subject.

It was also apparent through the observation and analysis of the lesson transcript that the fluidity of the conversation created some difficult problems to the student teacher. This can also be elicited from her own words when talking to me after the lesson

".. they say such things! .... what did he mean by iron emitting light? .."

".. actually I wasn't very sure about the mechanism of the photosynthesis .... I was interested only to know if they could identify light with the energy that plants need to carry out photosynthesis ..".

In summary, the general impression gained was that the nature of the interaction chosen allowed an approach to the teaching of the lesson content which fostered the achievement of the stated objectives and aims. Through a class discussion the student teacher provided opportunities in which pupils could be helped to develop critical-mindedness (e.g. exchange 150 in Appendix 15), and inquisitive-mindedness (see exchanges 129, 330, 369 in Appendix 15). Both were aims stated for the lesson. It was also apparent that the set of related types of teacher behaviours which tends to facilitate the development of these capacities in pupils still needed to be improved by student teacher S5.

This type of interaction, in a relaxed and friendly atmosphere allowed pupils to begin to articulate their own conceptions more easily, either as a question or in response to a question, in the course of requesting information or as a source of doubt or puzzlement. By this way pupils can be aware of their personal frameworks and the teacher's task is to help the progress of pupil's cognitive development through a constructivist perspective.

The nature of the interaction chosen seems to have been the most appropriate for the development of the skill of communicating, whenever the participation is well organized. Although plenty of opportunities for the development of this skill were provided by S5, it was apparent that her teaching skills to foster that development needed to be improved.

 Plenty of opportunities can also be provided within this form of interaction for the development of the scientific process skill-predicting as long as there is not a strong "framing" (control of knowledge) on the part of the teacher which was the case in this particular lesson.

Finally it was apparent, during this lesson, that S5 made a valid attempt to guide the interaction toward the achievement of the stated aims and, although
she was not highly successful, she was on 'the right track'.

My observations, and analyses of the task analyses of the pre-active phase and interactive phase of some of the lessons performed by S5 in her 9th grade class during the first half of the school year, and in her 8th grade class in the second half, revealed the following points.

a) The introduction of a new unit was usually preceded by some kind of activities aimed at disclosing pupils' intuitive ideas about the concepts to be approached. Then in a group discussion, following a similar pattern to the one presented in the lesson transcribed and analysed in Appendix 15, the "raising of conceptual awareness" and "anomalies introduction" steps in the teaching process usually took place.

b) The strategies used for the "theory construction" step were various depending on the nature of the contents of the lesson. Nevertheless, either through practical work, group discussion or class discussion, S5's concern to stimulate pupils imagination and to make them think by themselves was apparent. This was not achieved all the time.

c) S5's concern to try different strategies to achieve the aims stated as well as to analyse the results of these strategies in an attempt to seek what and why went well and what and why went wrong was apparent through the year.

d) In time her rapport with the 9th grade class allowed for a cooperative and working atmosphere in which she could fully implement the innovation. Nevertheless she revealed some intrinsic difficulties with the full achievement of it.

By the end of my observations the pupils were reacting well to her style of teaching and generally appeared alert, interested and enjoying the lessons. S5 was all the time concerned to involve pupils who seemed more passive, in what was going on in the lessons.

e) Although S5 kept telling me of the difficulties she found in the implementation of the model with her 8th grade class because of its passivity, when I started my observations in this class I could perceive that she did not give up. Slowly but surely pupils reacted to her style of teaching and, by the end of my observations, almost all of them were participating voluntarily in class discussions, and performing activities with apparent willingness.

7.4.4.3 Analysis of the data from the interview

The analysis of the transcript of the interview conducted with S5
at the very end of her teaching practice produced the following information.

a) $S_5$ was perfectly aware that she had not achieved a full implementation of the "innovative" model of teaching. The reasons pointed out by her for this fact were: Firstly, her inexperience in teaching

"... there are so many new things to do ... to plan materials ... to develop worksheets ... diagnostic tests ... to select texts ... to develop evaluative tests ... everything is new ... and I felt that there was not enough time left for reflecting on the best strategies for achieving the aims ... and ... in my opinion ... to teach according to this model requires much more thorough thinking about all these issues ... maybe because we aren't accustomed to this".

Only during the third and last term of the school year did she feel able to teach according to the model more regularly. During the two first terms she felt that in some lessons, she was close to the desirable aim, but in others was very frustrated because she felt she was too far from it. Nevertheless the experience of the first terms was highly positive and she reaped its reward during the third term.

Secondly, large class size was seen as a negative factor for the implementation of the innovation. In her own words

"... I know that there were pupils to who were harmed ... involuntarily ... because ... if the class size had been smaller I would have been able to help their development in a more efficient way ... I'm well aware that there were some pupils whom I wasn't able to help".

Thirdly, pupils' reaction to this style of teaching was, at the beginning, not very favourable. According to her there is a great accommodation by pupils to the traditional model of teaching

"... although pupils complain about teaching ... saying that it is bad and that they want new ways of teaching .... I think they don't know what those 'new ways' must be ... I also didn't know until very recently .... and when one tries this way .... making them think by themselves ... making them work by themselves .... I felt that they reacted against it ... you see ... it's easier for them to listen to the teacher .... they can 'switch off' if they want ... playing 'battle ships' if they want ... this is easier than to be required to participate actively ... facing a teacher who is always asking questions etc. ... but with the time ... mainly in my 9th grade class ... well I talked with them about the way physics and also chemistry was taught .. and they all agreed that this was the way of teaching they liked most"

b) She perceived a great lack of interaction between the group of teachers of the school, who were teaching the same subject, and the group of student teachers involved in the teaching practice

"... they haven't the same framework as we have ... they have a vague idea that we are trying to do new things ... that we want to develop scientific
"abilities" ... they find this ... "worthwhile" ... but they don't find it useful ... when talking about it with them they keep saying ... 'but can you cover the syllabus?' ... I think it's not enough to talk about these things ... we who are inexperienced ... they laugh at us ... and in this field ... the supervisors from the university have a great responsibility ... they should promote inservice formation ... and help inservice teachers to change their perspectives"

c) When asked which of the "abilities" she found less difficult to develop in pupils she remarked that

"... well that has a lot to do with the "abilities the teacher himself/herself has developed ... for me it was easier to develop in pupils scientific process skills ... I can say that there was a real improvement in both classes ... at the beginning what they wanted was to follow recipes ... but with time they were able to use practical work for the elaboration of conceptions and not to use it for the illustration of them ... they were able to design and plan experiments to sort out some problems ... although still with many deficiencies .... mainly concerning recording data ... interpreting results ... even observing ..... well this last one ... for me this was the most critical .. because .... well the problem is this .. I observe one thing .. but because I intend to observe it ... and the pupils observe other things ... but .... well I believe their observations are really valid .. because they have other mental structures ... but to understand this ... requires a great effort from the teacher"

To some extent, the last sentence conveyed her view of teaching and learning as a process of negotiation between the pupils and the teacher. Her position that people view and interpret things differently thus has a constructivist flavour.

d) To stimulate pupils to carry out individual or group extra-classroom work and even out of syllabus topics, analysis of texts, small research projects, were perceived by S5 as good strategies with which to develop the scientific "abilities" of critical-mindedness, accuracy and honesty.

e) Her experience during the year gave support to her idea of the importance of the individualized teaching

".. to help each one individually .. to understand each one individually ... to pay attention to each one's ideas is essential for helping each individual pupil to develop intellectually and cognitively".

She perceived that she had achieved it, to some extent, with most of the pupils, but ".. you know I had only two classes ... I don't know if this will be possible with five or six classes ..". This was a recurrent concern expressed by the other student teachers.

f) According to her, because she believed in the philosophy underlying the model of teaching she tried to implement, she felt at ease putting it into practice in a year of teaching practice everwhile she was being observed by four different
supervisors possibly with different philosophies. She also commented that, on the other hand, because it was a year of teaching practice it brought up opportunities to discuss and share ideas with others. She pointed out

".. it is easier to put into practice this kind of innovation in a teaching practice year than when one is alone .. later .. I think it would be more difficult".

This concern was conveyed also by other student teachers. It stresses the need of team-work for the successful implementation of an educational innovation.

7.4.5 Case study 5 - S.T. Sg

7.4.5.1 Class description

The total number of the pupils in the 9th grade class of Sg was 31, comprising 28 girls and 3 boys. Their ages ranged from 14 to 17 years, 15 the class average age. There were 7 repeaters. This class showed remarkable behaviour from the beginning of my observations. The majority of the girls were extremely alert, highly motivated and interested in participating.

Sg's 8th grade class was also a large class comprising 32 pupils, 18 girls and 14 boys, the average age level being 14. There were 4 repeaters. According to Sg, at the beginning this class was very passive and did not show any signs of disruptive behaviour. Sg had discipline problems in neither of the classes and she was very pleased with both throughout the year. The problems she had to face with both classes were of different kinds. While, during her interaction with the 9th grade class she had problems in organizing the participation and, in controlling it, with the 8th grade class she faced the problem of promoting its participation and making it to lose its passiveness.

7.4.5.2 Data from, and interpretation of, classroom observations

The general impression gained from the observations of Sg's lessons in both classes was that her main concern was the construction of knowledge by the pupils themselves. Only when completely necessary was information imparted by the student teacher to the pupils (e.g. scientific names, scientific symbols, informations that could not be found by the pupils). One predominant feature of her style was the provision of situations in which pupils had to think and decide by themselves. This is well illustrated through the analysis of one of her lessons,
presented in Appendix 16. This lesson was selected for presentation because it was of similar format of most of her lessons and because, in consequence of an episode that occurred, information was produced on pupils' reaction to the model of teaching she was trying to implement. The lesson was the first one on the unit of "Force and mass" and was based on the information Sg had gathered from the diagnostic test. One group of eleven pupils of her class went to the university on the following day for a session of microteaching performed by one of the student teachers of the second cohort on the course on "Physics Didactics". The lesson was on 'mass and weight' and the student teacher, who was aware of pupils' alternative conceptions about these two concepts, used a strategy similar to the one used by Sg in the lesson on 'force and mass'. When the microteaching session was over and the group of pupils was leaving the room, one of them turned back and came near me. I was standing near the tape-recorder, still on, used usually for recording the lesson. She addressed me in a kind of attempt to give her feelings about the way she had been taught and she perceived was being trained in that session. The following is the transcript of the conversation.

(R stands for myself).

"P1 - can I tell you one thing?
R - of course!

P1 - I like this subject because this subject (Physics and Chemistry) makes us think ... and it makes us see that sometimes we have ideas about things that are different .... well I don't know how to explain ... but really I'm finding that this subject is interesting .. it isn't a subject for cramming (laughs) ... but it makes us think".

In the meantime the rest of the group which had already turned back and entered into the conversation. One said:

"P2 - but .. you know ... it depends on the way it is taught .... because .. last year .. I'm a repeater .. my teacher when she taught us about mass .. well she arrived at the lesson and said 'mass is this and etc. .. etc.' ... and we wrote down the definition she gave .. but after some minutes or so .... we had already forgotten what mass was ... only this year I understood what mass is and ... you know .. although we studied mass last year .. only this year I realized that the idea of mass I hold was quite different from what it really is ..

P3 - that's true ... I think the way it has been taught .. this subject makes us think ... I'm really enjoying it

R - do you think that what you have been learning has something to do with your everyday life?

P3 - of course!

P4 - it has! .. it has! .. because it is a way of understanding that things we see in day-to-day life without thinking of that we are studying (laughs)

P5 - I think ... it is a good way to make us think .."
This feedback of Sg's way of teaching was given to her. It stimulated and encouraged her to progress in the implementation of the model of teaching.

In the impossibility of transcribing all the interesting situations that occurred in Sg's lessons, and which I had the opportunity to observe, I will transcribe small extracts of some of her lessons which give the constructivist flavour of her style of teaching.

In one of the lessons, whose content was the concept of work, after having explored pupils' intuitive ideas and leading the class discussion to the scientific meaning for the word, she presented the class with the following problem.

"Sg - suppose that a little girl and a man 50 years old are lifting a heavy book from the floor up to the same table .. tell me .. are they doing the same work?"

The class' reaction was immediate and spontaneous.

"P S - oh! no .. the poor girl made a greater work .. the poor girl made a much greater work than the old man ..

Sg - why do you say so?

P 1 - because she is weaker than the man!

P 2 - yes .. and although the book was the same ....

P 3 - and the distance was also the same .... the girl .. made a greater effort

Sg - well .. you are saying that the book is the same ... the distance is the same .... think more carefully about the work done by both man and girl ...

P 1 - .. well .... but the girl is weaker than the man isn't she? ..

P - .. but ... well ... really ... the work should be the same ...

P 3 - it can't be ... poor girl!

P 4 - yes .. that's true the work is the same .... because ... if the book is the same ... the book's weight is the same .. and the distance is the same ...

P 5 - but the man doesn't need to make the same force than the girl .. because he is stronger ....

P 3 - (all speaking)

Sg - please .. don't talk at the same time ..

P 4 - Miss can I explain? .. I think I understand ... the girl makes a greater effort than the man right? .. but the work is the same ..

P 3 - what?!? .. what is she saying?!

P 4 - I mean the work is the same .. but it's relative ... I don't know .. how to explain .. but I feel it ..

P 3 - it can't be!

P 7 - I think I can explain .... she is right .... it is relative
$S_6$ - what do you mean by relative?

$P_7$ - can I go to the blackboard?

$S_6$ - yes

$P_7$ - I'll try to explain with a drawing ... suppose this is the little girl's arm

( she draws)  
\[ \text{this is the book she is lifting} \]

\[ \text{this is her arm's muscle} \]

\[ \text{and this is the man's arm and his arm's muscle} \]

of course the muscle of the man is bigger than the muscle of the little girl

(laughs) when they lift the book the force is the same ... it's equal to the

book's weight but opposite to it ... and the distance they move is the same

... so the work is the same ... but well .. if we think about the effort made

by each one ... we can imagine .. for instance that it corresponds to taking

off a bit of each muscle .. well the quantity taken off in each muscle ....

is the same .. but relatively to the girl's muscle it's bigger than to the man's

muscle ... are you following me?

$P_5$ - oh! .. yes

.... uhm ...

$P_5$ - .. so ... the girl will be more tired than the man ...

$P_3$ - yes .. I see .... so ... the work is the same ".

The interpretation and explanation given by $P_7$ was really a very

imaginative one. It was interesting to note how well her peers accepted it and

how it helped the understanding of the situation. It is also interesting to note

the apparent concern of $S_6$ to provide anomalous situations which contributed

to foster creativity, debate and helped pupils to revise their own conceptions.

The episode illustrates very well how these intuitive conceptions are resistant

to teaching. After a process of construction of the concept of work, guided by

$S_6$, but in which, although through different situations pupils learned the concept,

when a conflict situation was presented pupils revealed that their intuitive ideas

were still untouched. $S_6$ was aware of this and acted accordingly.

In another of her lessons, in which she was helping pupils to draw

conclusions on the variation of weight with altitude and latitude, she instigated

pupils's thinking by saying ".. come on you need to think just a bit!". Comment

of one girl: "oh! Miss .. think a bit! ... what do we do all the time in physics lessons?

... we are always thinking .. thinking! ....".

Comments of this kind, convey, to some extent, the flavour of her

style of teaching and showed how pupils were aware of the difference between

this style and styles they were used to.
During my observations of $S_6$'s lessons in both classes it was apparent that, instead of given standarized definitions of the concepts (e.g. work, power, energy, mass, force, etc.) her concern was to present classes with situations related to the topic, promoting discussions and guiding them by integrating further questions, helping the pupils to reach the understanding of the concepts. Sometimes this was done with the help of simple experiments planned and usually performed by the pupils themselves.

An interesting episode happened at the middle of the second half of the school year when the student teachers were teaching the unit of "Electrostatics". This episode is presented because it illustrates the progress made by $S_6$ during her teaching practice and her willingness to introduce innovative strategies which could contribute to a better use of the model. A special event occurred in the town which as a consequence caused just a small number of pupils to attend school on that day. I was at the school to observe two following lessons, the first one given by $S_2$ and the second by $S_6$. When $S_2$ arrived at the classroom there were only 6 pupils attending the class. $S_6$ and myself were there to observe the lesson. The pupils asked $S_2$ not to give the lesson because they were just a few, but $S_2$ did not accede, and proposed that instead of advancing with new content they could talk about the previous lesson's content. Then a girl made a suggestion ".. Miss .. let me be the teacher today ... let me give the lesson". $S_2$ did not catch that opportunity and did not accept the suggestion. The lesson went on as a review of the last lesson's content.

Talking with $S_6$ I suggested that it would have been interesting to try this kind of experiment. Her next lesson was the following hour and in the class there were also few pupils, who asked her to let them go. Talking to them, she made the following suggestion

".. well ... as many of pupils aren't here .... we could do this ... one of you is going to play my role and give us the last lesson ... what do you think about it?".

The suggestion aroused immediate interest and various pupils raised their hands expressing their wish to perform the teacher's role. One of them was chosen and $S_6$ sat on a pupil's desk acting as a pupil. It was an interesting experience, obviously with many deficiencies, but which fostered great interest in pupils. Some days later $S_6$ asked me if I could go to her lesson because it would be interesting to observe what was going to happen. She told me that the pupils so much enjoyed the lesson performed by their peer that they had asked $S_6$ to let four of them to give another lesson with new content. She agreed and helped them to select the content and plan the lesson. I went to it. A task analysis of the lesson,
elaborated by those pupils, helped by Sg, was given to me. The lesson was audio­recorded. The analysis of the transcript and associated notes revealed the following points.

a) The lesson was very well prepared showing the great interest pupils had in this activity. They sought information from different books and encyclopedias.

b) The behaviour of the 'pupil teachers' was a kind of mirror of Sg's behaviour. They led the interaction, posing problems within the topic and instigating their peers' participation. These were extremely alert, interested and participating actively in the discussion, putting highly relevant questions which most of the time 'troubled' the teachers.

c) The role of Sg in this experience was extremely important in the sense that, acting as a pupil, she helped and led the interaction, through the right questions at the right time, for the clarification of the situations occurring during the lesson.

d) At the end of the lesson the enthusiasm and enjoyment felt by both groups of pupils was apparent, both the 'teachers' or the 'pupils'. The 'teachers' were happy but tired as they said ".. they put such questions? ...", "you know ... this made me feel the necessity of understanding this better", "... they are so tiring ... they don't keep quiet!".

The pupils enjoyed the lesson as they told us when we talked at the end ".. I learned a lot in this lesson ... really they were fantastic! ..", ".. I don't agree with him about that point ... but I will get more information before arguing with him ..".

e) Sg found the experience very interesting and very appropriate for achieving some of the aims proposed for her teaching. She stated her intention to use it more often.

Summing up: over the course of my observations and work on several task analyses of the pre-active phase of the interaction and lesson transcripts some recurrent points were revealed.

a) Sg did not find great difficulty in her attempts to implement the model of teaching and an increase of her capability to use the full innovation in the future was apparent.

b) Her great concern to use physics content to develop scientific "abilities" in pupils was also apparent. Plenty of opportunities were provided for raising conceptual awareness, anomalies introduction and theories construction.
c) Practical work was always preceded by a class discussion about the aims of the activity and the procedures to be used. It was always followed by a presentation of each groups' conclusions. Then she usually promoted a discussion concerning the interpretation of the results. Most of the time this covered more than one or two class time periods.

d) $S_6$ revealed a willingness to try new strategies which could help her in what she intended to be her role as a teacher. When applying a new strategy she showed a very good perception of how to use it, why and what to do.

e) Although she commented to me on her difficulty of leading her 8\textsuperscript{th} grade pupils to active participation, when I started my observations at the beginning of the second half of the school year, I found a participative class, interested and involved in a working atmosphere. Nevertheless there was still a difference between this class and the 9\textsuperscript{th} grade class' behaviour. It would by difficult to surpass the activeness, the interest and enthusiasm of the 9\textsuperscript{th} grade class.

7.4.5.3 Analysis of the data from the interview

The analysis of the transcript of the interview conducted with $S_6$ at the very end of her teaching practice revealed the following points.

a) $S_6$ perceived that the implementation of the model was more effective in her 9\textsuperscript{th} grade class than in her 8\textsuperscript{th} grade.

b) According to her experience two main extrinsic difficulties face the implementation of the model of teaching: i) a priori, some classes' characteristics make the implementation more difficult than in others. Some classes react negatively to this style of teaching because they are accustomed to be passive and the pupils prefer to be taught in a not so demanding way. It is easier for them and they do not see why they should be active if what is needed is to pass exams. It takes time to convince them that what is important is their development. This would be more easily achieved if it was considered in the final assessment; ii) large class size was also considered an obstacle to the full use of the innovation. To attend to each individual pupil's needs, to help the development of each pupil according to her/his own pace was seen an extremely difficult task with large classes. It would be easier with classes comprising only 15 to 20 pupils.

c) Observing, designing, planning and performing experiences, predicting and manipulating were seen as the "abilities" easier to achieved because, according to her, it was possible to work on them with almost all subject matter. Nevertheless she pointed out that how much capacities such as critical, creative and inquisi-
tive-mindedness were developed is more difficult to evaluate.

d) S\(g\) perceived an interest in what the teaching group was doing by some of the other teachers of the same area. In her experience she met some colleagues who wanted to try some of her strategies in their classes. They also showed a willingness to know more about the model of teaching she was trying to implement.

e) The teaching practice situation was not seen as a very favourable one for trying any kind of innovation due to the fact that being observed by several supervisors, who may not share the same perspective on teaching, can present some problems. It was her conviction that in the future, she would feel more at ease in trying new strategies that could improve the implementation of the model.

f) According to her the experience of the implementation of the model of teaching was very positive and her intentions were to carry on with it in her future professional life. Nevertheless she pointed out a very important aspect of the teacher's life. She said

".. I may have the intention of carrying on teaching within this model but .... some circumstances of life can interfere with this wish ... I mean ... suppose that I will be assigned to a school very far from home ... I'm having a baby soon ..... to be sent to a school in a place where I just can come home at weekends .... to be alone ... all that may create a state of mind not favourable for working on an innovation .... psychologically .. one shouldn't be in conditions to be motivated for doing new things ... I mean ... there must be the risk to work just for surviving ...... but .. well .. I hope .. I will be able to overcome the problem .. I think it is worth teaching within this model".

7.5 Findings emerging from Part B of the Main Study

The purpose of Part B of the Main Study was stated in section 7.1 of this Chapter. The investigation undertaken during this part of the study produced the following findings:

1. the results of the implementation of the adoption stage of each individual student teacher seem to indicate that no rejection of the innovation took place, although in two cases temporary "discontinuance" was found;

2. this temporary "discontinuance" seems to be due mainly to "intrinsic" difficulties;

3. in the two cases of "discontinuance" an attitude of discomfort about the situation was evidenced by the student teachers with whom this happened;
4. the above findings support the finding 2 of Part A of the main study concerning the effectiveness of the scheme on the change of the student teachers' perspectives towards teaching;

5. improvement in teaching skills appropriate for working within a constructivist approach seemed to have been achieved in all the student teachers with just one exception, although at different degrees in each student teacher;

6. the classroom ecological system was perceived as a very influential factor for a successful use of the innovation. A variety of forces was seen as acting on and shaping the ecosystem of a classroom. These include the aptitudes and past experiences of the pupils, the physical aspects of the classroom and its organization, and interventions of other agents such as aides, student teachers and resources specialists. Among these, the past experience of the pupils and the class size were perceived as the ones which presented more difficulties to the implementation of the model;

7. the 'raising of conceptual awareness' step in the teaching/learning process, in which the pupils are given the chance to become aware of their own models of understanding before being introduced to the curricular perspective by the teacher was seen as the most relevant step for:
   
   i) promoting rational conceptual change;
   
   ii) fostering the curiosity and interest for the new topic to be learned;
   
   iii) helping the development of the pupils' scientific-like aspects;

8. class discussions, group discussions, open debates in which emphasis is made upon pupil-pupil interactions were seen as the most fruitful strategies for sharpening awareness of pupils' alternative or intuitive conceptions. The introduction of anomalies either through imaginative experiments or simple experiments and/or demonstrations for which pupils are asked to do some prediction, was seen as an effective step in the construction of knowledge by the pupils. Practical work used as a means to help pupils to develop scientific process skills rather than following "recipes" was seen as an effective strategy for improving physics education;

9. some evidence of pupils' preference for a constructivist approach to teaching was obtained although a more deep investigation on this issue
would be needed for a more sound conclusion;

10. signs of interest in and recognition that something new and interesting was going on in the teaching of the subject of "Physics and Chemistry" were shown by some regular teachers, as well as from some pupils' parents;

11. one of the problems faced during the implementation of the model was the lack of research on the development of tests to assess pupils' development of scientific "abilities". Because Bloom's taxonomy of educational objectives is the one usually followed in our schools, the standardized tests used to assess learning are based on that taxonomy. The development of tests to assess the aims proposed by this model of teaching was, besides extremely time-consuming, highly empirical bringing out the need for thorough research in this field;

12. the practice of a constructivist approach to teaching was perceived as a more time-consuming task than the practice of the traditional one. The need for a growth in the number of teachers working within the same approach was seen as an urgent solution for the consolidation of an effective improvement in science education. This would be twofold: i) first to foster in pupils a more favourable attitude for working within the approach; ii) secondly to create in each school a group of teachers who could help and share the tasks of test elaboration, either diagnostic or assessment tests, worksheet elaboration, choice of texts, and any kind of materials appropriate for a constructivist approach.

7.6 Summary

In this Chapter five case studies based on the implementation of the adoption stage of five student teachers in their teaching practice were presented. The central focus was on the way each individual student teacher behaved during the pre-active, interactive and evaluative phase of her/his teaching practice.

The interaction between student teachers and their 8th and 9th grade classes, during physics lessons was followed over the academic year. Deep analyses of some lessons including task analysis of the pre-active phase, interactive and evaluative phases as well as documents such as worksheets, chosen texts and assessment tests were undertaken.

Two cases of temporary "discontinuance" were noted. Intrinsic problems
related to the two student teachers seemed to be the main cause of these situations. In the cases presented, four of the student teachers were quite aware of the specific deficiencies in their teaching skills for working within a constructivist model of teaching. This, per se, was seen as likely to lead to their improvement.

The student teachers' own perceptions of their learning experience, their feelings, ideas and decisions on future practice were obtained through interviews conducted with each one individually at the very end of their teaching practice.

Difficulties encountered during the implementation of the adoption stage in a teaching practice context were considered. Some possible solutions for overcoming these difficulties and others relating to the implementation of a constructivist approach to teaching were also considered.

The findings of Part B of the main study were presented. Some of them supported evidence to the findings of Part A of the same study.
CHAPTER 8

THE MAIN STUDY: PART C – THE FIRST YEAR OF PROFESSIONAL LIFE

8.1 Introduction

In Part C of the main study, three of the, by now former, student teachers, \( S_2 \), \( S_5 \) and \( S_6 \) were followed into part of their first year of professional life.

The purpose of Part C of the main study was to investigate:

i) the implementation of the adoption stage by each teacher within the context of her/his school.

ii) pupils' reaction to their new teacher's model of teaching

iii) the teachers' perceptions, feelings, ideas and intentions concerning their professional life.

The data gathering strategies used during this part of the study were:

i) I had contact with the three teachers through conversations at the weekends when they came to Aveiro or through some letters they wrote to me during the early part of their interaction with schools and pupils. This enabled me to gather information about their feelings, their perspectives and their perceptions of the new situation. I gathered information on pupil's reactions to their new teacher's style of teaching through informal conversations with some pupils during my site visits;

ii) I observed and audiorecorded some lessons taught to different classes (8th, 9th and 10th grades), most of them in physics but some also in chemistry during my site visits. This enabled me to gather information about the process of adoption of the innovation not only in respect to physics teaching but on the transfer of the innovation to other areas, namely to chemistry teaching;

iii) finally, I conducted an interview with each teacher at the end of the observation period. This enabled me to gather information about their feelings, ideas, problems faced and intentions concerning their present and future life.
Research findings (e.g. Ryan, 1970; Tisher, 1982) stress the view that the induction of new teachers is highly context specific, related in each instance to unique interactions of persons (who possess varying levels of skills and capabilities) and school contexts (which differ in the constraints and opportunities for action they present to beginning teachers). Zeichner and Tabachnik (1985) point out that

"...the strategy of describing central tendencies in groups of beginning teachers while assuming school contexts to be relatively homogeneous tends to obscure important differences among teachers and among schools and has generally failed to illuminate the subtle process of beginning teacher socialization."

These views support mine, that in order to understand the progress of the adoption process in each individual teacher, during the first year of professional life, it is necessary to describe the particular school context in which they were working.

The three teachers were assigned in their first posts in three towns in the interior of the country, each one being at approximately 250 km away from Aveiro.

Both S2 and Sq's schools were in small provincial towns of predominant lower socioeconomic status. S2's school consisted of preparatory and secondary educational levels having approximately nine hundred pupils. The number of other secondary school teachers was small, with only three of the teachers in all being of "Physics and Chemistry". S6's school was still smaller, comprising the secondary school level only. The total number of pupils was approximately four hundred and there were only two teachers of "Physics and Chemistry". This last school was housed in a new building but was still poorly equipped, specially as concerning didactic materials. For instance there was not any equipment for use during the teaching of the unit on optics. Both schools were the only ones in the towns.

S5 was assigned to one of the two secondary schools of a third town of predominantly middle socioeconomic status. The school was housed in a big building with total number of two thousand five hundred pupils. The number of teachers was around one hundred, with ten being of "Physics and Chemistry". While S2' and S6's schools had settings which were very different from the school where their teaching practice took place, the same did not happen for S5. Her school's characteristics were very similar to the school in Aveiro. Commenting on this, after her first contact with the school, S5 expressed her sorrow at not having the chance to have experience of a small school which, in her opinion,
should provide a more favourable and agreeable environment for work. All her colleagues in the group of teachers of "Physics and Chemistry" were teachers with tenure, S5 being the youngest of the group. This inhibited her from sharing her ideas and experiences freely with her older colleagues, because she did not find any others interested in what she was doing.

8.3 Case Study 2 - B.T. S₂

S₂ was in charge of two 9th grade, two 10th grade and one 12th grade classes. Her first contact with the school was very positive. The school seemed reasonably equipped and the atmosphere was very friendly.

Approximately one month after the beginning of the school year, in a letter addressed to me, S₂ said how much she was enjoying her new experience. She remarked that the thing she was finding most rewarding was the fact that the pupils in general considered the teacher as a friend who was there to help them. She was happy because

"... this year I feel I've been able to put into practice what I really believed .... I like the pupils .... they seem to like me and they are reacting very well to my approach to teaching".

Some time later, talking with her, she conveyed the same feeling and pointed out some reasons for that. Firstly the context in which she was working was seen by her as a favourable one for putting into practice what she perceived as worth trying. It was seen as more relaxed, friendly and open to innovation than the context of the previous year. In physics and chemistry teaching she was the only teacher with tenure and this fact made her feel a certain responsibility towards the improvement of physics and chemistry education. One of her colleagues specially was very interested in her work and was showing a willingness to put into practice S₂'s own ideas and model of teaching. They were working together on the development of tests and worksheets.

Secondly, the pupils in general showed a greater interest in learning than the pupils with whom she had had her first teaching experience. The relations between the pupils and herself were friendly and it seemed to her that the pupils were enjoying the lessons and the subject. Although having a very busy time she was encountering fewer difficulties in implementing a constructivist model of teaching than during the previous year.
8.3.1 Analysis of the data from classroom observations

Because in the previous year $S_2$ was unable to transfer the "innovation" to the teaching of the unit of "Force and Mass" I decided to visit her when she was teaching that unit. This was in the middle of the first semester of the school year. I spent a day and a half with her, observing lessons in two 9th grade classes and one 10th grade where she was teaching chemistry. The 9th grade lessons were audiorecorded and notes were taken both during the observations in these classes and in the 10th grade class. At the end of each lesson I managed to talk with some of the pupils and thus gathered some information about their perceptions of the new teacher's style of teaching.

The analysis of the two lesson transcripts and the notes taken during lessons and after the conversation with pupils produced the following information.

a) It was apparent that there was a good rapport between $S_2$ and all the pupils and that the atmosphere of her lessons was friendly and cooperative.

b) During the interaction with the 9th grade it was evident that she based her lessons on the information she had of pupils' intuitive ideas about concepts such as force, mass, volume and weight. It was also apparent her concern to provide situations in which pupils' ideas could be disclosed and the more scientific of them could be built upon.

c) Pupils were encouraged to think for themselves and their participation was extremely active although organized. This was apparent in the 9th grade classes and in the 10th grade class.

d) $S_2$ showed signs of a great professional growth. She appeared to be at ease in the conduction of the lessons, showing a more relaxed and self-confident attitude. She used the situations occurring during lessons to help her pupils' development.

e) The general impression gained from my conversation with the pupils was that:

- they were enjoying the lessons very much;
- they were feeling a great difference between the style of this teacher and the style of teachers they were used to. When asked what differences they noted, some answers were: "It's different and very much different! ... this teacher makes us think ... even if we don't want (laughing)", "... well you see ... last year ... we needed to cram only
... we didn't need to understand ... this year .... this teacher .... oh! boy! .. she makes us to think and to talk", ",..even the subject matter is more interesting", ",.. well this teacher lets us express our own ideas ...".

f) It was apparent that S2 definitely adopted the innovation. Although there were still some deficiencies in her teaching skills, she showed a great deal of improvement.

8.3.2 Analysis of data from the interview.

At the end of my observations an in-depth interview was conducted with S2. The analysis of the transcript revealed the following points.

a) When asked if she had been able to put the model of teaching developed in the course on "Physics Didactics" into practice she answered:

"... well it hasn't been ... easy ... at least with one of the classes .. although with the others .. I think .. I have been achieving it ... also .. they have been cooperating very well .. during the first few times it was difficult because they wanted nothing else but definitions ... informations .. they said that it should be the teacher who knows everything .... now it's better .. they are starting to understand that things aren't like that .... they don't say that anymore .. they understand now that they need to think for themselves".

There seemed to be a good agreement between these statements, my own observations in the classrooms and the pupils' comments on S2 style of teaching.

b) The school's characteristics were seen by S2 as a favourable factor which helped and encouraged her to implement the "new" model of teaching. According to her, the fact of being a small school, compared with the school where she had had her first teaching experience, enabled her to enter into empathetic relations with individual pupils as well as with individual colleagues. This contributed a great deal to her own willingness to carry on with the innovation. Another very favourable factor was her perception of the pupils' enjoyment of her lessons. Pupils usually participated actively in class discussions, expressed their ideas freely and were, in general, effectively involved in the activities provided by her.

c) The absence of the constraints faced by her during the year of teaching practice was seen as another factor that helped her to feel at ease and hence to try new strategies.
d) When asked how did she prepare the lessons she commented that she had decided not to use any particular textbook. When it was possible she applied a diagnostic questionnaire before starting a new unit, as happened in the case of optics. When it was not possible, due to existing constraints in the school i.e. when starting the unit of "Force and Mass" she could not apply a diagnostic questionnaire because the school had no money for xerox copies she used the information she had gathered in the previous year. She used her task analyses for the pre-active phase, elaborated in the teaching practice year, making some modifications arising from her own experience.

e) She stated her intention to continue to teach within the same approach because

"... I couldn't do it in the other way ... you know .. I believe in it .. I feel that I need to improve my teaching skills a great deal .. but ... I feel also .. when I'm 'slipping' into the traditional model .. when lessons turn to being more expositive .. I feel a kind of dissatisfaction with myself ... a kind of frustration .. I lose interest .. I don't enjoy those lessons .. and then .. I make an effort to reteach them more in conformity with my beliefs ... well .. and I think that my self-confidence is increasing".

8.4. Case Study S₄ - B.T. S₅

S₅ was in charge of one 10th, one 12th and three 8th grade classes. In the 10th grade class she was in charge of the subject of the vocational area, "Analytical Chemistry". In the 12th grade class she was teaching "Chemistry". Only in the 8th grade class was she supposed to teach "Physics and Chemistry" but, as was a rule of the school, the teaching of the subject started with the study of chemistry. Thus, for approximately half of the year she taught chemistry only.

Approximately a month after being at her new school S₅ talked to me, giving an account of her impressions, feelings and problems already faced. Although there was not a great difference between the two school settings (the new school and the school in Aveiro) she felt these pupils to be even more disinterested in learning than her previous pupils. The classes had a high percentage of repeaters and very few pupils seemed motivated.

At the same time she did not find any collaborative support from her colleagues and was feeling herself very much alone in the implementation of the innovation.

Another factor upsetting her was that her timetable was unsuitable for working within a constructivist approach. The lessons were concentrated in
a few days. On two days she had six lessons in the same afternoon, one after each other. This was very exhausting and, after three consecutive hours, she had to make a great effort to avoid "giving" the information without any attempt to help the development of the pupils.

8.4.1 Analysis of the data from classroom observations

I found the time to visit her when S5 was concluding the study of chemistry in the 8th grade classes, and using the last unit of the chemistry syllabus (action of acids upon metals) to make a transition to the study of the first unit of the physics syllabus. I spent a day with her, observing three lessons in her 8th grade classes and one 10th grade class.

In the 8th grade classes the average number of pupils per class was around 28, and the number of repeaters in two of the classes was extremely high.

The content of the three lessons of the 8th grade class was "The reaction of acids upon metals". The lessons were audiorecorded.

My observations, associate notes and analysis of the three lesson transcripts produced the following information.

a) Although having the same content, the nature of presentation and the pupils' activities were different in the three lessons. In one of the lessons pupils worked in groups, performing experiments. S5 told me that her aims for that lesson were to develop process skills in pupils - observing, manipulating and recording data. Pupils were asked to add dilute acids to some samples of metals and record that observations. No worksheet was provided. She went around groups stimulating and helping pupils in their attempts to organize things. As she told me, the pupils were not used to do experiments on their own and they showed great deficiencies in their scientific process skills. Thus she was using the chemistry content of the 8th grade syllabus mainly to help the development of those skills, but, as she told me, "... just a few skills at each time."

Difficulty in organizing data by themselves, without the help of an pre-designed worksheet was still apparent in pupils's performance. When the group work was over, one person from each group went to the blackboard to record the data from the experiment and the groups were required to compare their results with the ones recorded on the blackboard.

Pupils appeared interested and involved in the work, although a certain disorganization in the performance of the experiments and on the recording of
the data was still apparent. The impression gained was that, although $S_5$ was concerned with the development of the pupils' scientific-like aspects her teaching skills appropriate for achieving this aim still need a great deal of improvement.

b) In the second lesson observed and audiorecorded she tried without great success to promote a class discussion on the problem of the pollution of soil and the need for neutralization. The pupils did not show great interest in participating, although $S_5$ concern to make them do the talking was apparent. Nevertheless, as has been shown through the description of this study, $S_5$'s talk, in a monotonic and not very enthusiastic way, did not help the achievement of that aim. The class was not alert and motivated.

Commenting on the lesson, when it was over, $S_5$ told me that she did not like it and that she always felt great difficulties with that particular class because "... they really don't bother at all ... they don't want to think ... although it seems to me that they are .. a bit better now".

c) The next class was very different. A significant proportion of pupils very alert and highly interested. It was interesting to note how this affected $S_5$'s own behaviour. Her attitudes towards pupils appeared more friendly, more communicative and she herself was more alert.

Pupils were given a sheet with the results of an investigation undertaken by chemists, biologists and agriculturists, into the $SO_2$ pollution effects on the environment near a factory. Based on the document she conducted the lesson, promoting pupils discussion on the interpretation of graphs, analysis of data and the design of solutions to overcome some of the problems which emerged.

As she told me, her aim for that lesson was to help pupils to develop the process skills of interpreting data, communicating and designing experiments appropriate for the resolution of some concrete problems. She was also concerned to help the development of critical mindedness in pupils through this kind of activity.

It was interesting to note that, $S_5$ was able to conduct the interaction in order to achieve the aims proposed. Throughout the lesson it was apparent that pupils felt at ease to expand their opinions, to interpret graphs and draw conclusions by themselves.

d) The general impression gained was that $S_5$, although having adopted the innovation, did not show great progress in her teaching skills, these being still very much dependent on the characteristics of the class in which she was performing.
e) From my conversations with some of the pupils I perceived that, in general, they were enjoying the way their new teacher was teaching. Only the repeaters could point out some differences, perceived by them, between this teacher's style and the one of the previous year, because they were 8th grade pupils and the teaching of "Physics and Chemistry" started there.

Sentences like ".. last year we understood nothing ..", "..I like the lessons .. because we do a lot of experiments by ourselves .. and we understand better .. last year it was only the teacher who did things .. we just watched", ".. although the content is the same .. and I still don't like chemistry! .. I enjoy the lessons .. they are more interesting ", ".... well the worst .. are the numerical problems .. but this teacher help us to understand them ".

There were also some comments of disapproval. One 10th grade boy said to me "you know .. there are things I don't like in this teacher .. for instance .. last year (he was a repeater) the teacher used to solve the numerical problems on the blackboard and we wrote down the resolutions and we studied them at home .. this year the teacher doesn't do this .. she doesn't solve problems and only asks us to solve them alone .. I think it's not fair .. it makes things more difficult to us".

8.4.2. Analysis of data from the interview

The analysis of the transcript of our conversation at the end of my observations produced the following information.

a) According to S5, she was slowly achieving the aims she proposed for her teaching. Nevertheless she was meeting some obstacles to the implementation of the model, namely:

- classes had a large number of pupils,
- there was a lack of time to prepare material and to think carefully of better strategies to improve the development of the learner,
- the low sociocultural background of the majority of the pupils of the two of her 8th grade classes. As she said, this fact makes communication difficult because ".. sometimes I don't understand what they are saying .. and vice-versa".
- the lack of collaboration with colleagues. There was no sharing of experiences between them and ".. it would be easier to work within the same perspective
we could help each other on the development of materials .. diagnostic tests .. worksheets .. and to share ideas".

b) the fact of having five to six lessons one after another. Although she found it a bit tiring she overcame it by choosing different activities for each lesson. This solution was, to some extent, imposed by the different characteristics of the classes she had to face, within the constructivist approach she was trying to follow. She remarked that ".. probably it would be extremely boring if I was teaching in a traditional way!".

c) her situation this year, being alone without being observed, was seen by S5 as a more favourable one for the implementation of the innovation. "..last year .. if a lesson went wrong .. it was for me a small tragedy .. this year I'm more relaxed ... if one lesson doesn't go so well ... well .. next I will try another strategy .. may be it will work better .. I feel more at ease".

d) When asked how had she prepared the lessons she told me that usually she had not written the task analyses of the pre-active phase of the lessons "..I feel I don't need to write it down .. I analyse the lessons' content .. think on the "abilities" that can be developed in pupils through this content and .. that's the way I plan lessons".

e) In chemistry she did not apply diagnostic questionnaire although she tried to find pupils' ideas about chemical concepts with a few questions. Nevertheless she commented:"... may be it's more difficult in chemistry to find these ideas .. or may be these particular pupils (laughing) don't have ideas at all ... well I'm joking ...".

f) She conveyed her intentions to carry on with the innovation, although aware that she needed to adapt it to the particular features of each class as well as to improve her teaching skills.

8.5 Case Study 5 - B.T. S6

Due to family problems (birth of a child), although assigned to her teaching post in the beginning of the school year, S6 started work two months late. Meanwhile her classes were without lessons on "Physics and Chemistry". This fact imposed, a priori, some constraints to her achievement.

She was in charge of four 9th grade and two 10th grade classes.

Three weeks after having started teaching, S6 talking to me, expressed
her dissatisfaction regarding the general pupils' attitudes and behaviour in classes. They appeared completely demotivated and showing no signs of interest in being active and involved in the work. In the previous year they had had a bad experience in relation to the teaching of "Physics and Chemistry" and that was reflected in their attitudes towards the subject. A priori, the ecological system of the classes was not very favourable for the implementation of innovations. Although it seemed to me, during our conversation, that S6 was still unsettled in the new situation (away from home, with a small baby to look after) she conveyed a certain determination and willingness to work with pupils in order to lead them to enjoy participating and being constructive in their work during the lessons.

The fact that pupils had been without physics lessons for two months was unsettling for her and, to some extent, imposed some constraints on her teaching. As she told me

"... because they were so behind in relation to the 9th grade syllabus I did not apply a diagnostic questionnaire at the beginning of the unit and although I used the information gathered last year ... I feel it isn't the same ... they aren't very much motivated".

As happened with S2, S6 was the only teacher with tenure in the physics and chemistry area.

8.5.1 Analysis of the data from classroom observations

As elicited from the description of S6's case during the year of teaching practice, she had adopted the innovation and had decided to make full use of it. Her capability for teaching within a constructivist approach seemed to have improved a great deal during that year and she did not show any transfer problems. Thus, it was not to be expected that she could have any intrinsic problems with the implementation of the "new" model of teaching, whatever the subject matter was. Based on this, I decided to visit her when she was in the middle of the unit of 'optics', a month and a half after she had started her teaching in that school. I spent a day with her and observed four 9th grade classes. The four lessons took place one after each other. This situation was pointed out by some of the student teachers in the year of teaching practice as being one that could possibly, bring difficulties to teachers working within a constructivist approach. To give the same attention to the pupils, to act as a facilitator, to be concerned with each individual pupil during four consecutive hours, dealing with the same topic, seemed to be rather demanding and very exhausting. It would be even more demanding than if the lessons had been conducted in the traditional way.
The number of pupils per class ranged from 18 to 30, but the classes' behaviour did not show differences due to this variable. In each class the number of repeaters was unusually high, with the average age level of the classes being higher than normal.

The lessons were audiorecorded and notes were taken from my conversation with some pupils after the lessons. The content was "Reflection and Diffusion".

The analysis of the four lesson transcripts and associated notes revealed the following recurrent points.

a) In the four lessons Sg's concern to help pupils to explain for themselves the differences between 'reflection' and 'diffusion' was apparent. As the laws of reflection had already been taught in previous lessons, each pupil, one at a time was asked to go to the blackboard and, through drawings, apply the first law to two models of reflecting and diffusing surfaces.

b) Often pupils found great difficulties: i.e. i) to be able to concentrate on the resolution of a specific problem. The one at the blackboard was more interested to have some cues from peers than to think by her/himself, ii) to follow consistent reasoning; iii) to draw a perpendicular line to a surface; iv) to express their ideas in a clear way; v) to make efforts to overcome the problems they were presented with; vi) to apply the first law of reflection to different situations; vii) to use a protractor and to measure angles with appropriate correctness; viii) to draw conclusions from evidence. All these difficulties can be seen as a consequence of the way they had been taught.

c) The lessons appeared very carefully prepared, taking into account the above difficulties. Sg's concern to provide opportunities in which these difficulties could be disclosed, so that pupils could become aware of them and be helped to overcome them was also apparent.

d) The pupils to whom I talked perceived differences between the new teacher's style of teaching and the one they were accustomed to. Nevertheless they were still unable to define those differences. According to some of them ".. this year the teacher is quite different from the one we had last year ... he didn't care about anything ... we even didn't know what physics was about .... this year is different". When I asked them what were the differences one of them commented ".. you have just see ... she (the teacher) usually asks us to go to the blackboard and she doesn't let us go until we understand and can explain for ourselves".
8.5.2 Analysis of data from the interview

The analysis of the transcript of our conversation at the end of my observations produced the following information.

a) Although the situation that S_6 was afraid of had actually happened i.e. being assigned to a school too far from home, with a small child to take care of, she was facing up to it very well. To some extent, it was not interfering with her professional development. Her expectations concerning this situation, as expressed in the interview that took place at the end of her teaching practice, had been fulfilled. She was overcoming the problems imposed by the situation.

b) Two problems were seen by S_6 as the main difficulties in her role as a facilitator of pupils' development: i) first, and considered by S_6 to be the most constraining, was pupils' attitude toward learning in general and learning physics in particular. According to her, from the start, pupils appeared to be completely disinterested in learning anything. Being at school was seen as a means to spend some hours playing with peers. Pupils' past experience has contributed highly to this state of affairs. From her contact with the colleagues at the school she gained the impression that the majority of them were not very motivated to teach in the school and did not invest any effort or creative power on their work there. For most of them the school was seen as a temporary place where they had to be before being assigned to a more pleasant place nearer to the coastside or to big towns.

Pupils' past experience in "Physics and Chemistry" teaching had been disastrous. They had been trained to act as passive receptors, not accustom to think for themselves and their interest for the subject, or even for learning, had been supressed. This situation was for her, a strong obstacle to overcome. In her own words

"...it takes time ... great effort and a great deal of patience to change their attitudes ... it's not an easy task! ... sometimes ... it is discouraging ... it seems that there is no progress ... but ... anyway ... looking backward ... I can perceive that something has been changing ... they are starting to respond to my efforts ... and I will continue in the same way...".

ii) Secondly the lack of equipment, mainly concerning optical didactic materials, was being another source of difficulties. It was quite impossible to develop the pupils' scientific process skills without materials. Commenting on this aspect she said:
"I have been making some attempts to stimulate their imagination and make them think for themselves via 'imaginary experiments'.. but it isn't the same ... really .. sometimes I ask them to bring to the classroom some material they have in their houses.. torches.. mirrors.. etc. .. but it hasn't been working .. they aren't still interested .. and they forget .. and really .. as I'm not still settled down .. I haven't had spare time enough to find out immediate solution to this ... I have already asked the school board to order some material .. but .. you know how these things work ... if it arrives .. it will probably be only next year".

c) It was apparent throughout the interview that the constraints found in her new school setting did not play a significant role in $S_6$'s efforts to perform in a manner consistent with her initial predispositions. She was able to maintain her perspective which, to some extent, was in conflict with the dominant institutional culture in her new school. The degree to which $S_6$'s constructivist perspective and teaching skills were developing at the beginning of the year and the strength with which they were held, can be seen as the reason for the tenacity with which $S_6$ clung to her beliefs despite strong pressure to change them.

8.6 Findings emerging from Part C of the Main Study

The purpose of Part C of the main study was stated in section 8.1 of this Chapter. Despite the limitations imposed on this part of the investigation which will be discussed in the last Chapter of this thesis, its results produced the following findings. They must be viewed in a manner which accounts for both the uniqueness and commonality of the individual experiences.

1. The implementation of the adoption stage of the three teachers within the context of their new school settings indicates that no rejection of the innovation took place.

2. Despite the fact that the context of the first year of professional life was quite different from the one where teaching practice took place, the three teachers were able to maintain a constructivist perspective which was in conflict with the dominant teaching perspectives in their schools.

3. The findings of Part A of the main study showed that these teachers began their first year of professional life in different states of development of their teaching skills and desires to implement their perspectives on teaching. Although all three continue on a course of development shown during teaching practice, the student teacher that showed a less developed
state at the end of the teaching practice, showed, in the first year of professional life, a greater improvement both in her willingness to implement the innovation and in her enthusiasm towards teaching. Her self-confidence as well as a growing interest in, and identification with, the profession increased. She showed greater progress in her teaching skills development than her colleagues.

4. Among all the kinds of constraints imposed by the different institutional contexts and specific life situations, the pupils' past experience seems to be one of the factors that most difficulties presents to the implementation of the innovation.

5. There is some evidence that pupils' reaction to this approach to teaching, despite some resistance in the beginning, became highly positive. Yet further investigation in this field would be necessary for a more sound conclusion.

6. Some evidence was also produced that the approach was "new" and, at least, lessons and subject matter were becoming more enjoyable and interesting to pupils.

7. The decision to continue working within a constructivist approach was conveyed by the three beginning teachers who also showed an acquired sense of ownership of the innovation.

8.7 Summary

In this Chapter the implementation of the adoption stage in the first year of professional life by three of the student teachers was presented.

Through informal conversations, classroom observations and an in-depth interview with each of the teachers, their perceptions, feelings, ideas and intentions concerning their present and future situations were analysed. Despite different institutional contexts during their teaching practice and first year of professional life, the three teachers were able to maintain a constructivist perspective in their schools.

In the three cases, the teachers became more articulate about expressing, and more skillful at the implementation of, a constructivist approach
Some evidence of pupils' positive reaction to the approach used by their new teachers was also presented. The implications of their past learning experience was perceived as the greatest obstacle to the implementation of the innovative approach to teaching.
9.1 Introduction: A Review of the Study

In the first Chapter of this thesis an overview of the Portuguese Educational System was presented with the purpose of identifying the context within which this research was conducted.

A preliminary study aimed at identifying reasons accounting for pupils' attitudes towards "physics" and "physics teaching and learning" was reported in Chapter 2. Evidence was presented supporting the view that a "cultural transmission" perspective underlies current physics teaching. In this perspective, the primary task of the teacher is seen as the transmission of information, rules or values collected in the past. Authority and superior knowledge resides with the teacher, who has accumulated most truth. Thus the body of knowledge transmitted by schools and universities is not questioned. Teaching physics according to the "cultural transmission" perspective amounts to embracing orthodox philosophy of science. Suppe (1974) states that it was the view of many logical positivists that:

"science proceeds 'upwards' from particular facts to theoretical generalizations about phenomena, this upward process proceeding in an essentially Baconian fashion".

This image of science, and nature of scientific knowledge imparted from an orthodox philosophy of science has pervaded physics teaching and science teaching in general not only in Portugal but it has indeed influenced the academic tradition of western countries. Gilbert and Swift (1981) suggest that:

"the prevailing conception of science held by the public still appears to be a positivist, empiricist-inductivist one which bears a strong resemblance to Bacon's articulation of scientific method put forward at the beginning of the 17th century".

However, it seems that the Baconian basis to contemporary theories of science - teaching and its educational practices has probably been preserved partly by default, born of ignorance, rather than by design.

Contemporary philosophies of science provide a shared view which contrasts with the Baconian absolutist view of truth and argues the relative nature
of scientific knowledge. In recent years, the relativity of knowledge has become a major concern of educationalists and sociologists. Postman and Weingartner (1971) focus on this point:

"We know that each man creates his own unique world, that he, and he alone, generates whatever reality he can ever know .... The purposes and assumptions and, therefore, the perceptions of each man are uniquely his ... Among other things, this means that no man can be absolutely certain of anything. The best anyone can ever do is say how something appears to him". (p. 100)

These words echo the view of knowledge put forward by George Kelly. In Chapter 3 it was suggested that Kelly's theory and methodology provide a coherent, attractive and fruitful alternative framework not only for a conceptualization of science teaching, physics teaching in particular, but also for conducting research in the educational province.

Contrasting with traditional educational practice, Kelly views educational growth not as the accumulation of more and more pieces of information, but as the development of an increasingly complex structure for organizing and interrelating ideas. Instead of being treated as a "mechanism", as in a "cultural transmission" perspective, Kelly sees the pupil as a human being capable of construing. This capability should be taken into account by teachers in their teaching activities and also by curricula designers.

It was the 'perspective of the personal', the emphasis on the person as the meaning-maker, central to Kelly's position that I found most attractive and useful for the work presented here. I found that, in some of its aspects, Kelly's theory represents a "way of seeing and doing" which is potentially applicable to many teaching and learning situations. I got inspiration to bring under review, and rethinking, issues related to the teaching of physics from his theory.

Two main questions were found to be of great relevance in accounting for the findings of the preliminary study. Firstly; *Why teach physics at the unified level?* Secondly; *How can we teach it at this level?* To find answers to these questions would help me to envisage a means of improving the teaching of physics at the unified level and of fostering in pupils a positive attitude towards physics.

In Chapter 3, answers to these questions were proposed and aims for physics education at the unified educational level were derived in the light of Kelly's analogy of "man-the-scientist".

In Chapter 4, Rogers' developmental model of the adoption process
of an innovation was used as a framework for designing a scheme for promoting the change on student teachers' perspectives in the direction of a constructivist one and for developing teaching skills appropriate for teaching within this latter perspective.

The choice of a research methodology compatible with the assumptions underlying this study was justified by analysing the two main methodological approach used in educational research. This was done in Chapter 5.

In Chapters 6, 7, and 8, an investigation into the applicability and effectiveness of the scheme proposed was reported and the final conclusions of this investigation will be formulated in the next section.

9.2 Conclusions

The findings of the three Parts of the main study seem to give support to the conclusions presented in the following sub-sections. They are divided into three main areas, and will be discussed along with some of their implications for educational innovations. The first area relates to the findings concerning the effectiveness of the scheme designed for promoting change in student teachers' perspectives and in developing teaching skills appropriate for working within a constructivist approach. The second area relates to the findings concerning the research methodology and its implications for the understanding of the complexities presented in the field of science teacher education. The third area relates to the findings concerning to the application of a constructivist theory to the teaching of a methods course and to the teaching of physics at the secondary school level.

9.2.1 On the effectiveness of the scheme

As already stressed, this work was intended to be an exploratory study. Consequently its conclusions on the effectiveness of the scheme must not be taken as definitive and unique answers to the problems studied.

Before going on to the conclusions on the effectiveness of the scheme it is first necessary to note the constraints on the study which can by themselves be seen as conclusions drawn from the study. The constraints can be summarized under three general categories:
i) the sample of the student teachers;

ii) the conditions of the experiment;

iii) the time limitation on the follow up.

i) Constraints regarding the sample of student teachers

1. From the thirteen student teachers who took part in this study, only four had chosen the "Integrated Teacher Training Physics and Chemistry" degree as a first priority. This reveals the lack of interest by the majority of students in the teaching profession and their lack of willingness to become teachers. Thus, the teacher job's perceptions that these student teachers brought to the course influenced their initial attitudes toward this course, whose main objective was teaching "how to teach physics". It is most likely that, if there was a general willingness to become teachers on the part of student teachers, the purposes stated for Part A of the study would be achieved to a far greater extent.

   This constraint calls for immediate attention to the process of enrolment in university degrees as well as to a reappraisal of the social status of the teaching profession.

2. The weak scientific background revealed by the majority of the student teachers seemed to have contributed to most of the difficulties encountered in embarking on a constructivist approach to teaching. Their difficulties in understanding the basic concepts of physics and in relating and transferring to the secondary school level discourse the physics content learned in advanced courses, presented a great, if not the greatest, constraint on the scope of the investigation on the implementation of the scheme.

   This issue calls for reflection on the part of all the university physics teachers involved in teacher training degrees.

3. Another constraint imposed on Part B of the main study was the lack of familiarity by the student teachers with the complexity of a real teaching situation, which calls for a myriad of subskills that are subsidiary to the comprehensive teaching skills which are required in a constructivist approach to teaching.

   This calls for a rethinking of the structure of our teacher training degrees, possibly by introducing the student teachers sooner to real classroom problems before they become responsible for them.
4. The student teachers' past learning experience also created some constraints on the implementation of the first four stages of the scheme. The fact of being taught in a traditional way had such an influence on student teachers' attitudes towards the task they were required to accomplish that it was extremely time-consuming to help them to change those attitudes to more constructivist ones.

Concerning this point, the same problem faced by me during the implementation of a constructivist approach during Part A of the main study, was faced by the student teachers and beginning teachers during Parts B and C of the study. It would obviously be more supportive of the development of teaching skills appropriate to a constructivist approach if there was less resistance to it on the part of pupils in general.

If a constructivist perspective towards teaching is perceived by science educators to be a valuable and fruitful alternative approach capable of improving science education, this calls for an urgent dissemination of the innovation among practicing teachers.

There is now, in several countries, a growing group of science educators which advocates that the teaching of science should acknowledge what current philosophies of science recognise i.e. the role of personal construction in the development of scientific knowledge. Their metaphysical commitments impart a constructivist view on the teaching of science. I have hope that the still small group of Portuguese science educators sharing the same perspective will grow, allowing for an effective dissemination of the innovation among Portuguese science teachers.

ii) Constraints regarding the conditions of the experiment

The fact that Parts A and B of the main study have taken place in two situations (within a curricular course and a teaching practice) in which student teachers were also assessed for examination purposes, could have put some limitations on the value of the study. Knowing beforehand that their performances during the course on "Physics Didactics" would be assessed could have influenced student teachers' behaviour. Nevertheless, it appeared to me that because of the constructivist approach used in the course, and the relationship that evolved between the student teachers and myself, the apparently genuine interest in the process shown by all the student teachers, reduced this constraint very greatly. I recognize it, as a constraint inherent in the strategy of action research used
in Part A of the study.

The situation during teaching practice was seen by some of the student teachers as a favourable one for development of their teaching skills and for the implementation of the innovation. Others found that the practice created some problems for their personal development. In my opinion profound constraints on studies conducted in the same way as the one presented in this study, will operate if the group of supervisors do not share the same perspective on teaching, or do not possess general open-mindedness, and a receptivity to innovations.

iii) Constraints regarding time limitations on the follow up

An educational investigation, as any kind of scientific investigation, is an endless process. Conclusions that can be drawn from it are always subjected to constraints imposed by the time at which the researcher reports it. Each scientific investigation raises up issues such as the necessity to expand its scope and to explore new avenues not thought of before which could contribute to a better understanding of the phenomena under study.

The investigation undertaken during this study brought to light the need to expand the study of the individual student teacher's and beginning teacher's cases in order to investigate their subsequent behaviour all through their professional life. As time goes on would their teaching continue to have a constructivist flavour? Would their constructivist perspective be strengthened or modified during their professional life? Who and what influences the development of their perspective and teaching skills throughout their professional lives?

On the other hand, the development of the pupils' scientific "abilities" is also an endless process. It is not possible to assess, in such a short period of time as an academic year, the influence on it of a constructivist approach to teaching. The only possible conclusions concerning this point are drawn from pupils' comments and perceptions of their learning experiences, as well as from their teachers' perceptions of their reactions.

Again Kelly's emphasis on the study of the individual person influences my belief that if one wants to investigate in depth the result of a constructivist approach to teaching one can seldom draw meaningful inferences about individual human processes from group statistics. It is my belief that conclusions on a constructivist approach to physics learning can only be drawn within a constructivist framework, "... using non-comparative techniques in the first instance, under naturalistic conditions". (Gilbert, 1982)
Keeping in mind the constraints discussed above, the following conclusions seem warranted concerning the effectiveness of the scheme.

1. The findings of Part A of the main study support the view that the scheme's design and the way it was implemented can promote an effective change in student teachers' perspective towards teaching.

2. Some research has suggested that opinions held at the end of methods courses are abandoned a year later (e.g. Day, 1959; Ligana, 1970; Edgar and Warren, 1969; Hoy, 1968; MacArthur, 1978; Gaede, 1978; Hanson and Herrington, 1976; Wright and Tuska, 1968); other research suggests the opposite, (e.g. Bartholomew, 1976; Giroux, 1980; Zeichner and Tabanick, 1981). The results of the study presented in this thesis seem to demonstrate that student teachers' perspectives held by the end of the methods course were not abandoned in the teaching practice situation or during the first year of professional life. Indeed, the individual commitment to this teaching perspectives was enhanced over that period. This confirms the scheme's effectiveness in promoting student teachers' willingness to develop the teaching skills required by the innovation and to try additional actuations which could lead to a better achievement of the aims proposed. Thus the findings of Part C of the main study calls into question the pessimistic statements about the "reality shock" for beginning teachers, (Wubbels et al., 1982).

3. The results also suggest that the student teachers acquired a sense of ownership of the innovation which increased their willingness to make their total behaviour congruent with the role demanded by the innovation at the point that the innovation was no longer viewed as new; it had reached the incorporation stage.

The design of the scheme was aimed at fostering the mental development of each individual student teacher to the adoption stage of the innovation: - passing from first being aware of it, through her/his own experience of it, to a final decision to continue the full use of it. The aims of the scheme seem to have been successfully achieved.

4. Rogers' developmental model of the innovation process, although not regarded directly as a strategy for change-agents, proved to be a very appropriate framework within which a perspective's change on science teaching and the development of adequate teaching skills can take
Although the adoption process is an individual matter, knowing beforehand the five functions involved in it, to each of which a stage is assigned, helps the change-agent to devise activities for fostering the development of these five functions.

Finally, a loss of determination to go along with an innovation, a loss of idealism, and a loss of willingness to overcome obstacles, are not an inevitable result of induction into teaching. The efforts of formal teacher preparation programs are not necessarily in vain. It can thus be speculated that teacher training can have a greater impact on the professional socialization of teachers than has been realized.

9.2.2 On the research methodology

Magoon, (1977), describes three important assumptions held in a constructivist perspective on complex behaviour, such as in the case of teaching. A first assumption, considered by him as "a chief assumption", is that the 'subjects' being studied must, at a minimum, be considered knowing beings and that the knowledge that they possess has important consequences for how behaviours or actions are interpreted.

A second assumption is that the locus of control over much so-called intelligent behaviour resides initially within the subjects themselves. The important implication of the latter assumption is that most behaviour must be understood as purposive, i.e., aimed toward some end. It means that complex behaviour like teaching and learning might be best understood as being constructed purposefully by the subjects themselves, and cannot adequately be studied without accounting for meaning and purposes.

A third assumption is that human beings have a highly developed capacity for; (a) developing knowledge by organizing complexity rapidly; (b) attending to the meanings of complex communication rather than to surface elements; and (c) having individuals readily take on complex social roles and reconstruct elaborate social rules.

The phenomena studied in this investigation concerning the implementation of a constructivist approach to teaching in two areas of schooling, teacher education and secondary school education, were unavoidably sophisticated and highly organized. It is not surprising that the study called for an ethnographic approach; that is, an extensive, descriptive and interpretative effort at explaining
It is my belief that educational research is both "interpretive" and "scientific". "Interpretive" in the sense that it generates theories that can be grasped and utilised by practitioners in terms of their own concepts and theories; "scientific" in the sense that these theories provide a coherent challenge to the beliefs and assumptions incorporated in the theories of educational practice that practitioners actually employ. The findings assembled through research, any new theories developed as a result, will have little educational validity if they are unrelated to the theories and understandings of educational practitioners. They will have little educational value if they do not enable practitioners to develop a more refined understanding of what they are doing and what they are trying to achieve in their own situations. It is in this sense that Carr and Kemis (1983) stress that

"... the only legitimate task for any educational research to pursue is to develop theories of educational practice that are rooted in the concrete educational experiences and situations of practitioners and that attempt to confront and resolve the educational problems to which these experiences and situations give rise .... Action research, as the study of praxis, must thus be research into one's own practice". (p. 116)

The aims of the action research conducted during Part A of the main study were twofold: firstly, to pursue research by myself into my own teaching and, secondly, to help student teachers to conduct research themselves into their own learning. Thus both student teachers and myself adopted the following strategy: we deliberately experimented with practice while aiming simultaneously for improvement in the practice, understanding of the practice, and of the situation in which the practice occurred. We monitored the action, the circumstances under which it occurred and its consequences. Then we restrospectively reconstructed an interpretation of the action in context as a basis for future action. Knowledge achieved in this way was seen as a means of informing and refining both specific planning in relation to the practice being considered and the practitioner's general practical theory of education.

The findings of the research on the action research strategy itself support the view that the strategy was considered by all the practitioners as highly successful for the achievement of the aims proposed. It will, surely, influence student teachers' own future activities, as well as my own future activity.

The study itself was conducted as a case study of cases studies. As Walker (1982) points out:
"...while much can be learned from other subjects (from anthropology, history, psychiatry, literature and journalism), we lack a variety of good accounts of the particular circumstances encountered in schools, classrooms and other educational settings. Ideally we need accounts of the problems reported as they emerge, for these are most useful to the reader hoping to learn directly from the experience of others".

The case study reported in this thesis was an attempt to get some insight into two under-explored areas - the practice of a constructivist approach to science teacher education and to the teaching of science. I suggest that it makes some contribution to existing experience and to a humanistic understanding of these two areas. Although case studies are not a suitable basis for generalizations (Stake, 1978), it is my hope that the experience reported here may be epistemologically in harmony with the reader's experience and thus be, for that person, a natural basis for generalization.

9.2.3 On the adoption of a constructivist approach to Science Teacher Education

The early 1980s have been years during which most science educators have been active in reassessing the basic aims for science education. Yager and Hofstein (1985) point out that:

"A major failure in school science has been in trying to develop a meaningful definition of science for the students engaged in the study of science. Perhaps too little time has been spent with such a definition, especially in terms of first-hand experiences with it".

What is Science? If one attempts to define Science in a way that all can understand it perhaps one will meet great difficulties in so doing. In his address to science teachers, Feynman (1966), commenting on this question, said:

"What is Science? Of course you all must know, if you teach it. That's common sense ..... If you don't know, every teacher's edition of every textbook gives a complete discussion of the subject. There is some kind of distorted distillation and water-down and mixed-up words of Francis Bacon from some centuries ago, words which then were supposed to be the deep philosophy of Science. But one of the greatest experimental scientists of the time who was really doing something, William Harvey, said that what Bacon said Science was, was the science that a lord-chancellor would do. He spoke of making observations, but omitted the vital factor of judgement about what to observe and what to pay attention to. And so what Science is, is not what the philosophers have said it is, and certainly not what the teacher editions say it is. What it is .... All my life I have been doing science and known what it was, but .... (what science is) .. I am unable to tell you!"
Despite his lack of an explanation, three simple features of science emerged clearly: (a) "exploration" of the universe, (b) "explanation" of events and objects encountered during exploration and (c) "testability" of explanations offered. If one accepts "exploration", "explanation" and "testability" as representing the essence of science, these basic features should be the basic ingredients of a school science curriculum. Yet, as point out by Yager and Hofstein (1985) when examining course structure, course sequence, textbooks, learning materials and the other evidence of the science that pupils typically experience, it is rare to find any of the three features. They add:

"At best, one could argue that the traditional science curriculum focus on explanations - those offered by the others, i.e., active scientists. Science learning then becomes the mastery of information known by current scientists."

This activity accounts just for one dimension in science. Nevertheless advocacy groups in the past have argued for science education to move in certain new directions, but the thrust of the directions usually entailed little more than revising and updating science course content, and usually met relatively little resistance. Most curriculum innovations have been merely a re-ordering of the content or an updating of knowledge included in the various subjects.

Perhaps the greatest attempt to introduce a second dimension in science occurred during the late 1950s and throughout the 60s when there was a great emphasis upon science processes through discovery learning approaches to 'presenting' science. Nevertheless, in respect of the three main features of science ("exploration" , "explanation" and "testability"), the emphasis upon content and processes in the teaching of science reflects only a two-dimensional view of science.

In this thesis, a constructivist framework was proposed for the teaching of science, in the particular context of physics teaching, that emphasises the development of the "scientific-like aspects" of the learner. Teaching science in this perspective will enable the pupil to undertake "exploration", "explanation" and "testability" - the essence of science - thus reflecting the three-dimensional view of science. It will, overall, emphasize the learner as the meaning-maker: helping her/him to develop greater insights into the meaning of the endeavour.

Most of the practising teachers and student teachers have been educated in a system based on a non-constructivist approach to knowledge and on an empiricist view of the nature of scientific knowledge. It is understandable
that, in consequence of that, they tend to conceptualize their educational problems inside that framework. To adopt a constructivist view of science education requires the acceptance of a view by teachers and student teachers which, for most of them, implies a major conceptual change.

In this thesis an attempt to promote this conceptual change in student teachers was reported. The conclusions of the investigation concerning the adoption of a constructivist perspective will be presented in the light of the four conditions that, according to Posner et al. (1982), must be fulfilled before conceptual change takes place.

i) "There must be dissatisfaction with existing conceptions"

Identified dissatisfaction with the existing concept of "teaching physics", its understanding and practice was apparent from the findings of Part A of the main study.

ii) "A new conception must be intelligible"

Through opportunities provided for enabling each individual to grasp how teaching could be structured in a new perspective, s/he was able to construct a new conception of "teaching physics" and explore the possibilities inherent in it. The findings of Parts A and B of the main study produced evidence of that.

iii) "A new conception must appear initially plausible"

The adoption of the new conception of teaching, the innovation to which the student teachers were exposed, was seen as having the capacity to solve the problems generated by its predecessors and considered capable of rational incorporation into existing understanding. Evidence of this was obtained through the findings of Parts A, B and C of the main study.

iv) "A new conception should suggest the possibility of a fruitful research program"

The constructivist approach was seen as having the potential to be extended, to help to solve recognized problems, to open up new avenues for the improvement of physics teaching and to enhance professional growth. The findings of Parts B and C of the main study also produced evidence of that.
9.3 Recommendations and suggestions for further research

From the conclusions just presented, some practical suggestions and some research topics were identified. They will be presented as recommendations and suggestions for further research.

Recommendations

1. If the teachers' role is seen as a facilitator of the development of the learner, as it is in a constructivist perspective, it is essential that they already have a strong development of the scientific "abilities" they intend to develop in their pupils. The findings of this study support others (e.g. Harms and Yager, 1981) in that teachers usually teach on a basis derived from a slightly restructuring of the science courses that they have completed during their own formation. There is little evidence that they have ever done any 'real science' themselves. I would see it as highly advisable that, during teacher formation, opportunities be provided in which student teachers could be involved in science research projects. This would enable them to develop their own scientific "abilities" and at the same time acquire a better understanding of what science is.

2. Educational innovations like the one proposed in this thesis, cannot rely on immediate support from existing pre-service teacher education. The findings of this research point to the urgent need for a dissemination of the innovation. This implies the development of inservice training programs themselves conducted within a constructivist perspective. It means that the innovation should be conceived of as part of the personal professional development of teachers, since it should hinge on decisions taken in the light of a critical reflection on the part of the teachers on existing practices and materials, involving self-confrontation and a consideration of new knowledge which conflicts with current thinking.

The assumption underlying this kind of work should be that professional development cannot be forced - it is the teacher who develops (actively) not the teacher who is developed (passively). The need for change must be internalized if effective change is to occur: the client must have ownership of her/his own learning experience: and the inservice educator's role should be collaborative.
The conduct of the course on "Physics Didactics", in which part of the study reported in this thesis took place, was based on this assumption.

3. It is also recommendable that, in the light of the underlying assumption, the number of individuals involved, at a time, in both preservice and inservice teacher training programs, should be small. In a methods course, like the one described in this study, more than 8 or 10 student teachers enrolled in the course would present great difficulties to the organization of the course, especially in that a number of cycles of the action research process is seen as highly relevant for the conceptualization of the trial stage.

Concerning inservice programs, although research needs to be undertaken on the design, performance and effectiveness of such programs, I suggest that, taking into account the kind of interpersonal relationship that should be fostered in these interactions, the number of individuals involved in each action should be around 15.

4. An earlier contact with schools, even as non-participative observers would be highly recommended for students who are going to become teachers. The reasons for that were already expounded during the description of the study.

Suggestions for further research

1. Parallels to this study could be made in the field of science teacher education in other subject matters, namely chemistry, biology and geology. A constructivist approach to the teaching of these disciplines implies the identification of pupils' ideas about basic concepts included in the syllabus as well as the development of strategies to promote conceptual change.

2. The study could also be paralleled in the training of teachers in other academic fields. This would imply research on the implications of a constructivist perspective for the aims of each specific academic area. For example, in the teaching of the Portuguese language the meanings of words that pupils bring to Portuguese classrooms should be taken into account by teachers in order to promote a discourse that must
have meaning for both the teacher and the pupils. The same should happen in relation to the pupils' own interests in the subject.

The same argument applies to any other country, relating to the teaching of the mother tongue.

3. The study should be expanded in order to investigate the subsequent behaviour of the particular group of student teachers who participated in it, after some years of being teaching. This would give information of any "discontinuance" which occurred, and if so, what caused it and why and how could it be overcome.

4. An area needing urgent research seems to be the development of diagnostic questionnaires to investigate pupils' alternative ideas about all the basic concepts included in the physics syllabus of the different grades of the unified level. Although there is a large body of research on the identification of pupils' alternative conceptions there is a pressing need to produce diagnostic tests for use by teachers in classrooms and to make these widely available.

5. Tests used to assess traditional learning are not suitable for assessing the achievement of the aims proposed within a constructivist perspective. This raises an issue calling for an urgent effort by researchers in the development of suitable tests or activities to be used by the teachers in classrooms.

6. Further research is called for on the detailed identification of effective classroom strategies to promote conceptual change after the production of a viable model of conceptual change.

7. Another problem brought to light was the lack of ability to transfer scientifically advanced knowledge, acquired at the university, to the secondary school classroom. Does it mean that the learning of basic physics concepts is "taken for granted" by university physics teachers or does it mean that student teachers do not grasp the link between basic and advanced physics? To understand this lack of ability and to develop teaching models at university level that take into account of this issue seems, in the light of the findings of this study, to deserve some consideration.
8. In a constructivist view it seems extremely important for one who is going to teach or is already teaching science, to have oneself experience in doing science. The introduction of this component in the preservice or inservice teacher education, its implications, its effectiveness and its results open new avenues for researchers. Perhaps the findings of such investigation could bring up the need for a restructuring not only on the teacher training programs but also on the whole system of a teacher's professional career. Case studies with selected individuals in the two situations could be used for this purpose.

My state of mind as I finish the report of this study, is reflected by a final quotation - most appropriately by Kelly:

"To the constructive alternativist the next step is to see if he can improve his hypothesis, perhaps by formulating his questions in new ways or by pursuing the implications of some fresh assumption that occurred to him when he was writing up the conclusions to his last experiment."

(Kelly, 1969)


ALLEN, D. W., (1967), Microteaching: a Description. Stanford University, California.


CARTER, P. and DIBELLA, R., (1982), "Follow-up of 1980 - 81 Graduates at the Ohio State University's College of Education Teacher Certification Program". Technical Report no. 7. Columbus, Ohio: Ohio State University, College of Education.


CRONBACH, L.J., (1975), "Beyond the Two Disciplines of Scientific Psychology". 
_The American Psychologist, 30_, 116 - 127.

CRYER, P., (1983), "Materials for Academic Staff Development: A Study of an 

DAINTON, F.S. et al., (1968), _Enquiry into the Flow of Candidates in Science 
and Technology into Higher Education_. London: HMSO.

(1968), _Inquiry into the Flow of Candidates in Science and Technology 

and a New Approach". In M. STUBBS and S. DELAMONT (eds.), _Explora­
tion in Classroom Observation_. Chichester, John Wiley and Sons, 
1976, 3 - 20.

WRAGG (1979).

Chicago. Aldine.

DENZIN, N.K., (1971), "The Logic of Naturalistic Inquiry". _Social Forces, 50_, 
166 - 182.

DeTURE, L.R., (1979), "Relative Effects of Modeling on the Acquisition of 
Wait-Time by Preservice Elementary Teachers and Concomitant Changes 
in Dialogue Patterns". _Journal of Research in Science Teaching, 16_, 
553 - 562.


DIEM, R.A., (1982), "Measurements of Social Studies Content Knowledge in 
Pre-Service Elementary Education Majors". _Journal of Social Studies 
Research, 6_, 8 - 12.

DILLASHAW, F.G. and OKEY, J.R., (1980), "A Test of Integrated Science Process 
Skills for Secondary Science Students". _Science Education, 64_, 
601 - 608.


GALLOWAY, C.A., (1968), A Description of Teacher Behaviour: Verbal and Non-Verbal. Columbus, Ohio.


GRIFFINS, G., BARNES, S., HUGHES, R.Jr., O'NEAL, S., DEFINO, M.E., EDWARDS, S.A. and HUllIK, H., (1983), "Clinical Preservice Teacher Education:


KEMPA, R.F., (1983b), "Learning Theories and the Teaching of Science: Implications for Science Teacher Training". In P. TAMIR, A. HOFSTEIN and


KOELHER, V., (1984), "University Supervision of Student Teachers". Report no. 9061. Austin: Research and Development Center for Teacher Education, University of Texas.


MASON, R., (1961), Unpublished Data from an Investigation of the Adoption of Three Farm Ideas by About 150 Farmers in One Oregon County, Corvallis, Oregon State University. Quoted in Rogers (1967).


PERROTT, E. and DUTHIE, J.H., (1969), "University Television in Action: Micro-teaching". University Television Newsletter no. 7 (Bulletin prepared for working party on Inter-University Communications Cambridge).


RICH, R.W., (1933), The Training of Teachers in England and Wales During the Nineteenth Century. Cambridge: University Press.


-406-


SCHIRNER, S., (1968), "A Comparison of Student Outcomes in Various Earth Science Courses Taught by Iowa Teachers". A National Association for Research in Science Teaching Paper.


SEPERSON, M.A. and JOYCE, B.R., (1973), "Teaching Styles and Student Teachers as Related to those of their Cooperating Teachers". Educational Leadership Research Supplement, 146 - 151.


STONES, E. and MORRIS, S., (1972), Teaching Practice: Problems and Perspectives. London, Methuen.


SWIFT, D.J., (1983), Personal communication. University of Surrey.


TABACHNICK, B.R., POPKEWITZ, T. and ZEICHNER, K., (1979), "Teacher Education and the Professional Perspectives of Student Teachers". Interchange, 10, 12 - 29.


TAMIR, P., (1983 a), "Science Teacher Education - Problems and Issues". In P. TAMIR, A. HOFSTEIN and B. BEN-PERETZ (eds.), Preservice and


THOMAZ, M., (1980), "Interviews with Final Years Secondary Students". Unpublished. Department of Physics, University of Aveiro, Portugal.


presented to the 1st International Symposium on Representing Understanding. Guy's Hospital, London.


WEST, R. W., (1982), "Science Curriculum Review Project".


WHITHEAD, D., (1980), The Dissemination of Educational Innovations in Britain, Hodder and Soughton.


YEE, A.H., (1969), "Do Cooperating Teachers Influence the Attitudes of Student Teachers?", Journal of Educational Psychology, 15, 327 - 332.


APPENDIX 1

Physics Syllabus for Grades 8 and 9 of the Secondary School Level in Portugal

8th Grade

1. STATIC ELECTRICITY (8 class periods)
   - Conductors and insulators
   - Charging by friction, contact and induction
   - Electric pendulum
   - Attraction and repulsion: qualitative laws
   - The leaf electroscope
   - Interpretation of electronic theory
   - Structure of metals

2. ELECTRIC CURRENT (6 class periods)
   - Electric current and its production
   - Cells and batteries
   - Galvani and Volta
   - Electron flow through metals
   - Intensity of current; ampere
   - The potential difference; volt
   - Cells in series

3. ELECTRIC RESISTANCE (6 class periods)
   - Ohm's law applied to linear conductors: ohm
   - Relation between the resistance of an homogeneous lead and its length and cross section

4. HEATING EFFECTS OF AN ELECTRIC CURRENT (6 class periods)
   - Joule effect. Dependent variables. Applications
   - Bulbs in series and parallel
1. FORCE AND MASS (15 class periods)
   1.1 Examples of forces (weight). Vector characteristics of force
   1.2 Mass and Weight
   1.3 Units of force and mass
   1.4 Measurement of mass
   1.5 Experimental study of the action of a force on a spring. Spring balances

2. ENERGY (21 class periods)
   2.1 Forms of energy (without mathematical equations)
      Energy associated with bodies in motion
      Potential energy related to position
   2.2 Work (only cases where force and movement have the same direction)
      Work as a measurement of the transfer of energy between systems
      Unit of energy: Joule
   2.3 Machines
      Properties of pulleys
      Pulley systems
   2.4 The efficiency of machines
      Levers
      Power
      Unit of power: watt
      Kilowatt hour and its relation to Joule
   2.5 Energy transfer between bodies in contact at different temperatures
      Heat as a measure of energy transferred by the process
      Calorie: its relation to Joule

3. REFLECTION AND REFRACTION OF LIGHT (8 class periods)
   3.1 Laws of reflection and refraction of light
APPENDIX 2

Main papers analysed during the course on "Physics Didactics"
Dr. Richard P. Feynman was born in New York on 11 May, 1918. He received his B.S. degree at MIT in 1939, and his Ph.D. at Princeton University in 1942. At Princeton, he worked on the problem of the separation of U 235 from U 238 in connection with the Manhattan Project, and in 1942, he joined the Los Alamos Scientific Laboratory. There, as group leader in theoretical physics, he made important contributions to the development and understanding of the atomic bomb. In 1945, he joined the staff of the Laboratory of Nuclear Studies at Cornell University. He remained there until 1950, when he went to the California Institute of Technology where he now serves as Richard Chace Tolman Professor of theoretical physics. Professor Feynman received the Albert Einstein Award in 1954 and the Atomic Energy Commission's E.O. Lawrence Award in 1962 for "especially meritorious contributions to the development, use or control of atomic energy". In 1965, he received the Nobel Prize in physics together with Sin-Itiro Tomonaga and Julian Schwinger for the "creation of the theory of quantum electrodynamics".
I thank Mr. DeRose for the opportunity to join you science teachers. I also am a science teacher. I have much experience only in teaching graduate students in physics, and as a result of the experience I know that I don't know how to teach.

I am sure that you who are real teachers working at the bottom level of this hierarchy of teachers, instructors of teachers, experts on curricula, also are sure that you, too, don't know how to do it; otherwise you wouldn't bother to come to the Convention.

The subject "What is Science" is not my choice. It was Mr. DeRose's subject. But I would like to say that I think that "what is science" is not at all equivalent to "how to teach science", and I must call that to your attention for two reasons. In the first place, from the way that I am preparing to give this lecture, it may seem that I am trying to tell you how to teach science. I am not at all in any way, because I don't know. The other is I think that most of (because there is so much talk and so many papers and so many experts in the field) have some kind of a feeling of lack of self-confidence. In some way you are always being lectured on how things are not going too well and how you should learn to teach better. I am not going to berate you for the bad work you are doing and indicate how it can definitely be improved; that is not my intention.

As a matter of fact, we have very good students coming into Caltech, and during the years we found them getting better and better. Now how it is done, I don't know. I wonder if you know. I don't want to interfere with the system; it is very good.

Only two days ago we had a conference in which we decided that we don't have to teach a course in elementary quantum mechanics in the graduate school any more. When I was a student, they didn't even have a course in quantum mechanics in the graduate school; it was considered too difficult a subject. When I first started to teach, we had one. Now we teach it to undergraduates. We discover now that we don't have to have elementary quantum mechanics for graduates from other schools. Why is it getting pushed down? Because we are able to teach better in the university, and that is because the students coming up are better trained.

What is science? Of course you all must know, if you teach it. That's common sense. What can I say? If you don't know, every teacher's edition of every textbook gives a complete discussion of the subject. There is some kind of distorted distillation and watered-down and mixed-up words of Francis Bacon from some centuries ago, words which then were supposed to be the deep philosophy of science. But one of the greatest experimental scientists of the time who was really doing something, William Harvey, said that what Bacon said science was, was the science that a lord-chancellor would do. He spoke of making observations, but omitted the vital factor of judgement about what to observe and what to pay attention to.
And so what science is, is not what the philosophers have said it is, and certainly not what the teacher editions say it is. What it is, is a problem which I set for myself after I said would give this talk.

After some time, I was reminded of a little poem:

A centipede was happy quite, until a toad in fun Said, "Pray which leg comes after which?" This raised his doubts to such a pitch He fell distracted in the ditch. Not knowing how to run.

All my life, I have been doing science and known what it was, but what I have come to tell you—which foot comes after which—I am unable to do, and furthermore, I am worried by the analogy with the poem, that when I go home I will no longer be able to do any research.

There have been a lot of attempts by the various press reporters to get some kind of a capsule of this talk; I prepared it only a little time ago, so it was impossible; but I can see them all rushing out now to write some sort of headline which says: "The Professor called the President of NSTA a toad".

Under these circumstances of the difficulty of the subject, and my dislike of philosophical exposition, I will present it in a very unusual way. I am just going to tell you how I learned what science is. That's a little bit childish. I learned it as a child. I have had it in my blood from the beginning. And I would like to tell you how it got in. This sounds as though I am trying to tell you how to teach, but that is not my intention. I'm going to tell you what science is like by how I learned what science is like.

My father did it to me. When my mother was carrying me, it is reported—I am not directly aware of the conversation—my father said that "if it's a boy, he'll be a scientist". How did he do it? He never told me I would be a scientist. He was not a scientist; he was a businessman, a sales manager of a uniform company, but he read about science and loved it.

When I was very young—the earliest story I know—when I still ate in a high chair, my father would play a game with me after dinner.

He had brought a whole lot of old rectangular bathroom flour tiles from some place in Long Island City. We sat them up on end, one next to the other, and I was allowed to push the end one and watch the whole thing go down. So far, so good.

Next, the game improved. The tiles were different colors. I must put one white, two blues, one white, two blues, and another white and then two blues—I may want to put another blue, but it must be a white. You recognize already the usual insidious cleverness; first delight him in play, and then slowly inject material of educational value!

Well, my mother, who is a much more feeling woman, began to realize the insidiousness of his efforts and said, "Mel, please let the poor child put a blue tile if he wants to". My father said, "No, I want him to pay attention to patterns. It is the only thing I can do that is mathematics at this earliest
level". If I were giving a talk on "what is mathematics," I would already have answered you. Mathematics is looking for patterns. (The fact is that this education had some effect. We had a direct experimental test, at the time I got to kindergarten. We had weaving in those days. They've taken it out; it's too difficult for children. We used to weave colored paper through vertical strips and make patterns. The kindergarten teacher was so amazed that she sent a special letter home to report that this child was very unusual, because he seemed to be able to figure out ahead of time what pattern he was going to get, and made amazingly intricate patterns. So the tile game did do something to me.)

Mathematics is looking for patterns.

I would like to report other evidence that mathematics is only patterns. When I was at Cornell, I was rather fascinated by the student body, which seems to me was a dilute mixture of some sensible people in a big mass of dumb people studying home economics, etc. including lots of girls. I used to sit in the cafeteria with the students and eat and try to overhear their conversations and see if there was one intelligent word coming out. You can imagine my surprise when I discovered a tremendous thing, it seemed to me.

I listened to a conversation between two girls, and one was explaining that if you want to make a straight line, you see, you go over a certain number to the right for each row you go up, that is, if you go over each time the same amount when you go up a row, you make a straight line. A deep principle of analytic geometry! It went on. I was rather amazed. I didn't realize the female mind was capable of understanding analytic geometry.

She went on and said, "Suppose you have another line coming in from the other side, and you want to figure out where they are going to intersect. Suppose on one line you go over two to the right for every one you go up, and the other lines go over three to the right for every one that goes up, and they start twenty stops apart" etc. - I was flabbergasted. She figured out where the intersection was! It turned out that one girl was explaining to the other how to knit argyle socks.

I, therefore, did learn a lesson: the female mind is capable of understanding analytic geometry. Those people who have for years been insisting (in the face of all obvious evidence to the contrary) that the male and female are equally capable of rational thought may have something. The difficulty may just be that we have never yet discovered a way to communicate with the female mind. If it is done in the right way, you may be able to get something out of it.

Now I will go on with my own experience as a youngster in mathematics. Another thing what my father told me - and I can't quite explain it, because it was more an emotion than a telling - was that the ratio of the circumference to the diameter of all circles was always the same, no matter what the size. That didn't seem to me too unobvious, but the ratio had some marvelous property. That was a wonderful number, a deep number, pi. There was a mystery about this number that I didn't quite understand as a youth, but this was a great thing, and the result was that I looked for pi everywhere.
When I was learning later in school how to make the decimals for fractions, and how to make 3 1/8, I wrote 3.125, and thinking I recognized a friend wrote that it equals pi the ratio of circumference to diameter of a circle. The teacher corrected it to 3.1416.

I illustrate these things to show an influence. The idea that there is a mystery, that there is a wonder about the number was important to me, not what the number was. Very much later when I was doing experiments in the laboratory, I mean my own home laboratory - fiddling around - no, excuse me, I didn't do experiments, I never did; I just fiddled around. Gradually through books and manuals I began to discover there were formulas applicable to electricity in relating the current and resistance, and so on. One day looking at the formulas in some book or other, I discovered a formula for the frequency of a resonant circuit which was $f = \frac{1}{2\pi\sqrt{LC}}$, where $L$ is the inductance and $C$ the capacitance of the circle? You laugh, but I was very serious then. Pi was a thing with circles, and here is pi coming out of an electric circuit. Where was the circle? Do those of you how laughed know how that comes about?

I have to love the thing. I have to look for it. I have to think about it. And then I realized, of course, that the coils are made in circles. About half a year latter, I found another book which gave the inductance of round coils and square coils, and there were other pi's in those formulas. I began to think about it again, and I realized that the pi did not come from the circular coils. I understand it better now; but in my heart I still don't quite know where that circle is, where that pi comes from.

When I was still pretty young - I don't know how old exactly - I had a ball in a wagon I was pulling, and I noticed something, so I ran up to my father to say that "When I pull the wagon, the ball runs to the back, and when I am running with the wagon and stop, the ball runs to the front. Why?"

How would you answer?

He said, "That nobody knows!" He said, "It's very general though, it happens all the time to anything; anything that is moving tends to keep moving; anything standing still tries to maintain that condition. If you look close you will see the ball does not run to the back of the wagon where you start from standing still. It moves forward a bit too, but not as fast as the wagon. The back of the wagon catches up with the ball which has trouble getting started moving. It's called inertia, that principle:" I did run back to check, and sure enough the ball didn't go backwards. He put the difference between what we call it very distinctly.

Regarding this business about names and words, I would tell you another story. We used to go up to the Catskill Mountains for vacations. In New York you go to the Catskill Mountains for vacations. The poor husbands had to go to work during the week, but they would come rushing out for weekends and stay with the families. On the weekends, my father would take me for walks in the woods. He often took me for walks, and we learned all about nature, and so on, in the process. But the other children, friends of mine also wanted to go, and tried to get my father to take them. He didn't want to, because he said I was more advanced. I'm not trying to tell you how to teach, because what my father was doing was with a class of just one student; if he had a class of more than one, he was incapable of
doing it.

So we went alone for walk in the woods. But mothers were very power­ful in those days as they are now, and they convinced the other fathers that they had to take their own sons out for walks in the woods. So all fathers took all sons out for walks in the woods on Sunday afternoon. The newt day, Monday, we were playing in the fields and this boy said to me, "See that bird standing on the wheat there? What's the name of it?" I said, "I haven't got the slightest idea." He said, "It's a brown-throated thrush. Your father doesn't teach you much about science."

I smiled to myself, because my father had already taught me that that doesn't tell me anything about the bird. He taught me "See that bird? It's a brown-throated thrush, but in Germany it's called a halzenflugel, and in Chinese they call it a chung ling and even if you know all those names for it, you still know nothing about the bird. You only know something about people; what they call the bird."

"Now that thrush sings, and teaches its young to fly, and flies so many miles away during the summer across the country, and nobody knows how it finds its way," and so forth. There is a difference between the name of the thing and what goes on.

The result of this is that I cannot remember anybody's name, and when people discuss physics with me they often are exasperated when they say "the Fitz-Cronin effect" - and I ask "What is the effect?" and I can't remember the name.

I would like to say a word or two - may I interrupt my little tale - about words and definitions, because it is necessary to learn the words. It is not science. That doesn't mean just because it is not science that we don't have to teach the words. We are not talking about what to teach; we are talking about what science is. It is not science to know to change Centigrade to Fahrenheit. It's necessary, but it is not exactly science. In the same sense if you were discussing what art is, you wouldn't say art is the knowledge of the fact that a 3-B pencil is softer than a 2-H pencil. It's a district difference. That doesn't mean an art teacher shouldn't teach that, or that an artist gets along very well if he doesn't know that. (Actually, you can find out in a minute by trying it; but that's a scientific way that art teachers may not think of explaining.)

In order to talk to each other, we have to have words, and that's all right. It's a good idea to try to see the difference, and it's a good idea to know when we are teaching the tools of science, such as words, and when we are teaching science itself.

To make my point still clearer, I shall pick out a certain science book to criticize unfavorably, which is unfair, because I am sure that with little ingenuity, I can find equally unfavorable things to say about others.

There is a first-grade science book which, in the first lesson of the first grade, begins in an unfortunate manner to teach science, because it starts off on the wrong idea of what science is. There is a picture of a dog, a windable toy dog, and a hand comes to the winder, and then the dog is able to move. Under the last picture, it says "What makes it move?"
and so on.

I thought that at first they were getting ready to tell what science was going to be about; physics, biology, chemistry. But that wasn't it. The answer was in the teachers edition of the book; the answer I was trying to learn is that "energy makes it move."

Now energy is a very subtle concept. It is very, very difficult to get right. What I meant is that it is not easy to understand energy well enough to use it right so that you can deduce something correctly, using the energy idea. It is beyond the first grade. It would be equally well to say that "God makes it move," or "spirit makes it move," or "movability makes it move." (In fact one could equally well say "energy makes it stop." )

Look at it this way: That's only the definition of energy. It should be reversed. We might say when something can move that it has energy in it, but not "what makes it move is energy." This is a very subtle difference. It's the same with this inertia proposition. Perhaps I can make the difference a little clearer this way:

If you ask a child what makes the toy dog move, you should think about what an ordinary human being would answer. The answer is that you wound up the spring; it tries to unwind and pushes the gear around.

What a good way to begin a science course. Take apart the toy; see how it works. See the cleverness of the gears; see the ratchets. Learn something about the toy, the way the toy is put together, the ingenuity of people devising the ratchets and other things. That's good. The question is fine. The answer is a little unfortunate, because what they were trying to do is teach a definition of what is energy. But nothing whatever is learned.

Suppose a student would say, "I don't think energy makes it move." Where does the discussion go from there?

I finally figured out a way to test whether you have taught an idea or you have only taught a definition. Test it this way: You say, "Without using the new word which you have just learned, try to rephrase what you have just learned in your own language." Without using the word "energy" tell me what you know now about the dog's motion." You cannot. So you learned nothing about science. That may be all right. You may not want to learn something about science right away. You have to learn definitions. But for the very first lesson is that not possibly destructive?

I think, for lesson number one to learn a mystic formula for answering questions is very bad. The book has some others - gravity makes it fall; "the soles of your shoes wear out because of friction." Shoe leather wears out because it rubs against the side walk and the little notches and bumps on the sidewalk grab pieces and pull them off. To simply say it is because of friction, is sad, because it is not science.

My father dealt a little bit with energy and used the term after I got a little bit of the idea about it. What he would have done I know because he did in fact essentially the same thing - though not the same example of the toy dog. He would say, "It moves because the sun is shining," if he wanted to give the same lesson. I would say "No. What has that to do with the sun shining? It moved because I wound up the springs.
"And why, my friend, are you able to move to wind up the spring?"

"I eat."

"What, my friend, do you eat?"

"I eat plants."

"And how do they grow?"

"They grow because the sun is shining."

And it is the same with the dog. What about gasoline? Accumulated energy of the sun which is captured by plants and preserved in the ground. Other examples all end with the sun. And so the same idea about the world that our textbook is driving at is phrased in a very exciting way.

All the things that we see that are moving, are moving because the sun is shining. It does explain the relationship of one source of energy to another, and it can be denied by the child. He could say, "I don't think it is on account of the sun shining," and you can start a discussion. So there is a difference. (Later I could challenge him with the tides and what makes the earth turn, and have my hand on mystery again.)

That is just an example of the difference between definitions (which are necessary) and science. The only objection in this particular case was that it was the first lesson. It must certainly come in later, telling you what energy is but not to such a simple question as "What makes a dog move?" A child should be given a child's answer. "Open it up; let's look at it."

During those walks in the woods, I learned a great deal. In the case of birds, for example, I already mentioned migration, but I will give you another example of birds in the woods. Instead of naming them, my father would say, "Look, notice that the bird is always pecking in its feathers. It pecks a lot in its feathers. Why do you think it pecks the feathers?"

I guessed it's because the feathers are ruffled, and he's trying to straighten them out. He said, "Okay, when would the feathers get ruffled, or how would they get ruffled?"

"When he flies. When he walks around, it's okay; but when he flies it ruffles the feathers."

Then he would say, "you would guess then when the bird just landed he would have to peck more at his feathers than after he has straightened them out and has just been walking around the ground for awhile. Okay, let's look."

So we would look, and we would were, and it turned out, as far as I could make out, that the bird pecked about as much and as often no matter how long he was walking on the ground and not just directly after flight.

So my guess was wrong, and I couldn't guess the right reason. My father revealed the reason.
It is that birds have lice. There is a little flake that comes off the feather, my father taught me, stuff that can be eaten and the louse eats it. And then on the louse, there is a little bit of wax in the joints between the sections of the leg that oozes out, and there is a mite that lives in there that can eat that wax. Now the mite has such a good source of food that it doesn't digest it too well, so from the rear end there comes a liquid that has too much sugar, and in that sugar lives a tiny creature, etc.

The facts are not correct. The spirit is correct. First I learned about parasitism, one on the other, on the other, on the other.

Second, he went on to say that in the world whenever there is any source or something that could be eaten to make life go, some form of life finds a way to make use of that source and that each little bit of left over stuff is eaten by something.

Now the point of this is that the result of observation, even if I were unable to come to the ultimate conclusion, was a wonderful piece of gold, with marvelous results. It was something marvelous.

Suppose I were told to observe to make a list, to write down, to do this, to look and when I wrote my list down, it was filed with 130 lists in the back of a notebook. I would learn that the result of observation is relatively dull, that nothing much comes of it.

I think it is very important - at least it was to me - that if you are going to teach people to make observations, you should show that something wonderful can come from them. I learned then what science was about. It was patience. If you looked, and you watched, and you paid attention, you get a great reward from it (although possibly not every time). As a result when I became a more mature man, I would painstakingly, hour after hour, for years, work on problems - sometimes many years, sometimes shorter times - many of them failing, lots of stuff going into the wastebasket but every once in a while there was the gold of a new understanding that I had learned to expect when I was a kid, the result of observation. For I did not learn that observation was not worthwhile.

Incidentally, in the forest we learned other things. We would go for walks and see all the regular things and talk about many things; about the growing plants, the struggle of the trees for light, how they try to get as high as they can and to solve the problem of getting water higher that 35 or 40 feet; the little plants on the ground that look for little bits of light that come through, all that growth and so forth.

One day after we had seen all these my father took me to the forest again and said "In all this time we have been looking at the forest. We have only seen half of what is going on; exactly half."

I said "What do you mean?"

He said, "We have been looking at all these things grows but for each bit of growth, they must be the same agent of decay, otherwise the materials would be consumed for ever. Dead trees would there having used up all the stuff from the air, and the ground, and it wouldn't get back into the ground or the air, and nothing else could grow, because there is no material
available. There must be for each bit of growth exactly the same amount of decay."

There then followed many walks in the woods during which we broke up old stumps, saw funny bags and fungusses growing - he couldn't show me bacteria, but we saw the softening effects, and so on. I saw the forest as a process of the constant turning of materials.

There were many such things descriptions of things, in odd ways. He often started to talk about a thing like this: "Suppose a man from Mars were to come down and look at the world. For example, when I was playing with my electric trains, he told me that there is a great wheel being turned by water which is connected by filaments of copper, which spread out and spread out in all directions and then there are little wheels and all those little wheels turn when the big wheel turns. The relation between them is only that there is copper and iron nothing else, no moving parts. You turn one wheel here, and all the little wheels all over the place turn, and your train is one of them. It was a wonderful world by father told me about.

You might wonder what he got out of it all. I went to MIT. I went to Princeton. I came home, and he said, "Now you've got a science education. I have always wanted to know something that I have never understood; and so, my son, I want you to explain it to me." I said yes.

He said, "I understand that they say that light is emitted from an atom when it goes from one state to another, from an excited state to a state of lower energy."

I said, "That's right."

"And the light is a kind of particle, a photon, I think they call it."

"Yes."

"So if the photon comes out of the atom when it goes from the excited to the lower state, the photon must have been in the atom in the excited state."

I said, "Well, no."

He said, "Well, how do you look at it so you can think of a particle photon coming out without it having been in there in the excited state?"

I thought a few minutes, and I said, "I'm sorry; I don't know. I can't explain it to you."

He was very disappointed after all these years and years of trying to teach me something, that it came out with such poor results.

What science is, I think may be something like this: There was on this planet an evolution of life to a stage that there were evolved animals, which are intelligent. I don't mean just human beings but animals which play and which can learn something from experience (like cats). But at this stage each animal would have to learn from its own experience. They gradually develop,
until some animal could learn from experience more rapidly and could even learn from another's experience by watching, or one could show the other, or he saw that the other one did. So there came a possibility that all might learn it, but the transmission was inefficient and they would die, and maybe the one who learned it died too, before he could pass it on to others.

The question is: is it possible to learn more rapidly what somebody learned from some accident that the rate at which the thing is being forgotten either because of bad memory or because of the death of the learner or inventors?

So there came a time perhaps, when for some species the rate at which learning was increased, reached such a pitch that suddenly a completely new thing happened things could be learned by one individual animal, passed on to another, and another fast enough that it was not lost to the race. Thus became possible an accumulation of knowledge of the race.

This has been called time-binding. I don't know who first called it this. At any rate, we have here some samples of those animals, sitting here trying to bind one experience to another, each one trying to learn from the other.

This phenomenon of having a memory for the race of having an accumulated knowledge passable from one generation to another, was new in the world. But it had a disease in it. It was possible to pass on ideas which we're not profitable.

So there came a time in which the ideas although accumulated very slowly, were all accumulations not only of practical and useful things but great accumulations of all types of prejudices and strange and odd beliefs.

Then a way of avoiding the disease was discovered. This is to doubt that what is being passed from the past is in fact true, and to try to find out ab initio, again from experience, what the situation is, rather than trusting the experience of the past in the form in which it is passed down. And that is what science is; the result of the discovery that it is worthwhile re-checking by new direct experience, and not necessarily trusting the race experience from the past. I see it that way. That is my best definition.

Science is the belief in the ignorance of experts.

I would like to remind you all of things that you know very well in order to give you a little enthusiasm. In religion the moral lessons are taught, but they are not just taught one; you are inspired again and again, and I think it is necessary to inspire again and again, and to remember the value of science for children, for grown-ups and everybody else, in several ways not only that we will become better citizens, more able to control nature and so on. There are other things.

There is a value of the world view created by science. There is the beauty and the wonder of the world that is discovered through the results of these new experiences. That is to say, the wonders of the content which I just reminded you of; that things move because the sun is shining. (Yet, not everything moves because the sun is shining. The earth rotates indepen
dent of the sun shining, and the nuclear reaction recently produced energy on the earth, a new source. Probably volcanoes are generally moved from a source different from the shining sun.)

The world looks so different after learning science. For example, trees are made of air, primarily. When they are burned, they go back to air, and in the flaming heat is released the flaming heat of the sun which was bound in to convert the air into tree, and in the ash is the small remnant of the part which did not come from air that came from the solid earth instead.

These are beautiful things and the content of science is wonderfully full of them. They are very inspiring, and they can be used to inspire others.

Another of the qualities of science is that it teaches the value of rational thought as well as the importance of freedom of thought the positive results that come from doubting that the lessons are all true. You must here distinguish - especially in teaching - the science from the forms or procedures that are sometimes used in developing science. It is easy to say, "We write, experiment, and observe, and do this or that." You can copy that form exactly. But great religions are dissipated by following form without remembering the direct content of the teaching of the great leaders. In the same way, it is possible to follow form and call it science, but that is pseudoscience. In this way, we all suffer from the kind of tyranny we have today in the many institutions that have come under the influence of pseudoscientific advisers.

We have many studies in teaching, for example, in which people make observations, make lists, do statistics, and so on, but these do not thereby become established science, established knowledge. They are merely an imitative form of science, analogous to the South Sea islands airfields, radio towers, etc., made out of wood. The islanders expect a great airplane to arrive. They even build wooden airplanes of the same shape as they see in the foreigner's airfields around them, but strangely enough, their wood planes do not fly. The result of this pseudoscientific imitation is to produce experts, which many of you are. You teachers who are really teaching children at the bottom of the heap can maybe doubt the experts once in a while. Learn from science that you must doubt the experts. As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts.

When someone says, "Science teaches such and such," he is using the word incorrectly. Science doesn't teach anything; experience teaches it. If they say to you, "Science has shown such and such," you might ask, "How does science show it? How did the scientists find out? How? What? Where? It should not be "science has shown," but "this experiment, this effect, has shown." And you have as much right as anyone else, upon hearing about the experiments (but be patient and listen to all the evidence) to judge whether a sensible conclusion has been arrived at.

In a field which is so complicated that true science is not yet able to get anywhere, we have to rely on a kind of old-fashioned wisdom, a kind of definite straightforwardness. I am trying to inspire the teacher at the bottom to have some hope, and some self-confidence in common sense and natural intelligence. The experts who are leading you may be wrong.
I have probably ruined the system, and the students that are coming into Caltech no longer will be any good. I think we live in an unscientific age in which almost all the buffeting of communications and television words, books, and so on are unscientific. As a result, there is a considerable amount of intellectual tyranny in the name of science.

Finally, with regard to this time-binding, a man cannot live beyond the grave. Each generation that discovers something from its experience must pass that on, but it must pass that on with a delicate balance of respect and disrespect, so that the race (now that it is aware of the disease to which it is liable) does not inflict its errors too rigidly on its youth, but it does pass on the accumulated wisdom, plus the wisdom that it may not be wisdom.

It is necessary to teach both to accept and to reject the past with a kind of balance that takes considerable skill. Science alone of all the subjects contains within itself the lesson of the danger of belief in the infallibility of the greatest teachers of the preceding generation.

So carry on. Thank you.
Thinking, reasoning and understanding in introductory physics courses*

ARNOLD ARONS

Certain very basic cognitive difficulties shared by many students in introductory physics courses are well known to physics teachers, and their mention in this paper will come as no surprise. It is a fact, however, that existing instructional materials offer teachers very little help in overcoming these formidable obstacles to learning and understanding. It is my belief that deeper insights leading to improvement of instruction can come from careful observation of the details of student cognitive processes—observation based on what students say orally and put in writing when asked to articulate explanations of their own lines of reasoning. Such observations are quite similar, for example, to Piaget's studies of abstract logical reasoning in children.1

The purpose of this paper is to summarize a few results of such observations by giving specific examples of trains of thought and misconception exhibited repeatedly and reproducibly by many students, and to indicate some procedures that offer help in resolving the difficulties. Space does not allow the reproduction of detailed protocols of test response and Socratic dialog. I can only assert that the examples I have chosen are very widely prevalent and that the protocols of student verbalization frequently show remarkable reproducibility from individual to individual.

Use of ratio reasoning in geometrical scaling

Suppose all the linear dimensions of an object were increased by a factor of 2.4. By what factor would the total surface area, any cross-sectional area, the total volume, change? Most teachers are well aware of the difficulty students have in dealing with the ratio reasoning arising in such instances. Initially, very few students handle this at all. If problems are repeated, many students memorize the fact that the correct answer is sometimes obtained by squaring the scale ratio and sometimes by cubing it and proceed accordingly, hoping that they will make the appropriate connection in subsequent problems. Only a few students understand what is being done.

The majority of U.S. college students in introductory physics courses have difficulty with this problem. The proportion is lower at the level of calculus-physics for physics majors and engineers and is exceedingly high in noncalculus physics courses for premedical students, architects, forestry majors, etc. In science courses for nonscience majors, the incapacity extends to over 90%. What lies behind this widely prevalent difficulty?

If one asks a student who is having trouble with such reasoning what the term "surface area" means to him, he is immediately likely to elicit the answer "length times width." Sometimes the initial response is "extent, or amount, of surface," but if one then asks how one goes about assigning numerical values and measuring extent of surface, the response converges to "length times width." If one then sketches a very irregularly shaped figure with no definable length or width and asks whether a numerical value of surface area can be established in this case, the student is almost invariably at an impasse.

The basic cognitive problem with such students is that they have never formed or articulated a simple operational definition of "surface area." The fact that they have seen "told" about choosing a square to be taken as a unit, dividing any arbitrary figure into squares of this size and counting them, is immaterial. They have never gone rough the counting procedure; they have no recollection of the idea; they have only the memorized formula of length times width which they applied by rote to rectangles; they do not recognize this formula as a short cut counting the squares, and many feel that there must be something wrong with simple, direct counting because it does not involve a formula or use a more sophisticated mathematical procedure. All of this detail emerges repeatedly and reproducibly in Socratic questioning.

In this paper the term "Socratic dialog" is used in its classical sense, denoting a conversation in which an interlocutor asks his partner a sequence of questions eliciting a line of reasoning or inquiry without making didactic interpolations. I like to describe my own activity as that of asking probing questions and then shutting up and listening.

This part of the difficulty can be rectified by leading students to put an operational definition of "surface area" to their own words and having them execute the procedure several times by choosing their own unit squares, drawing an irregular figure, dividing it up by means of a grid and counting the squares— including making estimates of fractions of squares around the periphery. Many students initially feel that there is something wrong or evil about estimating the fractions. They need help and support in tolerating the uncertainty and including an estimate of uncertainty in the final total. At this point they can also be led to see how accuracy can be improved by using smaller and smaller squares. The final limit of the exercises can be the determination of an area by cutting out and weighing the irregular figure and cutting and weighing an integral number of squares drawn on the same paper. The reasoning which must now be invoked is a useful exercise, saving the way to the more sophisticated problem which initiated this section.

Articulating a clear operational definition of areas as process of counting unit squares is a necessary preliminary to the problem of scaling, but with many students, it is not sufficient; still another step is required. It proves helpful to them to visualize first what happens when the orthogonal dimensions of a figure are doubled: seeing that each unit square "divides" like an amoeba to form four nears of the same size everywhere throughout the figure; similarly, if the dimensions are cut in half, each group of our unit squares contracts into one; hence the factor of in area when a factor of two is applied to each of the o dimensions. The effect of other integral and non-inegral factors then emerges fairly rapidly. Homework exercises in which students sketch several suggested situations and carry out the arithmetical calculations are a necessary supplement. It is important also that students make up several additional problems of their own—however similar these might be to ones already posed.

It should now be clear that exactly the same sequence of ideas (operational definition and scaling ratios) must be articulated in connection with "volume." Most students seem to be able to carry this through when the task is laid out for them after initial Socratic help with "area." Repetition in the altered context helps induce assimilation of the overall scheme. Piagetians would probably label the operating cognitive processes as "accommodation" and "equilibration."

Kinematics

The Greeks did not resolve Zeno's paradoxes, and it took the human mind 2000 years to invent and clarify the concepts of kinematics as we now know them. It is necessary to allow our students to relive some of this conceptual development, and it should not be surprising that they have serious difficulty with the same subtleties which bewildered able minds in the past. This is a huge area of instructional problems, and space does not allow me to deal with it comprehensively. I shall give two illustrations which bring out what I believe to be important issues and refer interested readers to more detailed observations reported elsewhere by my colleague Dr. Lillian McDermott and her graduate student Dr. David Trowbridge. 2

A point of serious difficulty, well known to every teacher, is that of the concept of instantaneous velocity. Trowbridge shows, for example, that many students do not really discriminate between position and velocity when confronted with actual motions. Even after having had quite a bit of formal instruction in kinematics, they watch an experiment with one body overtaking another in rectilinear motion and point to the instant of passing as the instant at which the two objects have the same velocity. 2

Socratic dialog with students reveals the following difficulties (among others): (1) They regard the term "instant" as referring to a time interval of perhaps short, but nevertheless finite, duration. Very few text presentations are careful with the linguistic aspects in this context; they do not discriminate between clock readings (instants) and time intervals (durations) formed out of the difference between two clock readings. Similarly, many texts fail to discriminate between position numbers and displacements formed from the difference between two such position numbers. The distances measured from zero to position numbers on a scale do not necessarily have anything to do

Very few text presentations discriminate between clock readings and time intervals or between positions and displacements.

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The ball leaves our hand with an instantaneous upward velocity of +30 m/sec. (Taking the magnitude of acceleration to be the round number 10 m/sec\(^2\), what will be the instantaneous velocity of the ball at the end of one second? +20 m/sec. At the end of the next second? +10 m/sec. What algebraic value are we assigning to the acceleration in this framework? -10 m/sec\(^2\). What will be the instantaneous velocity at the end of the third second? zero m/sec. For how long does the ball possess this particular value of velocity? zero seconds. What is the instantaneous velocity at the end of the next second? Here there is frequently hesitation or floundering because the full meaning of the algebraic signs has not been absorbed in the prior study of text exposition and from performance of the usual end-of-chapter homework problems. The breakthrough at which the student says "-10 m/sec?" and begins to perceive that textbook statements about "uniform acceleration" have meant that the acceleration is -10 m/sec\(^2\) all the time, not altering at the top of the flight, signals a significant step toward accommodation and equilibration.

The concept of force

Despite the legitimate epistemological questions which can be raised concerning the Newtonian concept of "force," and despite ingenious efforts of several major thinkers to eliminate it from physical theory, it is unlikely that "force" will yield its presently established place in our comprehension of natural phenomena. The cutting edge of

Students do not begin to understand the concept of force until they become able to apply Newton's third law correctly.

The same set of ideas can now be formulated by a simple numerical examination of the behavior of the rising ball: Suppose we take the positive direction to be upward. The ball leaves our hand with an instantaneous upward velocity of +30 m/sec. (Taking the magnitude of acceleration to be the round number 10 m/sec\(^2\), what will be the instantaneous velocity of the ball at the end of one second? +20 m/sec. At the end of the next second? +10 m/sec. What algebraic value are we assigning to the acceleration in this framework? -10 m/sec\(^2\). What will be the instantaneous velocity at the end of the third second? zero m/sec. For how long does the ball possess this particular value of velocity? zero seconds. What is the instantaneous velocity at the end of the next second? Here there is frequently hesitation or floundering because the full meaning of the algebraic signs has not been absorbed in the prior study of text exposition and from performance of the usual end-of-chapter homework problems. The breakthrough at which the student says "-10 m/sec?" and begins to perceive that textbook statements about "uniform acceleration" have meant that the acceleration is -10 m/sec\(^2\) all the time, not altering at the top of the flight, signals a significant step toward accommodation and equilibration.

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Students do not begin to understand the concept of force until they become able to apply Newton's third law correctly.
One aspect quickly emerging in Socratic dialog is that students do not translate the usual statements of Newton's third law into the perception that an interaction involves two distinct forces, that these two forces act on different bodies, and that each force appears on a different diagram. Regardless of what the textbooks say, in order to save space they usually proceed to illustrate with compact diagrams in which the interacting bodies are not clearly separated from each other on the page. The various forces are all tangled up in what amounts to a single diagram, and the students are not constrained to discriminate which force acts on what object. Such discrimination does not, in fact, begin to develop in the majority of students until they are forced to re-draw the text diagrams for themselves, widely separating the sketches of the interacting objects and showing the forces acting on each. Furthermore, it is essential to make students describe each force in words — a verbal description being a statement of what object exerts each force on what. Only when, as in the simple case of the book resting on the table, they have written out the statements that "this force is exerted by the book on the table" and "this other force is exerted by the book on the table" does one begin to see a light in the eye and hear the student say something to the effect that "Oh, there are two different forces appearing on separate diagrams!"

The text and teacher have said all this, of course, but not until the student is led to articulate the description himself and to recognize the significance of the transpositions of the prepositions "on" and "by" in the verbal descriptions, does he actually begin to translate the usual jargon of Newton's third law into his own personal grasp of what transpires in an interaction.

Another obstacle revealed through Socratic dialog, particularly with slower students, is the deep persistence of a vitalistic notion of force as a push or pull which must be exerted by muscular action of a living entity. This is revealed occasionally by candid or even indignant student queries such as "How can the table exert a force on the book? It has no power!" Here it is helpful to expose students to the notion of a "passive" force which develops in mechanical situations when bodies are deformed but tend to spring back to their initial shape: springs, when they are extended or compressed, exert a force on the object which is in contact with them; a bed or easy chair deforms and exerts an upward force on you when you sit on it; a hard chair and the floor both deform, albeit imperceptibly when you sit or stand; finally, the table is deformed and exerts an upward force on the book; the table is deformed even when a sheet of paper is placed on it. The latter effects must be seen in the imagination rather than directly with the senses. These perceptions assist students very substantially in assimilating the force concept, and the passive force idea is subsequently available to assist assimilation of the concept of frictional force. It is useful to help students develop the insight that passive forces have an upper limit: springs, chairs, and tables break when overloaded. Static frictional force acts in a given situation "breaks" at a more or less reproducible upper limit.

to speak of "feeling the weight of an object when you hold it in your hand." By revealing the profound confusion this location precipitates in the learner's mind, Socratic dialog supports the wisdom of restricting the term "weight" to one and only one meaning: a name for the gravitational force exerted by the earth on the object. From this point of view, what we feel when we support an object is not its weight but an entirely different force — the force exerted by the object on us. This force happens to be numerically equal to the weight only under those circumstances in which no other action is pressing the object downward or tugging it upward. When students are led to articulate these distinctions, they begin to recognize the different forces acting in everyday situations and genuine understanding slowly takes shape. Further progress in the conceptual development is then catalyzed by consideration of the block accelerating along an inclined plane. Here the force exerted by the block on the plane (and the force exerted by the plane on the block) are clearly different in both magnitude and direction from the weight of the block. Grasp of this distinction is seriously impeded if students have previously been allowed to confuse weight of the object with the force the object exerts on whatever supports it.

I find the difficulties and misconceptions outlined above (as well as a number of others) widely prevalent through the entire spectrum of students in introductory physics — from non-science majors in general education courses through future physics majors and engineers. It is illusory to suppose that one rectifies these difficulties by offering lucid explanatory statements to passive students. In my experience it is necessary to make students draw force diagrams and describe each force in words, on about four or five tests, spread out over a period of weeks, before the majority (two thirds to three quarters) have rectified their misconceptions. We draw force diagrams of objects thrown vertically upward before and after they have left our hand. We draw force diagrams of a frictionless puck before and after it slides off the edge of the table. (In these diagrams we include the earth, our body, the table.) We draw force diagrams of a block being pushed along the floor and of the region of floor in contact with the block the next time the block is pressed against a wall and pushed upward by an oblique force, and we draw force diagrams of both block and wall. Next time the block may be made to slide along the ceiling. We draw force diagrams of our body, the car seat, the car and the road when the car moves at uniform velocity or is speeding up or slowing down or going around a curve. It is useless to "explain" to the students that acceleration is imparted to the car by an unbalanced force exerted by the road, not by the car. This is "explained" to them repeatedly, but they fail to comprehend, or even remember the idea, until, with surprise, they articulate it in their own words out of their own force diagrams. Sometimes the force diagram task is coupled with a numerical problem; sometimes it stands as a qualitative exercise in its own right. There is only a low correlation between the correctness of the force diagram and that of the numerical application of the second law. Many students memorize calculational procedures in which they get correct numerical results in simple problems without having any appreciable understanding of the phenomenology of the forces.

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Essentially the same results apply to other areas, such as ratio reasoning and scaling. Didactic explanation and a ncentrated remedial exercise do not help the majority of students overcome a cognitive difficulty. Much greater access is achieved through providing students with related opportunity, in slightly differing situations, to trace line of reasoning and articulate it in their own words, orally or in writing. In my own experience, something like four or five repetitions, in altered context and read over a period of weeks, are required to engender control of the reasoning in a substantial majority.

A supplementary remark is appropriate concerning force diagrams, mentioned earlier, of objects thrown upward and of frictionless pucks flying off the edge of a table. Many students initially show an upward force acting on the object after it has left the thrower's hand, and they show a horizontal force acting on the frictionless puck after it leaves the edge of the table (even though they showed no such force while the puck moved at an instant velocity on the table). Their attitudes concerning forces, as revealed in Socratic dialog, are reminiscent of medieval motions of "impetus" such as those associated with Buridan and Oresme. In this sense, their introduction of extraneous forces shows an incomplete grasp of the concept of inertia, even though they have memorized the verbal statement and glibly regurgitate it on command. Thus, making their mistakes on these very basic examples is a requirement that students sketch for themselves and visualizing which the sketches force them to undertake and insights thus formed provide intelligible motivation for the invention of field theory instead of leaving the latter in the realm of unintelligible magic, which is the impression deposited by most text presentations.

Still another realm which transcends sense perception is that of the kinetic-molecular model. Socratic dialog quickly reveals that it is not enough to provide a few sketches and verbal statements in a text. Even vivid films and demonstrations fail to deposit a well retained and equilibrated view. Added to the preceding instructional components must be a requirement that students sketch for themselves, however crudely, pictures of what the surface of a solid might look like on the atomic-molecular level; pictures of what happens when a gas is compressed, when diffusion takes place, when a liquid evaporates, when a solid goes into solution. Only after doing the thinking and visualizing which the sketches force them to undertake do many students begin to do more than just memorize statements and procedures for problem solving.

Recognizing what is not the case as well as what is

Our text presentations, as well as questions and problems, give students very little opportunity to articulate explicitly what is not the case as well as what is, and to deal with the implications in various important contexts. I find through Socratic dialog that many excellent opportunities for accommodation and equilibration are lost in this oversight.

For example, students have very substantial difficulty in articulating the sequence of propositional reasoning associated with Galileo's experiments in rolling balls
down a grooved plank: what is actually observed? How do we move logically from the factual observation to the inference that the acceleration is uniform? How do we move logically from the inclined plank to free fall? As in previous instances, it is necessary to make students say or write the story in their own words and correct their mistakes. They simply memorize and fail to retain didactic explanation, however lucid. The insight of the students is substantially deepened if the questioning is explicitly broadened to include: what conclusions would follow if the observed time interval were not proportional to the square root of the displacement from rest? What conclusions would follow if this proportionality obtained at low angles of inclination of the plane but departed more and more significantly with increasing inclination?

Similarly, it is useful to have students discuss inferences that would follow concerning the structure of matter if the laws of definite and multiple proportions did not emerge from measurements of chemical composition, or to have them describe the phenomena that would be observed on earth if the ecliptic either coincided with or were orthogonal to the terrestrial equator. Not only do such contrasts vary the context in a way which multiplies the opportunities for accommodation and equilibration but they also help exercise the capacity for hypothetico-deductive reasoning—a capacity little more than vestigial or not yet developed at all in many of our students.

Other facets of the "what is not the case" device are exhibited in more restricted contexts. Consider, for example, the familiar expression for centripetal force acting on a particle in uniform circular motion:

$$F_c = \frac{mv^2}{R}$$

I find in dialog with students that they are using this as a formula into which to substitute numbers without consideration of the phenomena to which it applies. One way of opening up consideration of physical significance is to ask: "how will the particle behave if we apply a centrally directed force smaller than $mv^2/R$? larger than $mv^2/R$? The students have not previously considered any such possibility and have not been led to visualize situations in which the force does not satisfy the equation. As they begin to visualize the departure from circular motion, they acquire an entirely different grasp of the meaning of the equation and of the concept of centripetal force. Subsequently these insights can be connected with the decay of a satellite orbit and of the concept of centripetal force. Subsequently these insights can be connected with the decay of a satellite orbit and of the concept of centripetal force. Subsequently these insights can be connected with the decay of a satellite orbit and of the concept of centripetal force. Subsequently these insights can be connected with the decay of a satellite orbit and of the concept of centripetal force.

Consider, for example, the graphical solution of thin lens problems in geometrical optics by the drawing of principal rays. Many students will grind out formal algebraic solutions using the lens equation without any understanding of the physics and without connecting the algebraic solution with a ray diagram. They have memorized the formal procedures, including the manipulation of algebraic signs with essentially no comprehension of the physics. These students frequently have as much trouble with the ray diagrams as do the students who are less facile algebraically.

When a student is having trouble setting up a ray diagram, I now invariably first ask him to tell me in his own words the meaning of each principal focus of a converging and of a diverging lens in terms of principal rays. Invariably, the student turns out to be unable to do this. If he is on the verge of giving an adequate description, I usually lead him through it Socratically. If he is not on the verge, I send him back to the text for these particular definitions and proceed when he returns.

Once the student is able to describe in his own words the meaning of each focal point and the drawing of each principal ray, he usually proceeds to draw ray diagrams (even for two-lens systems with virtual object) with little further difficulty. Since I am unable to carry every student through this sequence in personal conversation, I have to reach many students by testing. I always say in advance that (a) test questions will require ray diagrams as well as algebraic solutions and (b) that it will be necessary to write out a verbal description of how every principal ray was
If you send somebody to teach somebody, be sure that the system you are teaching is better than the system they are practicing.

Will Rogers
Significant physics content and intellectual development—cognitive development as a result of interacting with physics content

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Increasingly during the past 20 years intellectual development has been recognized as the central purpose of education. The Piagetian model of intellectual development tells us that each student must engage a subject in a manner appropriate to his or her present stage of development if he or she is to advance to the next stage of development. When applied to college physics teaching, this theory implies that the large fraction of introductory physics students who are at the concrete operational stage of development must observe physical phenomena directly while they themselves are manipulating the equipment. Only in this way can they progress to the formal operational stage that characterizes professionals in the field.

In the past, physics instructors at college and secondary school levels have not been too concerned about the intellectual status of their students. The assumption was made that when students accumulated information about physics—mechanics, heat, sound, light, electricity, and modern physics—intellectual development occurred. Physics, as a discipline, then, had properly discharged its educational responsibility when students were exposed to its content.

There is only one overt indication that the general topic of intellectual status was considered by schools when placing physics in the curriculum. In the United States, secondary school physics is usually taught in the twelfth (and last) year. Perhaps the assumption was made that an older student (17 or 18 years of age) is better able to cope with the abstractions of physics than one who is younger. Hence, physics was placed in the final year. There is, however, another defensible assumption to explain placing physics at that educational level: by that time, students would have had more opportunities to study mathematics. Regardless of the reason for its grade placement, physics teaching to the present has assumed that students possessed a level of intellectual development adequate to handle the abstractions of the discipline. The manner in which physics has been taught at college and secondary school levels and the content selected to be used, however, demonstrate that those teaching it felt little (if any) responsibility for promoting intellectual growth. A cursory examination of the secondary school course of study in physics produced by the Physical Science Study Committee or of that prepared by the Harvard Project Physics group will reveal the basic assumption that the students studying those curricula had the ability to handle the abstractions of physics.

Intellectual development is those changes in the mental functioning of an individual that permit him to move from thinking only with concrete objects as a child to utilizing such thought forms as propositions and axioms as an adult. The discipline of physics can be used to promote intellectual development if the instructor recognizes three premises:

1. The central purpose of secondary schools and the early years of college instruction is intellectual development.

2. Intellectual development takes place while investigations are being conducted and is not adequately represented by the investigation's end products, that is, in facts, principles, laws, and generalizations. In fact, until intellectual development has taken place, many of the end products of an investigation cannot be understood.

3. The discipline of physics is structured around investigations which ultimately lead to the understanding of natural phenomena.

The first of these premises generally provokes vigorous discussion because "central" is understood to mean "most important." The use of "central" in the first premise was not accidental. That term was chosen carefully and has its usual meaning—"the center of." At the center of everything done by educational institutions must be found the development of the intellect. All teaching methods and materials as well as evaluation procedures must reflect this concern. If responsibility for that concern is not accepted by schools and colleges, they will be unable to lead their students to achieve such traditional purposes as citizenship, social responsibility, and self-support, because those traditional purposes all represent abstract thought. If intellectual development has not taken place, even the most traditional purpose for which schools exist—the induction of youth into society—will not be fulfilled. Promoting intellectual development in the school has a danger, however: students may reject some of the abstract principles which govern a given society.

Intellectual development can be thought of as acquisition by the student of the ability to think abstractly. In general, abstract thought is that type of thought which utilizes axioms and propositions rather than information gathered from first-hand experience with actual objects, events, and/or situations. Abstract thought is the type that utilizes the "If..., then... therefore..." form. That form of thought can be exhibited in equations by a mathematician, in verse by poet, on canvas by an artist, or in hypotheses by a physicist.

Whenever a student abandons the concrete realities of the world for theories and propositions about its existence and interactions, he has moved from concrete thought to abstract thought.

Because abstract thought can be represented by a form, the Swiss psychologist-epistemologist Jean Piaget has called it formal thought. Piaget describes the formal thinker as one "who thinks beyond the present and..."
She who at election time understands issues and
its consequences, and who understands the
consequences of his actions. He is also the thinker
who can design and assemble apparatus, collect data, and
construct models from those data. He can think about
consequences of his actions. He is also the thinker
who delights especially in
olved from exploring concrete objects, events, and/or
concepts. Notice that all the mental operations just
be invented for him which employ the exploration
ation, and he can discover the usefulness of those
cepts. Such a thinker is truly concrete operational.
mal thinker need not consider reality only; a
re thinker must. A formal thinker places all
ation in the context of a form of thought; a
re thinker must utilize the concrete information he
es. Both can gather information through
 sharply depend upon student interaction with
act of the concrete to the formal thought
comprehensive. Intellectual development,
ally takes place during an experience and is not
resented by its end products. That is, of course, the
ence of premise (2).

The logic of the foregoing argument hinges on the
position that content from a particular discipline with
which concrete thinkers can function is different from that
which formal thinkers can utilize. There is, in other
words, concrete content and formal content. From that
frame of reference, the proposition itself suggests that,
when examinations are prepared, those questions
evaluating understandings of concrete content are concrete
questions. Similarly, those questions evaluating
understandings of formal content are formal questions.
Accepting the foregoing proposition, Lawson and Renner
developed and validated examinations in secondary school
biology, chemistry, and physics that contained
approximately equal numbers of concrete and formal
questions. The content for the examinations was selected
after consultation with the teachers of the 133 students
who were to complete them. The examinations, which
measured understandings of concrete and formal concepts,
were administered near the end of the 1973 academic
year.

A concrete test item and a formal test item which
illustrate the questions Lawson and Renner used in the
examination in physics are given below. The type of
concept being tested—concrete or formal—is indicated at
the beginning of each item. The reader must keep in mind
that, if a concrete student has memorized an algorithm
and if the test item is constructed so he can use it, that
student often responds correctly to test items which
purport to measure understandings of formal concepts. To
be sure that success on a formal item, therefore, is
demonstrating understanding of a formal concept, the
types of experiences the student has had should be
known. In other words, teachers who teach students to
memorize types of problems may be getting some
performance from concrete students on formal items. That
experience, however, has not changed the type of thought
of which the student is capable.

Concrete item

This test paper is sitting at rest on your desk.
Which of the following statements best describes
the situation?

(a) There are no forces acting on the paper.
(b) There are many forces acting on the paper
but they are balanced.
(c) The paper exerts no force on the desk.
(d) Your paper is at rest in any coordinate system.

Formal item

The acceleration of an object is directly
proportional to and in the same direction as the
unbalanced force acting on it and inversely
proportional to the mass of the object. A force of 2
kg m/sec² accelerates an object of 10 kg. 0.2
m/sec². If the force were tripled and the mass of the object doubled, acceleration would be

(a) 0.6 m/sec²
(b) 0.4 m/sec²
*(c) 0.3 m/sec²
(d) 0.1 m/sec²

In addition to completing one of the examinations, each student in the sample participated in an interview during which several of the tasks designed by Inhelder and Piaget⁵ to identify formal thought were used. The results of those interviews allowed the grouping of the students into seven categories: early concrete (IIa), transitional concrete, concrete (IIb), postconcrete, early formal (IIIa), transitional formal, and formal (IIIb). The graph in Fig. 1 shows the mean percentage of items (with chance eliminations) answered correctly by each of the seven intellectual development categories. Of special significance is the fact that no student in the concrete operational category achieved any success with formal questions. Not until the postconcrete category was reached was any success registered with questions which evaluated understandings of formal concepts.

The data from Fig. 1 tend to confirm the proposition that concrete thinkers cannot profit from attempting to study formal content. If intellectual development is to be achieved by using content, therefore, the content used must be selected to match the intellectual development level of the learner. If it is not so selected, that content does not assist the learner to achieve intellectual growth because the learner cannot think about it. Not only does the learner not advance intellectually, he does not "learn" the content. Thus when schools neglect the promotion of intellectual development, they do not lead students to achieve even the most traditional of their purposes, that is, "learning" content. That is exactly what was meant in premise (2) when the statement was made that, if intellectual development had not taken place, the end products of the learning could not and would not be understood. The data shown in Fig. 1 tend to confirm that statement.⁶

In the fall term of the 1974–1975 academic year at the University of Oklahoma, data from two groups of students further confirmed premise (2). Those data were obtained from 77 students in a physics course designed for students in the liberal arts and education (prospective elementary school teachers). On the very first day of the semester those persons were given an examination which measured their mathematical understandings. The content of the examination extended from counting through simple trigonometric functions. The performance of those students on two types of content—percentage and geometry—lends support to the position taken in premise (2). The simple percentage question was missed by 66% of those taking the examination. The percentages of students unsuccessful on various geometry concepts follow: computing circumference when π is known, 83%; using a ratio to find one missing side of two similar triangles, 90%; computing the area of a triangle, 74%; and using the Pythagorean theorem, 67%. All of these students had "studied" simple geometry and percentage in earlier education. A percentage is, of course, a ratio, and the ratio concept involves a relationship which seems to require formal thought. An independent measurement demonstrated that 60% of these students could not solve a simple \( \frac{a}{b} = \frac{c}{d} \) type ratio. Geometry is based upon a series of postulates which are not necessarily related to reality; it is a postulatory-deductive system and its concepts have meaning because of their position within that system. Geometry consists of formal content. Obviously these persons had not moved into the formal thought stage by studying that formal content.

The data just presented seem to justify the position that concrete students who are required to interact with formal content do not achieve increased intellectual development and do not understand and/or remember the content itself. That interpretation of the data presented raises serious questions relative to the value of formal lectures to concrete (and probably early formal) students. The entire educational process—utilized particularly in the early years of college—of large lectures, many abstractions, and a minimum of contact with the materials of any discipline seems of questionable value when data such as those presented here are considered. Furthermore, when students are given remedial work to overcome deficiencies in subjects such as mathematics, the experiences they are given are usually replicas of those experiences which they had originally and which developed the deficiency. Educators seem unwilling to recognize that to handle formal content a student must first become an abstract thinker; providing him experiences with formal content does not move a concrete thinker into the formal stage.

How then should physics content be used to promote intellectual development? What possibilities exist for utilizing physics with concrete operational thinkers? At the beginning the assumption is made that what is taught at any level under the title of physics must in fact be physics. Studying how a washing machine or a carburetor works is not physics; that is technology. The carburetor, for example, can be used in the discovery phase of learning as an opportunity to see the usefulness of Bernoulli's principle. To use the carburetor as the focus of attention to teach Bernoulli's principle obscures physics and emphasizes technology. To many teachers,
The flow of fluid is accompanied by a decrease in pressure. However, in order to provide that pressure is reduced. Next the concept was invented and the construction in its design observed. The students know that in the constricted area the pressure is reduced. Now a thorough mental structure has been built in a completely scientific fashion. The carburetor has not been used to teach physics, but its operation has been an important discovery with the invention made from information gathered through exploration.

Has this physics content just discussed been used to promote intellectual development? First, the concept was selected to be taught, and experiments were designed to lead students to collect information the instructor could use to invent the desired concept. Next the concept was found to explain other phenomena and/or apparatus. However, most important in the entire process, the experiments of the students were done with concrete objects, and they did not know the outcome in advance. In other words, the learners were provided experience interacting with their environment and the objects in it.

Notice that emphasis has been placed upon the student doing the experiments himself. To be of value in promoting intellectual development, the experiments must be done by the students. Piaget has stated, "an experiment not carried out by the individual himself with all freedom of initiative is by definition not an experiment but mere drill with no educational value." Piaget's position is that in order to move from one intellectual stage to another—for example, from the concrete to the formal stage—experience is one of four factors which must be present. Our research has confirmed that experiences such as those outlined here do encourage students to move from concrete to formal thought.

To say that the discipline of physics is rich with opportunities to permit students to interact with their environment is to belabor the obvious. Physics is a discipline that demands much observation of phenomena, extensive interaction with apparatus, careful measurement, interpretation, and courageous prediction. In addition, understandings are deepened and made secure by interacting with other persons—social interaction. In short, physics is a discipline which demands that students attempt to understand it in interacting with it, and interaction with the environment and those persons in it is what encourages students to move from one intellectual level into another or move more deeply into the presently occupied level. Physics is a discipline which attempts to explain natural phenomena, and the "attempting to explain" is what provides the experience necessary to intellectual growth. However, in order to provide that

The fan experiment clearly demonstrates that the area occupied by the air stream can be increased velocity in air flow is accompanied by a decrease in pressure. So the pressure in the tubing is less than that in the syringe or, when the passage through which fluids flow is constricted, the velocity rises and the pressure drops. The finding regarding the constriction is an important discovery. An automobile carburetor can now be introduced and the conformation in its design observed. The students know that in the constricted area the pressure is reduced. Now a thorough mental structure has been built in a completely scientific fashion. The carburetor has not been used to teach physics, but its operation has been an important discovery with the invention made from information gathered through exploration.

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experience, the student must interact with the materials of the discipline.

Is physics taught in an exploration, invention, discovery fashion that allows students such an interaction with its materials? Frequent not. Often materials are provided the student after he has been told what he is to find. He has had no freedom of initiative. Piaget was quoted earlier as saying such an experience was "mere drill" and has "no educational value." When a student is told the abstractions of physics and then sent to the laboratory to verify them, the instructor has made three assumptions: (1) the student can understand the abstractions; (2) the discipline has no responsibility to develop formal thought; (3) learning the abstractions of physics constitutes education in the discipline. The position taken here is that assumptions (2) and (3) are not true and assumption (1) is probably true if the course is taken by the students on an elective basis. Our data have shown upon two separate occasions that between 70% and 90% of those who elect secondary school physics are formal thinkers. Our data demonstrate that, of the students required to study physics, approximately 40% are concrete thinkers. This latter group certainly needs the exploration, invention, discovery experiences physics can provide. The former group has already segregated themselves on the basis of ability. In all probability they would profit from the interaction with the materials of the discipline, but that interaction is not as essential as with the concrete group.

What physics instructors have done in the secondary schools and colleges of the United States is to fashion a course for formal thinkers only, and the "student grapevine" has—using different language—made that fact known. One of the principal procedures used to make physics for formal thinkers only is to make profuse use of mathematics. Most of the mathematics beyond counting, addition, and subtraction is composed of formal concepts. The result of this unwise pedagogical decision is to deprive the vast majority of students of the opportunity to experience physics and utilize it to develop intellectually. That is culturally and educationally regrettable.

What can be done by a physics instructor to develop and present a physics course which is representative of the discipline and which will provide the opportunity needed for intellectual growth? First of all, physics teachers must discard some of their substitution of mathematical treatment of phenomena for actual experience with the phenomena. For example, $F = ma$ (or at least $a \propto F$) should be a relation which arises from observation and experimentation and should not be presented intuitively. As a further example, students should experience an object traveling a greater (or lesser) distance in equal time intervals and the result of the experience should allow acceleration to be invented. Such a pedagogical procedure is far superior to defining acceleration as $\Delta v/\Delta t$. The heart of a physics course should be the laboratory and not the chalkboard.

The procedure for designing a physics course which has intellectual development as one of its purposes is (1) selection of the concepts which represent the content to be taught, (2) provision for laboratory experiences which provide information the instructor can use to invent the concepts, (3) teacher-student interaction during which the concepts are invented, and (4) determination of other events, objects, and/or situations which can be explained with the invented concepts. In most learning situations everything examined with the newly invented concept will probably not be fully explained. In that case additional investigations (attempts to explain natural phenomena) are made, the learning cycle starts over, and additional concepts can be invented.

There is no pedagogical procedure that is fail-safe. The foregoing procedure is no exception to that generalization, but our research has shown that it does promote intellectual development. In addition, the procedure provides students with an enjoyable experience with the discipline of physics; they finish the course liking the discipline and feeling good about themselves. It is possibly that is more important than knowing that $a = d^2 s/dt^2$.

2. L. Kohlberg and C. Gilligan, *Daedalus* 100, 1051 (1971).
4. Renner et al., Ref. 3.
9. McKinnon and Renner, Ref. 3.
10. McKinnon and Renner, Ref. 3.
12. In the United States less than 5% of the students in grades 9–12 study physics.
Death of an Investigation*

Robert E. Samples

This article illustrates the differences between two approaches to the problem of involving students in laboratory activities in the science classroom. The first approach is what may be called "authoritarian," whereas the second is often referred to as "investigative."

The setting is a ninth-grade classroom where students are supposedly determining the density of ice (ESCP Investigation P-2). The basic ideas, however, are applicable at all grade levels, from elementary to college.

As the class period opens the teacher instructs the students.

"The alcohol costs money, so don't waste it. The proper way to use it is to pour 25 ml. of alcohol into the beaker and place the ice cube in the alcohol. As you notice, the ice cube will sink. Add water slowly, mixing it until the ice cube just floats. Remove the ice cube, weigh the solution, and measure its volume. This will give you the information necessary to determine the density of the ice cube. All right, get your materials and get to work. Let's not have a mess; you're not third graders."

As the students silently proceed through the lab, one drops a beaker as it is being filled.

"All right, butterfingers, let's see you finish the lab without one of your beakers. Can't you people do this kind of thing without somebody holding your hand? You don't think science got this far without some discipline, do you?"

The rest of the "investigation" is explosively punctuated by outbursts from the teacher that follow the same pattern.

"I thought I told you to pour water into the alcohol. Can't you people listen?"

"I said, take the ice cube out of the solution after it starts to float. You know why?"

The students shake their heads.

"What's the temperature of the room?"

A chorus of "I dunnos" is interrupted by a scattering of "70 degrees."

"Right, it's 70. What is the temperature of the ice cube?"

"Thirty-two." It rings clear this time.

"Okay, so you don't want the ice to melt into the solution or it will change your results and the accuracy of the answer will be out the window. Hurry up, I want this place spotless before the bell rings. Watch your math and follow the instructions or you will never get the right answer which is .974 grams per milliliter."

The writer never actually heard this particular monologue, but it is
typical of the sort of teaching in too many classrooms. At the end of a
session like this, the teachers' lounge probably echoes with complaints
about the lack of quality to be found in junior high students, lecturers,
and curriculum writers. In all but the first instance, the teacher may be
right. The junior high student is intrinsically a dynamic, highly inter­
ested human being. In a learning environment such as the one described,
he is almost superfluous.

First, the ritualistic recitation of the instructions had nothing to do
with the investigation and little to do with the students, except, of
course, the management of their actions. In a sense they form the chess
board upon which the game is to be played. The students cannot leave
the confines of the pattern without being ridiculed any more than a
rook can move 25 spaces to the left without leaving the board. The
teacher is the mover and by innuendo guides the course of action.

And the students? They are the mute pieces that mechanically shuffle
through the constricting corridors created by the instructions. Like the
chessmen, the students are different, but their motions are still governed
by external rules.

Is this analogy preposterous? Unfortunately, it isn't. Things like this
happen in classrooms and often the teacher feels that the orderliness of
the action is a criterion for judging the quality of the "science." It
would seem, by this view, that science is good if the students report their
psychomotor obedience with an equally obedient communication effort.
If you examined the total situation you would find that the "writeup"
is an end in itself, and, being an end, the means to it should be subject
to rigor.

However, any teacher, even the mythical one who provided the
monologue, would cry heresy if it were suggested that there wasn't
room for the students to think during an investigation. In reality the
thoughts of the students were probably of a Darwinian survival type.
They recognized the teacher's stimulus and responded accordingly. The
peripheral concepts that could have been achieved, the process of inves­
tigation, and the basic idea of intellectual honesty, are never made
available to the student.

Let's be specific. The detailed instructions remove the "investigation"
from the activity and make it a demonstration problem. The only differ­
ence between this and more traditional approaches is that the student
baits the hook before fishing for the answer.

By being so specific in the instructions, "place the ice cube in the
alcohol. As you notice, the ice cube will sink. Add water slowly, mixing
it until the ice cube just floats," the teacher removes the exercise from
the realm of science. The students should have been permitted to dis­
cover the need for controls such as "slowly mixing until the ice cube
just floats." Such precisely phrased instructions may make the student
wonder why it is necessary to mix the water with the alcohol. The
teacher might answer that the densities of alcohol and water are differ­
ten, so it is necessary to mix them. Since this is true, why not allow the
students to establish the truth themselves?

The reason for the second instruction, "Remove the ice cube, weigh
the solution, and measure its volume," is provided when our mythical
teacher says "... you don't want the ice to melt into the solution or it
will change your results and the accuracy of the answer will go out the
window."
Because equilibrium is a scientific concept of such stature, why not let the students discover it for themselves if at all possible? In the discourse, the teacher stresses the sanctity of the answer several times, even suggesting a value of .974 g/ml. It is highly probable that most of the students will manipulate their data until the lie .974 g/ml appears on their papers. After all, the handwriting is on the wall. The bubbles that were in their ice cubes, and which really gave them a value of .914, will be ignored, as will the other variables that should have affected their results. The accuracy of their measurement of mass and volume of the solution may also be ignored if they interfere with getting the “right” answer.

In short, all the science involved in the investigation will have been sacrificed for adherence to the recipe. No one will have realized that more science went into writing the recipe than in following it.

This point of view might rightly be termed idealistic and dismissed with the comment, “that approach looks good on paper, but it’s impossible in a real classroom.” After all, the critics might add, junior high students are too immature to perform without rigorous guidance. And more certainly, they must be guided through the material to be covered.

There is little that can be said to a teacher whose attitude demands rigid adherence to the rules. The very foundations of such an attitude are rooted in two disputed notions. The first notion conceives of science as a veritable mountain of information over which novices must be guided by rigorous routes. The second conceives of scientific inquiry as a rigid methodological pattern of behavior. The precision of performance and adherence to “the routine” would be the criteria for evaluation under these concepts.

These notions project an image of science and inquiry that modern science curricula are attempting to erase. By modern educational standards, science must be presented as both inquiry and the knowledge gained by inquiry. The knowledge is never an end in itself, but a stepping stone to further inquiry.

How can a teacher participate in the investigation described earlier and sponsor inquiry in a more effective manner?

“What do you people see here on the table?”

“Two beakers of water.” The class members at their places view these beakers at the teacher’s demonstration table.

“What would happen if I put ice cubes in the beakers?”

“They would float.”

The teacher then places an ice cube in each beaker. In one beaker it floats, and in the other it sinks. The excitement generated by this “anti-intuitive” event is at once apparent by the excited murmur throughout the room.

“What’s wrong?” the teacher asks.

“One of those beakers contains some pretty silly water.”

“One ice cube is heavier than the other.”

“The cube that sank is not ice.”

The responses of all the students are directly related to the nature of the materials that are viewed. They are mildly frustrated by being unable to touch and handle the materials. This kind of reaction is generally true of student response to demonstrations of any kind.

“What can I do that will allow you to check some of your ideas?”

The teacher asks the question only after he is sure that the students have exhausted a good supply of possible explanations.
"Switch the cubes," one student challenges to a chorus of approval from his peers.

The teacher switches the cubes and the results are the same. The cube sinks in the same liquid in which it had sunk previously and floats in the same liquid in which it had floated before.

"The ice cubes are the same," a student offered, "so the liquids have to be different."

"I told you it was silly water," said the student who originally proposed this notion.

"Well, we proved it couldn't be the cubes," said others.

"Since you people have worked with calculating the densities of different materials, can we make some kind of a statement about the densities of these things we are viewing?"

After a bit of further discussion, the students decide that they can rank the density order of liquids on the basis of ice. The liquid in which the ice floats is denser than ice, and the liquid in which it sank is less dense than ice. The teacher writes these relationships on the board.

"Okay, here's your assignment: Using these liquids, which are, by the way, water and rubbing alcohol, you will measure the density of an ice cube. You will need scales, beakers and the liquids. Go to it."

From this point on, the teacher's role is to act as director of inquiry who turns student questions back on the results of the demonstration, their knowledge of the technique of measuring density, and their own ideas as to how the problem might be solved. Several groups decide on different ways of solving the problem; they are concerned at first about the differences in their approach. The teacher tells them that they should try what they proposed and evaluate the results. There is not, he assures them, an only way to reach the solution.

Throughout these multiple approaches the students "discover" the variables that might affect their results, such as the melting of ice in the alcohol-water solution mentioned by our first teacher. They also become aware of the change in volume of the ice while the mass is being measured on the scales. The materials themselves guarantee that these variables will become apparent.

What fundamentally was the difference in the two approaches? In both, the students were doing something. In both, they were manipulating materials. Both would be categorized by an outside observer as a laboratory approach to science. So again, let us ask what the difference in approach is.

In the first classroom, the students performed as the teacher told them to. In the second, they performed as they thought they should perform. In the first, science was being done by recipe; in the second, it was being done by inquiry. If the students gained confidence in anything in the first classroom, it was in the safety of following the teacher's instructions. In the second, it was likely that they gained confidence in using their own minds in the process of inquiry.

Perhaps the most discerning summary of discovery-type inquiry was stated by Bruner (1963). Bruner describes the advantages of discovery learning under four headings: (1) the increase in intellectual potency, (2) the shift from extrinsic to intrinsic rewards, (3) the learning of the heuristics of discovering, and (4) the aid of conserving memory.

Increased Intellectual Potency. Discovery learning increases intellectual potency by allowing students to recognize fundamental order and rela-
tionships through their own framework of perception and experience. Rather than receiving the order through the perception of the teacher, who in turn probably received it through the perception of scientists the student perceives real order because it happened during his inquiry. The relationships perceived by direct inquiry will be much more relevant than any recipe-type order handed down in terms of content or process.

**Shift from Extrinsic to Intrinsic Rewards.** Quoting Bruner’s introduction to this section, we find the essence of this advantage of discovery learning:

"Much of the problem in leading a child to effective cognitive activity is to free him from the immediate control of environmental rewards and punishments" (p. 87).

In the first classroom the students were operating in an environment in which their observance of the teacher’s rules provided the reward. In the second, the extent to which they used their minds was much more closely related to the reward pattern. In the first, the environment defined their course of action. In the second, their course of action defined their environment.

**The Heuristics of Discovery.** It is only through the process of making discoveries that a student will be able to learn how to make discoveries. If, through discovery, a student defines his particular style of inquiry, then it is probable that the style will become part of this thought process in the face of further inquiry.

**Conservation of Memory.** The body of information composed of facts that are “stored” in our memories is often considered to be the knowledge we possess. This view has retarded progress in science education more than most other notions. We are all alert to those things which we “memorized” dozens of times and promptly forgot. Certain facts have not been forgotten, and this is most often related to the use of these facts. In order to use information, it must be “retrieved from storage,” to use Bruner’s terminology. The retrieval process is enhanced by discovery-type inquiry and thus memory, as such, is similarly enhanced.

If as seems likely, these notions have validity and are the results of discovery-type inquiry, then what can be our role as teachers of science? It appears that to teach science we must retain the intellectual honesty of science in our teaching. If science is inquiry and its knowledge is the product of inquiry, then we must allow the students to inquire.

It is difficult to relinquish the role of alerting the students to the elegant logic of the teacher’s mind. But we must, for what we really want is for the students to become confident in the use of their own minds. We want their minds to become facile enough to enjoy the tentative and adhere to the restrictions imposed by the nature of scientific inquiry, rather than the restrictions imposed by the recipes offered by authoritative teaching. The excuse that "there isn’t enough time to teach this way" is not valid, for there is too little time not to teach this way.

**Reference Cited**

The Power of Purpose

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Introduction

A recently published study identified perceived problems in science education (Gallagher & Yager, 1980) and a second publication identified proposed solutions to those problems (Renner & Yager, 1980). One of the problems identified was the uncertainty about the purpose of science education. There is little doubt that a need exists in science education today to establish a purpose and to link purpose with a theory base for the actions of the profession. This article addresses the power held by persons who construct curricula, teach, and do research from a frame of reference that includes definite purposes for and theories about science education.

Science Education and Purpose

Maintaining exact differentiation among such ideas as goals, objectives, and purpose is a tiresome task that carries with it only small rewards. During the course of this article, therefore, the term “purpose” shall be used as an umbrella to include all terms which identify why a particular research activity is undertaken, a particular course is taught, or schools exist.

In isolating why and how purpose has power in science education, we must first establish the overall purpose of the discipline, because only then can we know if any particular educational purpose has relevance. The position of this article is that science education as a discipline has purposes which are well defined at its lower educational limit and undefined at its upper educational limit. These purposes are (1) to improve the existing procedures for teaching science, and (2) to establish new and verified procedures for teaching science. Science educators generally would agree with these purpose statements when considering the lower educational limit of our profession, that is, kindergarten through, possibly, grade 13. However, there would probably be disagreements as to where the upper educational limit of those purposes exist.

The Discipline of Science

The purpose of science education, therefore, is to be concerned with the education in science of the students who populate the schools. The power inherent in that purpose is a responsibility—the responsibility to educate those students in the true nature of the discipline itself. Regardless of how sophisticated the procedures and materials are for teaching science, if we are not teaching the true nature of the discipline, we are neither teaching science nor fulfilling the purposes for science education just stated. In order
to facilitate our communication, therefore, a need exists to clearly identify what the
discipline of science is.

Richard Feynman (1966), speaking to the National Science Teachers Association
in 1966 explained that he learned a great deal of science by accompanying his father on
walks in the woods. Some of his friends also took walks in the woods with their fathers.
One day he and a friend were playing in a field and his friend asked: “See that bird
standing on the wheat there? What’s the name of it?” Feynman replied, “I haven’t got
the slightest idea.” The friend said, “It’s a brown-throated thrush. Your father doesn’t
teach you much about science.” Feynman explained his reaction to this friend’s evaluation
of the senior Feynman’s teaching like this:

I smiled to myself, because my father had already taught me that that doesn’t tell anything about
the bird. He taught me, “See that bird? It’s a brown-throated thrush, but in Germany, it’s called
a Hazenflügel, and in Chinese they call it Chung Ling—and if you know all those names for it,
you still know nothing about the bird. You only know something about people; what they call the
bird.” (Feynman, 1966, p. 8)

In other words, science to Feynman was the finding out something about the bird.

Related to this idea is a quote by Henri Poincaré: “Science is built up with facts, as
a house is with stones, but a collection of facts is no more a science than a heap of stones
is a house” (Kelly, 1941, p. 240). That quotation reveals Poincaré’s view that physics
is more than such factors as Maxwell’s equations and the other language elements of that
discipline. Feynman’s finding out about the bird and Poincaré’s need for a process to make
a collection of facts a science seem to have the same purpose, that is, emphasizing that
science is the process of extracting meaning from the environment.

A succinct statement which explains science and gives meaning to the beliefs of
Feynman and Poincaré was made by University of Oklahoma science historian, Duane
Roller. Roller states (1970, p. 23): “Science is the quest for knowledge, not the knowl­
dge.” When one remembers that the complete name of the discipline is “natural
science”—or the science of nature—then the content into which quests are to be con­
ducted is easily identifiable.

From this theory-base, therefore, science is a discipline which investigates the natural
world and science education is a discipline devoted to discovering how to lead students
to learn to investigate the natural world. The power of establishing the purposes of science
education has led to the conceptualization of the nature of the discipline of science.
Therefore, whenever materials and instructional procedures are designed to teach science
(or research is done with them), the content selected must allow the questing nature of the
discipline to be evident and obvious. Making sure that the facts, principles, and
generalizations are clearly spelled out is not adequate. In fact, spelling out the principles
and generalizations may be deleterious because students must experience the search in
isolating the relevant information needed to invent the principles and generalizations.
Furthermore, evaluation must not only concern itself with ascertaining if students know
the information—as most standardized and teacher-made tests do—students must be
evaluated upon how they would find something else. Since the purpose of science is to
teach the quest for knowledge, that purpose is indeed powerful in determining what types
of experiences schools should provide their students.
Science and the Learner

The only justifiable purpose of teaching is learning. But often courses in teaching methods and procedures are neither linked to nor dependent upon courses which teach models of how human learning occurs. Students are arriving in classes from which they are to learn how to teach science with little or no understanding of models of how learning takes place. That understanding is essential before students can be taught how to teach science or anything else. Student's experiences in professional education courses should begin with a rich experience in a course entitled "Human Learning." That course—and this is most important—should be taught using the model the students are expected to learn. Giving a lecture on inquiry, for example, is a contradiction.

For a particular learning model to be useful in teaching a discipline, that model must be compatible with the discipline being taught. After extensive watching and participating in the role of teacher, my conclusion is that there are two dominant theories of how learning occurs. Each of those theories has as one purpose leading students to be able to master content, but one of the theories has a second purpose. The first theory, which may be called Theory A, leads students to master the content just as a teacher gives it to them. That mastery is then usually demonstrated by performance on a test of some kind. The second theory, which may be called Theory B, leads students to develop understandings of content that are their own, not teacher's.

Hopefully, Theory B also leads to an adjustment of understandings held about an entire concept and/or area of knowledge. Each of these theories goes about accomplishing its purposes differently and it is in those differences that the power of the purpose of each theory lies. That power allows education to match learning theory with the nature of the discipline to be taught or the particular task to be accomplished.

Theory A uses a specific procedure in accomplishing the purpose of a mastery of content. This learning theory makes the basic, fundamental assumption that the knowledge we possess is directly dependent upon what we have passed on to us by those who already know. The primary purpose of courses in science using Theory A is to inform the students not only of the basic principles, facts, and generalizations of a particular discipline but also of the latest developments within a particular field.

Because the purpose of Learning Theory A is to inform, its power lies in teaching procedures designed to further that purpose. In general, the teaching procedure used can be described as inform, verify, and practice. The information is usually delivered to the learners orally (that is, by lecture), through some medium such as television or motion pictures and/or by the printed page. In all of these forms the assumption is made that the language used in informing has meaning for the learners. There need not be, according to this teaching procedure, any prior experience to make the language meaningful other than a careful definition of terms. That is why textbooks which do the informing carry carefully prepared vocabulary lists. Regardless of how the information is passed, the first phase of a teaching procedure stemming from Learning Theory A is to inform the learner of what is to be known. Reading has a prominent position in this teaching procedure.

The second phase in the teaching procedure under Theory A is verification. The learners must be able to verify that what has been passed on to them is accurate and authentic. In science there exists for students perhaps the best procedure found in any discipline.
for testing the authenticity of what they have been told. Apparatus and materials are available to do the needed testing. Thus, when students are told that a particular chemical reaction is exothermic, they can carry out the reaction and verify it for themselves. Such verifications are sometimes called experiments. However, they are not true experiments because in such an activity the outcome is known before the activity is carried out. Such activities are simply verification and are extremely important to the teaching procedure based upon Learning Theory A. The verification phase is the best opportunity the students have to attach meaning to the language of the concept which they have been given during the information-giving phase.

The practice phase of the teaching procedure under Theory A is carried out in a multitude of ways. The questions and problems in the textbook are certainly the most widely used practice vehicles and quizzes and extra readings are also frequently used. Further experience with the apparatus and materials of the discipline is usually absent in the practice phase and the practice is usually conducted on the verbal level. The mastery-of-content purpose of Learning Theory A, therefore, results in a three phase teaching procedure. The fact that probably in excess of 90 percent of the teaching-materials market adheres to what has just been described should begin to suggest the power of the purpose of Learning Theory A.

Learning Theory B also has the purpose of the mastery of content, but it has an additional overt purpose. That purpose is to lead the students to adjust the understandings held about a field and/or concept. Learning Theory B starts with a different assumption about learning than does Learning Theory A. According to Learning Theory B, each of us develops the understandings we hold about a particular phenomenon. While biologically ontogeny recapitulates phytogeny, intellectually each of us at least partially goes through the knowledge recapitulation process in developing our understandings. Learning Theory A operates upon the assumption that what is to be learned must be given to the learner and the language comes first. Learning Theory B is based upon the assumption that learners can, with proper experiences, create for themselves what is to be learned. At that point the language can be provided for the learners and it will have meaning for them because they have experienced the concept. Experience is the key to the implementation of Learning Theory B. Learners are provided experience with the phenomenon to be understood and its meaning is absorbed from that experience. Just as organisms assimilate nutrition biologically, the human organism assimilates ideas intellectually. At this point the learners are asked to accept or accommodate themselves to the language that society has given to the ideas they have just assimilated. Thus when students first experience that there is an area around a magnet in which the magnet normally attracts certain materials, the proper label for that area is magnetic field and the students need to accommodate to it. But each new idea we absorb must, according to Learning Theory B, be integrated or organized with all other ideas we hold about the particular phenomenon being investigated and the natural world in general. That organization process requires further experience with the idea being considered. In summary, Learning Theory B provides a learning model of (1) experience with the phenomenon through the materials of the discipline, (2) the introduction of the language of the phenomenon to label the new idea, and (3) organization of the new idea with existing knowledge to expand that knowledge and the newly acquired idea.

The purpose of Learning Theory B is to assist learners in creating their own knowledge
of and about a particular phenomenon and therein lies its power. A teaching procedure can be drawn from the Learning Theory B model. The learner must first explore the materials of the discipline under the guidance of the teacher. That guidance, however, should not inform the learners of what is to be found before the exploration is made. In other words, in the teaching procedure which evolves from Learning Theory B the meaning of the phenomenon being investigated comes from exploration of the materials of the discipline and not from the printed page or from the teacher as in Learning Theory A. In the second phase of the teaching procedure resulting from Learning Theory B, the teacher intervenes and assists the students in interpreting what they have found in their explorations. In addition, the teacher now provides the language and symbols for the newly acquired concept.

The third phase of the teaching model resulting from Learning Theory B provides the students further experiences with the concept to expand its meaning. That is done in a multitude of ways and normally requires further experience with the materials of the particular discipline being studied. Those experiences—as do the experiences in the first phase—approach being experiments because the outcomes to be expected from them are not known even though the students know, in the third phase, the concept that controls the investigation. But there are other experiences which will assist in expanding the idea just acquired and among them are questions to answer, problems to solve and most assuredly reading about the concept. However, in the teaching model resulting from the purpose of Learning Theory B, reading occupies a much different place than in the teaching model based upon Learning Theory A. Furthermore, the reading is done for an entirely different reason. Reading in the Learning Theory B teaching model is assigned not to lead the students to attempt to learn an idea (as it is in the teaching model from Learning Theory A), but to help expand and stabilize an idea already understood. That orientation requires a different type of reading materials than is found in the usual textbooks now provided in the schools. Consider the topic of electric circuits. Textbooks carefully explain the different kinds of circuits as well as their similarities and differences. When following the teaching model inherent in Learning Theory B, such basic principles are learned through phases 1 and 2. Reading is encountered in phase 3. For the topic of electrical circuits we have used a reading which explains how circuits in a home are in parallel with transformers, transformers are in parallel with power substations, and substations are in parallel with the power station. Thus, in the reading done in this third phase, the students continue to do what they have done throughout the entire learning process, that is, create their own knowledge through their own activity.

Earlier, science was identified as the quest for knowledge, not the knowledge. Considering that identity for science gives us the power to select a learning theory that is compatible with the discipline. Learning Theory A is really a guided tour into a concept where the guide—the teacher—points out all the sights to observe and makes every effort not to permit the students to take any detours that are not productive in seeing the concept to be learned. In short, Learning Theory A does not advocate searching for an idea because there is no need to wonder about what the idea is. The teacher has already provided the idea and the students are verifying that it is accurate. To be as basic as possible, Learning Theory A represents a training model and there are places in education in general and science education in particular where training is not only desirable but necessary. Learning Theory A is not, however, compatible with science as the quest for knowledge.
Learning Theory B can support learning through search if the stringent requirements for use of the teaching procedure based upon it, which were outlined earlier, are observed by the teacher. Those requirements include allowing assimilation of the idea to be learned from the materials of the discipline, not providing the students the idea orally or by the printed page when assimilation is occurring, basing conclusions about the idea being investigated upon the data collected, and providing the language of the idea only after the data from the investigation have been analyzed.

When fully comprehending the purpose of Learning Theory B and the purpose of science, the conclusion may be drawn that unless science teaching is being carried out using the teaching procedure based upon Learning Theory B, science is not being taught. Information about science, training in using the products of science, and perhaps some history of science may be taught, but science as the discipline seems to be structured is not being taught. An examination of the science teaching materials available today demonstrates that the majority of them are much more concerned with training in science than they are with education in science.

Science and the Schools

As science teachers, we must keep in mind that our discipline must be supportive of the purposes for which the United States citizens have established and maintain the schools. To be able to justify that science belongs in the schools, therefore, that discipline and manner in which it is taught must be shown to be supportive of the purposes of education.

In 1961, a statement of educational purpose was made (Educational Policies Commission, 1961) that was succinct and which provided directions for implementation. That statement says, "The purpose which runs through and strengthens all other educational purposes—the common thread of education—is the development of the ability to think" (p. 12). The purpose statement goes on and defines "the essence of the ability to think" (p. 5) as the rational powers of the free mind. Those rational powers are said to be recalling, imagining, classifying, generalizing, comparing, evaluating, analyzing, synthesizing, deducing, and inferring. According to this statement of educational purpose, the development of the rational powers is the central purpose of education and the school must be oriented to that central purpose "if it is to accomplish either its traditional tasks or those newly accentuated by recent changes in the world" (p. 12). Furthermore, the statement makes clear that many agencies contribute to educational purpose, but this central purpose—the development of the rational powers—"will not be generally attained unless the school focuses on it" (p. 12).

Earlier, the statement was made that in order to justify teaching science in the schools, teaching has to be supportive of the purpose of education. Accept, at least momentarily, that the central purpose of education is the development of rational powers. In order, therefore, to use that purpose to justify science teaching, a direct link must be found between the teaching and learning of science and rational power development.

Science has been identified as a quest for knowledge. The dictionary gives "investigation" and "search" as synonyms for quest. A true investigation certainly involves imagining, comparing, classifying, analyzing, evaluating, synthesizing, deducing, inferring, and generalizing. There is, therefore, a great compatibility between the 1961 statement
of educational purpose and the discipline of science. In order for that compatibility to manifest itself, however, the persons teaching must believe that students develop their rational powers by using them and must permit the development to occur through student involvement with the materials of the discipline. As the rational powers are used with the materials of a particular scientific phenomenon, students develop their own knowledge of that phenomenon. Student's developing their own knowledge was identified earlier as one of the purposes of Learning Theory B. The 1961 statement of educational purpose, therefore, has the enormous power to direct not only how the content of the discipline must be treated and how teaching must take place, but also demands that schools subscribe to a particular learning theory to achieve that particular purpose.

**Purpose and Research**

How does the power of purpose influence the research we have done or that can be done? Schneider and Renner (1980) reported the first efforts (at the secondary school level) of testing the value of letting the power of the purpose of a learning theory dictate what should go on in a classroom. When teaching procedures were based upon the two learning theories described here, the results showed that students experiencing the teaching procedures based upon Learning Theory B made superior gains in knowledge of content and in intellectual development, retained content better, and showed a much different pattern in IQ shift than did the other groups. A second study (Purser & Renner, in press) has now been completed at the secondary level and it confirms what the first study hypothesized.

Perhaps the most satisfying evaluation of our power-of-purpose hypothesis was made by the students at Senior High School in Norman, Oklahoma. Six years ago physics and chemistry were converted to the teaching procedure based upon Learning Theory B. That meant writing all student investigations, readings, and teachers' guides. Norman Senior High School enrolls approximately 1400 students and when the process was begun, two sections of physics and seven sections of chemistry were taught; those enrollments had been stable for some time. During the current academic year five sections of physics and 12 sections of chemistry are being taught. Those data suggest that students are responding satisfactorily to these instructional procedures after experiencing them over several years.

There are several areas that deserve to be carefully considered in planning further research in this area. First of all, the hypothesis has been that during the time that students explore the materials necessary to lead them to the concept they absorb the essence of that concept. True, their data are perhaps disorganized and students need assistance in consolidating what their investigation has told them, but, we hypothesize, the essence of the concept has been absorbed. That, however, is an hypothesis. Research needs to be done which will determine empirically what really is absorbed—or assimilated—from that exploration experience.

Another hypothesis is that the reading done during an investigation is most profitably done during that phase of the process when the students are expanding a newly acquired idea to other related areas. In order to test that hypothesis, it may be fruitful to investigate what happens to that idea expansion if reading is dropped or if different styles of reading are used.
The teaching procedure from Learning Theory B has encouraged students to begin immediately collecting data about the concept to be learned. Our reason is that students will absorb the idea best when they are given the apparatus and materials and are guided to collect data which are meaningful to them. However, they often have no idea what concept they are working toward. That procedure has produced excellent data documenting students’ abilities to invent desired concepts, and high levels of student motivation. Nevertheless, another research question to be addressed is whether even better results may be produced by beginning each investigation with a few questions regarding what will be experienced during the investigation. This may assist students in better organizing their observations.

Our preliminary data have led us to believe that a teaching procedure based upon Learning Theory B produces student learning which is superior to that student learning which is the result of using a teaching procedure based upon Learning Theory A. In other words, we can explain how the process works and what happens when the process is used. We cannot explain, however, why the process works and we believe that is essential. Answering that “why” will occupy our attention in the immediate future.

References


Feynman, R. P. What is science? Unpublished address delivered to the Fourteenth Annual Convention of the National Science Teachers Association, New York City, April 1-5, 1966.


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Many research studies in recent years have shown that children have beliefs about how things happen and expectations which enable them to predict future events (Driver & Easley, 1978). Evidence is accumulating from a wide variety of sources (Clement, 1977; Nussbaum & Novak, 1976; Leboutet-Barrell, 1976; Stead & Osborne, 1980) to show that children, on the basis of their everyday experiences of the world, hold these beliefs and expectations very strongly. Moreover, children have clear meanings for words which are used both in everyday language and also in formal science (Gilbert & Osborne, 1980; Osborne & Gilbert, 1980a). Such views of the world, and meanings for words, held by children are not simply isolated ideas (Champagne, Klopfer, & Anderson, 1979) but rather they are part of conceptual structures, which provide a sensible and coherent understanding of the world from the child's point of view. These structures may be termed children's science.

In the development of science curricula the existence of children's science has usually either been ignored or inadequately considered (Fensham, 1980). The two different assumptions on which science teaching has been based, and one on which it could be based, can be readily identified.

The "Blank-Minded" or "Tabula Rasa" Assumption

This approach, which by implication underlies many modern curricula (Fensham, 1980), assumes that the learner has no knowledge of a topic before being formally taught it. The assumption is that the learner's 'blank mind' can be 'filled' with teacher's science ($S_T$). This is diagrammatically shown in Figure 1.

The "Teacher Dominance" Assumption

The assumption here is that, although learners may have some conceptual view of a new science topic before being taught it, this understanding has little significance for learning and can be directly and easily replaced. Thus, even if children's science views ($S_{Ch}$) exist, they are not strongly held in the face of science teaching. This is diagrammatically shown in Figure 2.
The "Student Dominance" Assumption

This assumption recognizes children's science views as sufficiently strong that they will persist and interact with science teaching. The interaction is diagrammatically shown in Figure 3.

There is growing evidence that the learned amalgam $S_{CH} \setminus S_{T}$ of children's science and teachers' science can co-exist in varying proportions. 'successful' learners use teachers' science when required in tests and examinations, but still retain children's science in dealing with many every day situations.

If science curricula and teaching are to be based on the third assumption, rather than on either of the first two, it will be necessary for us to learn much more about children's science: to know how to explore it, to know about its nature, and to consider the various ways in which children's science may, or may not, be modified by learning experiences.

The Exploration of Children's Science

A variety of methods have recently been developed for use in investigating children's science. White (1979) has analyzed the similarities and differences of some of these methods. Most involve in-depth interviews with children (see, for example; Pines et al., 1978; Brumby, 1979; Tiberghien, 1980). This study used two such methods which we have called the Interview-about-Instances approach and the Interview-about-Events approach. The Interview-about-Instances approach (Osborne & Gilbert, 1980b; Gilbert, Watts, & Osborne, 1981) explores children's meanings for words by means of taped individual interviews. For a particular word, e.g., work, force, living, up to 20 familiar situations, depicted by line drawings on cards, are presented to the child. Some of the situations present an instance of the scientific concept embodied in the word and some do not. Children are asked, for each situation in turn, whether they consider it an instance
Patterns in Children's Science

On the basis of the findings from research which has been carried out using the two investigatory techniques, referenced above, at least five different patterns of children's science can be described (Osborne & Gilbert, 1980a). These patterns will be illustrated from the sequence of discussions on physical change (Appendix A). These illustrations arise from interviews with 43 New Zealand school children spread evenly over the 10-17 year age range. (The 10-15 year olds were studying general science, the 16-17 year olds were studying physical science). The pupils were selected by their teachers as being of average attainment in science (Cosgrove & Osborne, 1981). Each quote given will be followed by the step in the discussion sequence to which it applied, and the age of the interviewee.

Everyday Language

Many words in science are used in an alternative way in everyday language. Often a student can listen to, or read a statement in science and make sense of it by using the everyday interpretation of the word. The interpretation is not the one intended by the teacher or textbook writer. For example:

The air is made up of small particles (is anything else made up of small particles?) glass . . . they are made out of small particles of sand which have been turned hot . . . turned clear and then sort of take them out . . . and put them between two pieces of metal when they have been hardened and when they take it off they find that they have a clear surface called glass.

(Step 7; age 11)

The word 'particle' is commonly used in science classes to mean atom, molecule or ion. In everyday use it refers to a small, but visible, piece of solid substance. The everyday
The ‘particle’ size in sand is retained in glass. A parallel has been drawn between glass and air based on appearance.

**Self-Centered and Human-Centered Viewpoint**

Many very young children have very egocentric views of the world. By age nine or ten most children no longer adopt this strictly egocentric view but they still interpret and consider things in terms of human experiences and commonly held values. For example:

Ice is just frozen water (what's the difference between frozen water and ordinary water?) You can't drink it very good.

(Step 7; age 10)

Properties as a drink govern the evaluation made by this child of ice and water. A second example is:

I think I said it was oxygen in the bubbles... but if you put your face over (the steam) and breathe in... it doesn't seem you can breathe too well... so I don't think there is much oxygen... it be more hydrogen.

(Step 2; age 17)

Steam has been evaluated here by its capacity to support breathing, oxygen being known to be effective. In both cases, simple human concerns have governed the interpretation made of phenomena.

This different focus on how and why things behave as they do can result in children viewing situations in quite a different way to the more analytical, and impersonal, view of science. Answers given by children in science classrooms are sometimes apparently ‘off the track’ hoped for by the teacher because of this difference in perspective of science teacher and student. The anthropocentric view often takes the form of some widely held beliefs—heavier objects do fall faster, things do get lighter when they are burnt, animals are things you take to the vet—and these human-centered views are reinforced by everyday language to some extent.

**Nonobservables Do Not Exist**

To a number of children, and some learners despite formal teaching, a physical quantity is not present in a given situation unless the effects of that quantity or the quantity itself is observable. Some examples are: “If you cannot feel an electric current it is not present” (Osborne & Gilbert, 1979); “if the effects of the presence of light, for example, flickering on a wall, are not observable the light is not present” (Stead & Osborne, 1980).

Oh, it has evaporated. (what does that mean?). Well it has not gone into the steam form because it doesn't look as if it has gone up in the water state... it must have split up because you couldn't sort of see steam or anything rising. (what do you mean split up?) The hydrogen and the oxygen molecules.

(Step 5; age 16)

The student has presumed that, on all occasions, the visibility of water is maintained on the transition from the liquid state to the vapor state. When this visibility is not maintained, an explanation is presented in terms of elements known to be invisible and con-
Endowing Objects With the Characteristics of Humans and Animals

Children often endow objects with a feeling, a will, or a purpose. This is partly related to children's view of living things being much broader than the biologists' viewpoint (Stead, 1980), but it is also reinforced by the use of metaphor in both common language and even in the teaching of science. Teachers' make statements like "the electric current chooses the path of least resistance," "the positive ion looks out for a negative ion." However, it would appear that, not surprisingly, children do not always consider such statements to be metaphoric. For example:

It's cold in there and the chill's coming to the outside... the coldness just... um... oh, it's cold in there and it's just trying to get out... and it's somehow got out.

(Step 6; age 13)

'Cold' is thought to move towards the outside of the jar under the effect of an implied will.

Endowing Objects With a Certain Amount of a Physical Quantity

It is not uncommon for children to endow an object with a certain amount of a physical quantity and for this quantity (e.g., force, momentum, energy) to be given an unwarranted physical reality. For some physical quantities (e.g., force, coldness, etc.) this tendency of children leads to considerable difficulties in learning, particularly in appreciating the abstract nature of these quantities and their relationship to other quantities. For example:

The heat makes the air bubble come out of the element.

(Step 2; age 12)

The implication here is that heat is a physical entity. It is thought to physically force the air bubble to come out of the heating element in the kettle. Both the nature of heat and the source of air bubbles have been unconventionally understood. A second example is:

The coldness of the ice could have brought the water... but that's a bit funny.

(Step 7; age 12)

Here 'coldness' is thought to have a physical identity.

Teachers' Views of Science

Just as by children's science we mean those views of the natural world and the meanings for scientific words held by children before formal science teaching, so scientists' science (S_s) means the consensual scientific view of the world and meaning for words. Ideally the view of science presented to children by teachers, or directly through curriculum material, will closely relate to scientist's science. However this may not always be so. Teachers undoubtedly have a wide variety of viewpoints, S_{T}, ranging from almost children's science to scientists' science, but often different from both these in distin-
Figure 4. Strongly held teachers' views of science may persist or interact with the views in science curricula.

guishing less clearly between the objects of science and the concepts that relate to them (Fensham, 1979). This teacher's view of science interacts with the science curriculum and its materials as he/she prepares for teaching. This may or may not modify this view in the direction of scientists' science as shown in Figure 4. The resultant is the viewpoint presented by the teacher to the pupils. It is the interaction of children's science and their teacher's science that will have profound implications for the outcomes of teaching.

The Consequences of Children's Science for Teaching

A further consideration of the data collected using the Interview-about-Instances and Interview-about-Events techniques suggests that for children who have been taught science there are at least five patterns of outcomes from these interactions. The five outcome patterns will again be illustrated from protocols using the same Interview-about-Events sequence in Appendix A (Cosgrove and Osborne, 1981).

The Undisturbed Children's Science Outcome

Some children have an undisturbed viewpoint despite formal teaching. Reasonably common among this pattern of learners are those who now incorporate some language of science to describe the viewpoint, but whose viewpoint is essentially unaltered. The following is an example of undisturbed children's science despite teaching:

(Where have you used the word particle?) In the science lab. (Are there particles in the jar of ice water?) Yes, I suppose so. (Which are the particles to you?) The ice blocks. (Has the water got anything to do with particles?) Oh, they melted into the water.

(Step 7; age 13)

The children's science view was that a visible piece of ice is a particle. The language of science, using 'particle' to mean molecule of water, has had little impact on this view. This type of interaction is presented in Figure 5. Similarly:

The water has melted it . . . it has become part of the water . . . but there are parts of it left that you can't see . . . the taste of sugar.

(Step 4; age 11)

The children's science view, that taste is separate from material substance, has not been modified by contact with the phenomenon of dissolving.

Figure 5. A prelearning or children's view of science can persist unchanged by science teaching.
Figure 6. Science teaching can result in a second view being acquired for use in school but the original children's view persists elsewhere.

The Two Perspectives Outcome

It is possible for the student to basically reject the teacher's science as something that can be accepted in terms of how to view the world, but to consider it as something that must be learned, e.g., for examination purposes. The student, therefore, has two views, but the learned science viewpoint is not one that has been adopted for use outside the formal learning situation. For example:

It is dry... the water has evaporated... the water has gone (where to?) well... the teachers tell me that it has gone you know... that it makes up the clouds, you know in the sky and that sort of thing. (I see, it has gone up to the sky?) no, I don't think so... (how does it get from here to the clouds?) I don't know (magic?) no... it's sort of a gas there... not magic (where did you learn about clouds and evaporation?) in about fourth grade (9-10 years)... around there somewhere (oh, well they wouldn't have talked about it in much detail at that sort of level would they?) no (and all that you can sort of remember is that when water evaporates it goes into the clouds?) yet (but you don't have a picture of how that goes on?) no, except for little arrows that point up (I see, what were those arrows do you think?) can't remember (so you have got this sort of picture of water, arrows and clouds?) yes, and it sort of comes down as rain.

(Step 3: age 14)

This student has the view that water disappears from a place into the air. However, the standard explanation, concerning evaporation and using diagrams, has proved less than believable to the student. Nevertheless, it has been learned but is not used willingly to explain phenomena. This type of interaction is presented in Figure 6.

The Reinforced Outcome

The dominance of the students' prior understandings and meanings for words can, as suggested earlier, often lead to quite unintended uses of what is being taught. One common example of the outcomes of this is the confusion between physical quantities. Quantities defined in science in a particular way can be misinterpreted to mean something quite different. In Figure 7, the children's science viewpoint is being maintained following

Figure 7. The original children's view is strengthened by science teaching which now is misapplied to support it.
teaching but now scientific concepts are put forward to explain or underpin a particular viewpoint. For example, the statement by a younger student:

It would come through glass

(becomes, for an older student)

Through the glass... like diffusion through air and that... well it hasn't got there any other way (a lot of people I have talked to have been worried about this water... it troubles them) yes, because they haven't studied the things like we have studied (what have you studied which helps?) things that pass through air, and concentrations, and how things diffuse.

(The notion of diffusion, learnt in connection with movement through air and water, has been applied to explain movement through glass. The children's science idea of 'movement through air' has been transformed into 'diffusion through glass'.)

The Mixed Outcome

In many cases, scientific ideas are learned, understood, and appreciated by learners. However, the interrelationships of these ideas are manifold and at any one time only a limited amount can be learned. Often this results in students holding ideas that are not integrated and may be self-contradictory. In this outcome the learners' views are a mixture of amalgam of children's science views and teachers' views, Figure 8. For example:

I think it is the same atoms in the ice before and now they are unfrozen in the water (what else is in there besides the atoms? the stuff that freezes?) no... I don't know... yes... no... it's all atoms but the atoms are just frozen.

(The idea of the conservation of matter between physical phases has been learned. However, the microscopic change in structure is being interpreted as a general change in the properties of microscopic components, i.e., atoms (sic).)

The Unified Scientific Outcome

The aim of all science education is that a learner should obtain a coherent scientific perspective (S2) which he understands, appreciated, and can relate to the environment in which he lives and works. Students can be found who have this view in relation to specific words and viewpoints that we have investigated. In some of these cases, the learned
viewpoint is in fact more closely aligned to scientists' science than to the teacher's views of the science. This outcome is represented in Figure 9. A typical example of the coherent scientific perspective:

It is wet on the outside... 'cos the jar's cold... 'cos the ice is inside it and therefore the water molecules that are in the air moving around... although we can't see them... when they hit the cold jar... that makes them cold... and therefore they group together again in their groups of molecules and then they become water again because they've been cooled down.

(Step 6; age 15)

It is the outcome that all teachers would wish to arise from their interaction with students.

Conclusion

This paper suggests, by argument and example, that the view which children bring with them to science lessons are, to them, logical and coherent and that these views have a considerable influence on how and what children learn from their classroom experiences. Our conclusions from a variety of studies support the view of Wittrock (1977) that people tend to generated perceptions and meanings that are consistent with prior learning. Learning can be anticipated and understood in terms of what the learners bring to the learning situation, how they relate the stimuli to their memories, and what they generate from their previous experiences.

We have also attempted to suggest, by argument and example, that the aim of science teaching and learning can be viewed as the development of children's science. Traditionally, the goal of the development is scientists' science. This has proved to be an immense task that is often very incomplete even among so-called successful learners. As happens in many present science classes, we may have to be satisfied with largely undisturbed children's science as our outcome. A more modest and manageable goal in these cases would be to make these learners aware that there is another viewpoint, the scientists' viewpoint, which is useful to scientists and may have more general use also. Only by adapting our teaching to make these two views explicit is this new goal likely to be achieved. This approach may also facilitate the development process on its way. Such a development will only occur in a genuine and nonsuperficial way if the scientific perspective appears to students to be at least as logical, coherent, useful, and versatile way of viewing the world than their present viewpoint.

Whatever the goal, it would seem that teachers need to be aware of children's science and to encourage students to express their views. We all need, as teachers, to listen to, be interested in, understand and value the views that children bring with them to science lessons. It is only against that background of sensitivity and perception that we can decide what to do, and how to do it. This is a major challenge for science teaching.

Appendix

Interview-about-Events Outline Schedule for Physical Change

Step 1  The interviewee is presented with a screw-top jar containing ice and is invited to dry the jar thoroughly. The jar is then set aside.
Step 2 The interviewee is invited to observe the water coming up to, and boiling, in an electric kettle. Preliminary questions are 'What is happening?' and 'What are the bubbles made of?'

Step 3 The interviewee holds a saucer in the steam and is invited to comment on what is observed and why it has happened. After these questions, it is put, inverted, to one side.

Step 4 Some of the hot water (from step 2) is put in a cup. The interviewee puts some sugar in it and stirs the mixture. The preliminary question is again 'What is happening?'

Step 5 The inverted saucer (see Step 3) is now reconsidered. The dryness is discussed through 'What has happened to it?' and 'Why is that?'

Step 6 The jar (see Step 1) is now reconsidered. It now has water on the outside. The interviewee is asked 'Is that different to when you had it before?' and 'Can you tell me about that?'

Step 7 The lid of the jar (see Step 6) is removed, and some water and ice extracted on a spoon. The questions begin with 'What is happening here?'

Reference Notes


References


Accepted for publication 10 November 1981
APPENDIX 3

Investigating pupils' understanding of phenomena occurring in simple D.C. circuits:
Implications for teaching

1. Purpose

The purpose of this study is to investigate:

- how pupils of ages between 12 and 16 manipulate and observe materials used in simple electric circuits.
- Which models they use to interpret the phenomena observed.
- What their predictions are about phenomena in simple D.C. circuits.
- What relation could exist between these models and the way they manipulate materials or observe phenomena.
- To what extent "abilities" such as, 'creative-mindedness', 'team-work', 'self-confidence', 'observing', 'manipulating', 'communicating', 'predicting' and 'inferring' are developed in pupils at this age.

2. Materials

batteries: 1,5V and 4,5V
light bulbs: 3,5V and 0,2V
electric toy motors
bulb and battery holders.

3. Methodology used

Clinical observation through interviewes with 13-to-16 years old children during the performance of experiments with simple electric circuits was the methodology used in this study. The nature of the interaction between interviewer and interviewee allows a more detailed observation of behaviours and models.
used by pupils than statistical observations. It necessarily involves a smaller number of individuals. The behaviours and models observed may allow an elaboration of useful categories for a statistical treatment.

4. Design of an interview schedule

"Interview about experiments"

4.1. Introduction

During the interviews with children prior to and after being formally taught about "electric current" the language used will be descriptive and simple. It can easily replace traditional electrical terminology. For example, "a complete path" might mean the same as "a circuit" in some situations and will be easier for children to understand. "Making" and "breaking" a circuit are terms used to describe the completion and interruption of the circuit respectively. Certain common electrical and magnetic terms, such as "voltage", "power", and "magnetic field", will be deliberately omitted from the conversation. They are technical expressions with specific definitions that often conflict with common usage and are abstract being too far from daily experience to include here. Too often children think they understand something, whereas in reality they have only learned a formal name. Although terms such as "current" or "resistance" are also technical, their technical usage is very close to their everyday usage and so they will be included in the interview.

4.2 The set of experiments and questions proposed

1. First set of experiments

During the first set of experiments each pupil will be presented with:

1 - battery 1,5V
1 - 20 cm piece of plastic-covered wire
1 - light bulb
1 - stripper
paper, pencil and rubber.
With the purpose of evaluating pupils knowledge and understanding of some everyday materials the type of questions proposed will be:

- do you know what this is? (battery)
- what is it for?
- and this (light bulb)?
- can you describe the bulb?
- do you know how it works?

Another set of questions are designed to investigate pupils' understanding of the process of lighting a bulb, as well as investigating to what extent their 'abilities' of inquisitive and creative-mindedness, consistency, observing, manipulating, communicating, predicting and inferring are developed.

- Can you make the bulb light using just this piece of wire and one battery?
- How?
- What happened?
- In how many different ways can you make the bulb light?
- Can you make sketches of your various attempts, including those that do not work?

At this time another piece of plastic-covered wire will be given. The covering will have to be removed both ends. The removal of the covered ends enables the observation of how different pupils handle this situation. (They have a striper near by).

- Using another wire, what are your predictions about what will happen in some particular arrangements? For instance: what will happen if I put this other wire

![Diagram](image_url)
After each prediction the child will be asked to try to say what happened and why it happened. If the evidence is different from the prediction, the child will be asked for an explanation.

The children's models of current flow in a simple circuit can also be explored with this set of experiments.

More bulbs, bulb and lamp holders, a screw driver and more pieces of end bare plastic-covered wire will be provided.

Another set of questions is proposed.

- Suppose you would like to light four or five bulbs at the same time, what would you do?
- Why?
- Do you need a bulb holder?
- How does the bulb holder work?
- What would happen if you tried to light just one bulb with 5 batteries?
- Try it
- What happened?
- Why?

Then the children will be asked for predictions, when they are presented with sketches of some arrangements. For example:

- What will happen if you do this?
- Will the bulb light up?
- Why?
- Try it
And if you do this?
Will the bulb light up?
Why?
Try it
Can you make a "rule" for lighting the bulb?

2. Second set of experiments

During the following set of experiments the interview will be conducted with two or three children working together. More bulbs, bulb holders, batteries, pieces of wire and screw drivers will be available and the children will be asked to predict and to project experiments to test their predictions. For example:

What will happen to the brightness of bulbs in the following situations and why?

1. 

2. 

3.
In this last situation what will happen if a single wire is connected between A and B?

Why?

Try it

How do you explain this?

And if it is connected between A and C?

If we connect these five bulbs like that will the brightness of the bulbs be the same or will they be different? Why?

Try it

How can you explain that?

What will happen if we change the connection on the battery?

In the situation above what will happen if a single wire is connected between A and B?

And between A and C? Why?
Can you tell me how you could make a set of lights for your Christmas tree?

Why?

Suppose we change the piece of wire A in this situation for a rubber band

What will happen?

Why?

Try it

Can you design an instrument to check which materials, connected in the pathways, will allow the bulb to light?

Try it

We shall call your instrument a battery-and-bulb tester

Here is a closed box with six metal buttons on one side. We don’t know what is inside the box. Without opening it, could you find out what is inside? There must be some connections inside between the buttons and other things

How could you find out?

3. Third set of experiments

With this set of experiments both the consistency of the model of current flow held by each child can be tested as well as its implications for the understanding of the phenomena being observed.
Questions proposed are the following:

- What do you think would happen to the brightness of the bulb if we connect the motor between the two points A and B?

- Why?

- And what will happen if we connect it between C and D?

- Why?

- If we connect another motor between E and F

- What will happen to the brightness of the bulb?

- Why?

- And now if we put the second motor on the other side of the bulb what happens to its brightness?

- Why?

- Try it
In this situation what will happen to the brightness of the two bulbs if we connect one motor like this?

Why?

Try it (more batteries are needed)

And what happens to the brightness of the two bulbs if we put a second motor right here?

In another activity children are presented with a household bulb.

Can you describe this bulb?

Tell me what do you see inside the bulb?

And outside?

Compare it with these bulbs we have been working with. Can you tell me what they have in common?

Do you think it would be possible to light it with this battery?

Why?

Try it

What would we need to light it?

Can you tell me any application of this experiments that we have been doing to your day-to-day life?

Have you ever thought about the importance of electric devices in our everyday life?

Can you point out some situations in which that is evident?
5. Population

Twenty six children (15 girls and 11 boys), ages between 12 and 16, were interviewed. Thirteen have had already received formal teaching on electric current and the other thirteen had not.

Things were arranged in order that during the first part of the interview, the first set of experiments was done just by one child. During the second and subsequent set of experiments two children were interviewed together and their capacity for team-work were observed.

Through our conversation I could infer that some children, mainly boys, had already had contact with the kind of materials we were working with by playing with toys and electric kits.

6. Data relating to pupils' understanding of phenomena occurring in simple electric circuits

1 - To light one lamp (3,5V) with one battery (1,5V) and one wire.

\[ \text{number of pupils} \]

\[ \begin{array}{c}
\text{i - Considering the battery and the lamp as unipolars objects} \\
\text{9 had already had formal teaching on this subject.}
\end{array} \]

\[ \begin{array}{c}
\text{ii - Considering the battery as a bipolar object and the lamp as unipolar} \\
\text{3 had already had formal teaching on this subject.}
\end{array} \]
iii - Lightning the bulb without difficulty

4 had already had experience in manipulating these materials but hadn’t yet had formal teaching on this subject.

2 - To light one lamp (3.5V) with one battery (1.5V) and two wires.

**Observed models**

- Battery and lamp unipolar
- Battery bipolar
- Lamp unipolar
- Battery bipolar
- Lamp bipolar

**Extract of an interview**

(P stands for pupil and I for interviewer)

P - (makes in this way it doesn't work!)

I - why?

P - ... because ... well the battery has energy ... which goes through the wire to the lamp ... and it should catch that energy and it should light up

I - ... but it didn’t light up ... why should that be?

P - ... well ... perhaps it (the lamp) has to receive negative energy also ... because this one passing here ... (pointing the wire) is positive ... it comes from the positive pole ... I need another wire
I - (gives another wire)

P - makes ... I don't understand why it doesn't work ... energy goes ... through here (pointing as the arrows) ... it should light up ... ah! ... perhaps the battery hasn't enough energy I need another battery

I - (gives another battery and another wire)

P - makes ... I don't understand ... I don't know

Pupils' models for interpreting what is going on in a simple electric circuit

Model 1

"The energy ... or the current goes from the battery to the lamp ... this wire here (the hatched line) ... isn't really necessary"

(13 years old)

Model 1 - (unipolar). There is no current in the return wire; only one pole of the battery is seen as active. The return wire is necessary but passive.

Model 2

"There are two currents ... one coming from the negative pole and another coming from the positive pole ... they meet at the lamp and because of that it lights up"

(14 years old)

Model 2 - (opposite currents). The current goes to the lamp from the two poles of the battery.
Model 3

"... some charge is wasted in the lamp ... and so in the new wire the current is less because energy is wasted in the lamp ..."

(14 years old)

Model 3 - (No conservation of current). The current flows in the circuit only in one direction leaving the battery from one pole and getting back in at the other but there is less current in the return wire.

Model 4

"The current is the same through all the circuit"

(13 years old)

Model 4 - The scientific model.

Some implications for these models on the pupils' understandings and predictions

Extracts from interviews

"... if there is current in the liquid? ... well I don't think so ... because the positive current that goes through here (arrow 1) ... and the negative current that goes through here (arrow 2) ... they go up to the liquid ... and they cancel out."

(15 years old)

"... lamp C will be less bright than lamp B ... and B will bright less than A ... because energy will be wasted a bit when it passes through A ... and then through B ..."

(15 years old)
"If D went off? ... well .... I think the others would continue to light up because the current goes up to where it can pass".

(14 years old)

"... if the motor is at this side of the lamp ... it (the lamp) will have the same brightness that it had before the motor was there ... but if the motor is on the other side ... before the lamp ... it (the lamp) will be less bright because there was already a waste of energy in the motor."

(14 years old)

"well ... I think if we use two wires ... the lamp's brightness will increase ... because ... there are two wires carrying energy to the lamp."

(13 years old)

"... well ... I think there is electric current stored in the battery."

(13 years old)

---

**Some conclusions and implications for teaching**

- A significant difference in behaviour relating to the proposed activities was shown between pupils who had been under formal teaching on this subject matter and the ones who had not.

- A significant difference in behaviour was shown between pupils who had had already some experience in manipulation of these materials through informal teaching and everyday life.

- There is strong evidence of confusion between the concepts of electric current, electric energy, electric charge and potential difference.
In this population, in general, girls showed more difficulty in the manipulation of these materials than boys.

When the group was mixed (one boy and one girl) the boy normally showed leadership.

When asked to observe a lamp and to describe it, it was interesting to note that the majority of pupils only mentioned what was inside the bulb. Most textbooks, when describing a bulb, only mention what is inside. Describing what is outside a bulb is important for an understanding of the process of lighting it.

It was also noted that, in general, girls were less persistent in their attempts to light the bulb than boys, although a great curiosity in the phenomena observed was shown by all participants.

**Implications for teaching**

If enough opportunities are not provided in which pupils can test their models of current flow in a simple electric circuit, those models will resist formal teaching and will negatively influence the learning of more complex circuits.

The pupils' models existent before formal teaching ought to be taken into account in a pedagogical approach that helps the pupil to construct his scientific knowledge by starting from what he already knows.

Teachers should be concerned with the skills of observation that pupils have. Instead of describing, for instance, objects and apparatus, etc., they should help the pupil to observe accurately and describe them by himself. An accurate description made by the pupils themselves can lead them to a better understanding of the phenomena observed.

The electric current concept is an abstract concept. Pupils need concrete models upon which they can base their ideas. The use of hydraulics and gravitational analogies and many opportunities to test their intuitive models experimentally could help pupils to substitute them by scientific ones.
Analogous studies have been undertaken in other countries with similar results, as for instance:


Overall results indicating the percentages of uncorrect responses by the different population groups

<table>
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<tr>
<th>POPULATION GROUPS</th>
<th>SITUATION</th>
<th>1</th>
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<th>5</th>
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<tbody>
<tr>
<td></td>
<td>Number of students</td>
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<tr>
<td>9th year of schooling</td>
<td>99</td>
<td>96%</td>
<td>98%</td>
<td>100%</td>
<td>55%</td>
<td>74%</td>
<td>72%</td>
<td>53%</td>
</tr>
<tr>
<td>10th year of schooling</td>
<td>89</td>
<td>94%</td>
<td>97%</td>
<td>100%</td>
<td>49%</td>
<td>73%</td>
<td>51%</td>
<td>25%</td>
</tr>
<tr>
<td>1st year Univ. Science</td>
<td>103</td>
<td>75%</td>
<td>79%</td>
<td>97%</td>
<td>41%</td>
<td>63%</td>
<td>34%</td>
<td>33%</td>
</tr>
<tr>
<td>1st year Univ. Humanities</td>
<td>66</td>
<td>95%</td>
<td>99%</td>
<td>100%</td>
<td>85%</td>
<td>86%</td>
<td>91%</td>
<td>42%</td>
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APPENDIX 5

QUESTIONNAIRE FOR THE STUDENT TEACHERS ABOUT
"LIGHT AND ITS PROPERTIES"

Question 1

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On a clear, dark night, a car is standing parked on a straight flat road. The car has its headlights dipped. A pedestrian, who is standing in the road, is able to see the headlights. The figure is divided into four sections.

In which sections is there light?

Explain your answer.

Question 2

a) Why do you see the light from the candle?

b) What happens to the light from the candle?
   i) does it stay on the candle?
   ii) does it come out? If it does, how far?

c) Why do see the candle?

Question 3

Does the light from the candle
a) stay on the candle?

b) come out to a certain distance between you and the candle?

c) come out as far as you but no further?

d) come out until it hits something?

It is night. You are using a candle to read a book.
Question 4

A person is in front of a bar heater switched on. It is day time.

Does the light from the heater

a) stay on the heater?

b) come out to a certain distance between you and the heater?

c) come out as far as the person but no further?

b) come out until it hits something?

Question 5

If the same situation happens at night in a dark room, how would you answer to the same question.

Question 6

Compare the shadow of the same object when it is in front of a very bright lamp and in front of a dim electric lamp.

Question 7

A person is looking at himself in a mirror

. is there any light in the mirror?

. why does the person see himself?

. is there light coming out from the mirror behind the person?

Question 8

A room is painted all white and it is closed except for a small hole in the wall.

A person is inside the room.

. what does the person see if the hole is closed?

. what does the person see if we put a light source behind the hole?

Question 9

The same room is now painted black.

Answer to the same question.
Question 10

Consider three cubes of the same size, one painted black, other painted red and another painted white.

a) how can you distinguish them in a dark room?

b) how can you distinguish them in a lighted room?

c) why do you see one black, one red and one white?

Question 11

A person is looking down into a bucket. There is a piece of plasticine on the bottom of the bucket. The person cannot see the piece of plasticine. Explain why not, and add a drawing to your answer.

The bucket has now been filled with water. The person is able to see the piece of plasticine, although he has not moved, and the bucket has remained in the same place. Explain why the person can see the plasticine, and add a drawing to your explanation.

Question 12

A torch is shone on a white door. A spot of white light can be seen on the door. Then a plate of transparent red glass is placed in front of the torch. A spot of red light is seen on the door. Explain how the plate of glass changes the colour of the spot from white to red. Add a drawing to your explanation.

Question 13

How can you explain the rainbow?
APPENDIX 6

List of aims for Physics Education in General Education elaborated by the fourth year student teachers enrolled in the course on "Physics Didactics" in 1983/84.

The physics teaching should help pupils to:

- develop creativity (intrinsically linked to curiosity)
- make an understanding of the world easy
- stimulate self-confidence
- develop scientific thinking
- provide understanding (acquisition of scientific concepts)
- arouse interest in Science and enjoyment in knowledge in general
- develop the skills of communication in, and the social characteristics of, human beings
- stimulate critical mindedness and openness to criticism by self and others
- develop practical mind and psychomotor skills
- develop thinking skills
- stimulate the capacity for inference
- contribute to the happiness of Man
- stimulate an open mind to innovation

Note from student teachers:

No priority was given in the list.

We are aware of the difficulty in achieving the wholeness of each one of these aims. Even so we believe that this ought to be the main point of our endeavours.
APPENDIX 7

LIST OF AIMS FOR PHYSICS EDUCATION IN GENERAL EDUCATION

8th and 9th Grades

To help pupils to develop:

A. SCIENTIFIC CAPACITIES

A1 - open-mindedness
A2 - inquisitive-mindedness
A3 - critical-mindedness
A4 - creative-mindedness
A5 - team-work
A6 - self-confidence

B. SCIENTIFIC ATTITUDES

B1 - accuracy
B2 - honesty
B3 - consistency
B4 - rationality
B5 - efficiency

C. SCIENTIFIC PROCESS SKILLS

C1 - observing (accurate and systematic)
C2 - formulating hypotheses (to explain observations and measurements)
C3 - designing, planning and performing experiments
C4 - recording, organizing and interpreting data
C5 - manipulating (materials, measuring instruments, apparatus, etc.)
C6 - communicating
C7 - predicting
C8 - inferring
To help pupils to:

$D_1$ - be aware of their personal frameworks in scientific observation

$D_2$ - progress in their intellectual development

$D_3$ - progress in their cognitive development

$D_4$ - develop positive attitudes towards physics

$D_5$ - appreciate science as an activity of interest for the common person
APPENDIX 8

Diagnostic questionnaire about "Light and its Properties"

A. The purpose of the questionnaire was to investigate:

1. What is the pupils' meaning for the word "light".
   (questions 1 and 2)

2. To what extent pupils identify light as the source of light.
   (questions 2 and 4)

3. To what extent pupils identify light as energy.
   (questions 1 and 9)

4. To what extent pupils use the model "light exists and propagates in space" to explain optical phenomena.
   (questions 3, 4, 6, 7 and 10)

5. What ideas pupils have about the link between object and eye when common objects are seen.
   (questions 5, 12 and 13)

6. To what extent pupils distinguish between luminous and non-illuminated bodies.
   (question 8)

7. How pupils explain that white light changes colour when passing through a filter.
   (question 12)

8. How pupils explain the phenomenon of refraction.
   (question 13)
B. Diagnostic questionnaire administered to pupils at the beginning of the unit of "Optics".

Question 1
. What is 'light' for you?

Question 2
. Where is there 'light' in this room?

Question 3

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<th>II</th>
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. On a clear, dark night, a car is standing parked on a straight, flat road. The car has its headlights dipped. A pedestrian, who is standing in the road, is able to see the headlights. The figure is divided into four sections. In which sections is there light?
   Explain your answer.

Question 4
. Does 'light' move?
   Explain your answer.

Question 5

"Ana" and her physics teacher are discussing seeing.
Teacher: Explain how can you see the book!
"Ana" : Signals go along nerves between the eyes and the brain.

Teacher: Yes, this happens between the eyes and the brain. But there's is some distance between the book and the eyes. Does anything happen between them?

What would you answer? Draw and explain!
Question 6

For each question there are four possible answers. Choose the one you think best answers the question. Place a tick in the square to show which answer you think is best.

The light from the candle:
A. stays on the candle

B. comes out about halfway towards you

C. comes out as far as you but not further

D. comes out until it hits something

You are watching a candle burning during the day.

You are watching a candle burning during the day.

The light from the candle:
A. stays on the candle

B. comes out about halfway towards you

C. comes out as far as you but not further

D. comes out until it hits something

It is night and you are reading at a light candle.

It is night and you are reading at a light candle.
We can see through the window that Mr. Smith is reading a book.

1. Where is there light in the room?
2. Why is he able to read the book?
3. Why can you see the picture?

Which of the following objects is a source of light?

- the eyes
- a candle
- a pencil
- the Sun
- a mirror
- a bottle
- the sky
- a TV set
- a window
- a lamp

1. What happen to green plants when in a dark room?
2. Why?
3. At a certain depth into the sea (120 m) there are no green plants. Can you explain that?
4. Why do people choose sunny places for walking in a cold day?
5. What conclusions can you draw about sunlight according to your answers?
Question 10

A torch is shone at a door. A spot of white light can be seen on the door. Place a tick in the square to show where you think there is light.

A. in the torch

B. on the door

C. in the torch and on the door

D. between the torch and the door

E. in the torch, on the door and between the torch and the door

Explain your answer.

Question 11

A plate of transparent red glass is placed in front of the torch. A spot of red light is seen on the door. Explain how the plate of glass changes the colour of the spot from white to red.

Add a drawing to your explanation if you wish.
There is a small stone on the bottom of an empty bucket. In a certain position you cannot see it. Explain why not, and add a drawing to your explanation.

The bucket has now been filled with water. You are now able to see the stone, although you have not moved and the bucket has remained in the same place.

Explain why you can see the stone now that the bucket is full of water, and add a drawing to your explanation if you wish.

C. The main difficulties found can be listed as follows:

- Identification of a light as the source of light
- Identification of light as a source of electric and thermal energy
- The model "light exists and propagates in space" is not held by a great number of pupils. In consequence 'light exists only near the source of light or only on the source'. Far from the source 'what exists is brightness'.
- Objects are seen as a consequence of 'visual rays'. Light goes 'out from eyes to the object'.
- None of the pupils could explain the phenomenon of reflection. (even the repeaters).
- For some pupils light takes away the colour of the filter. For others the filter paints the light.
A. Purpose of the questionnaire about "Force, Weight and Mass"

The purpose of this questionnaire was to investigate:

1. The pupils' meaning for the words "mass", "weight" and "force" before formal teaching.
   (questions 1, 2 and 3)

2. To what extent pupils make the distinction between the concepts of "mass" and "volume".
   (questions 1 and 4)

3. To what extent pupils make the distinction between the concepts of "mass" and "weight".
   (questions 2, 5, 6 and 8)

4. To what extent pupils recognize the existence of forces in interaction at a distance.
   (question 7)

5. Pupils' ideas about the characteristics of weight.
   (question 9)

6. To what extent pupils make the distinction between the concepts of "force", "motion" and "velocity".
   (questions 3 and 10)

7. Pupils' ideas about relativity of the increase in weight with the height to which the object is raised.
   (question 11)
B. Diagnostic questionnaire administered to pupils at the beginning of the unit "Force weight and mass"

**Question 1**

What does "mass" mean to you?

**Question 2**

What does "weight" mean to you?

**Question 3**

What does "force" mean to you?

**Question 4**

In plate A of the beam balance there is a plastic ball and in plate B an iron ball. The beam balance is balanced.

Place a tick in the square you think makes the correct sentence.

"The ball in A has

- more
- the same
- less

mass than the ball in B"

Explain your answer.
Question 5

Mr. Smith found his weight on Earth and on the Moon.

The weighing machine indicated more weight on Earth than on the Moon.

Place a tick in the square you think makes the correct sentence.

"The mass of Mr. Smith on Earth is

bigger

the same

smaller

than on the Moon.

Explain your answer.

Question 6

Mr. Smith couldn't lift up the barbell. He took it to the Moon and he lifted it up easily there. How do you explain this fact?
Consider the three following situations and give your ideas.

10. \( \text{A. Why does the nail move?} \)
    \( \text{B. Is there any force acting on the nail?} \)
    \( \text{C. If you think there is, say which one is it?} \)

20. \( \text{A. What happens to the ball?} \)
    \( \text{B. Is there any force acting on the ball?} \)
    \( \text{C. If you think there is, say which one is it?} \)

30. \( \text{A. Why does the apple fall down?} \)
    \( \text{B. Is there any force acting on the apple?} \)
    \( \text{C. If you think there is, say which one is it?} \)
Question 8

Place a tick in the square you think makes the correct sentence.

"One Earth, the force made by the boy on the ball is

bigger

the same

smaller

than the force made by the boy on the ball when he is on the Moon"

Explain your answer.

Question 9

Consider an apple falling down from the tree in four different places on Earth.

Draw an arrow illustrating the weight of each apple at the different places on Earth.
A ball is thrown up in the air. It leaves the boy's hand, goes up through point A, gets as high as B and then comes back down through A again.

The following pictures refer to this situation. The arrows in the pictures are supposed to show the direction of the force on the ball.

1.- Which pictures do you think best shows the force on the ball on its way up through A?

Explain your answer.

2.- Which pictures do you think best shows the force on the stone when it reaches the point B (maximum height)?

Explain your answer.
3.- Which picture do you think best shows the force on the stone when it is passing through the point A on its way down?

Explain your answer.

**Question 11**

These two men are stopping the cars rolling down the hill. Both cars are the same and have the hand brake off.

The following pictures refer to this situation. The size of the arrows are supposed to show the size of the forces exerted by the people on the cars.

Which drawing do you think best shows what is happening.

Explain your answer
Questions 10 and 11 are based on work by Watts and Zylbersztajn, (1981).

C. The main difficulties found can be listed as follows

A great number of pupils identify the concept of "mass" with the concept of "volume". This view implies for instance,

"... two bodies with different volume can't have the same mass ... how can I have the same mass as a big wardrobe!..."

(a pupil of the 9th grade)

For some pupils mass of an object is identified with what makes up a body.

This view seems to be very resistant, as could be observed during lessons. It implies, for instance,

"... one brick or two bricks have the same mass ... of course ... they are made of the same thing"

(a pupil of the 9th grade)

A great number of pupils identify the concept of "mass" with the concept of weight". This view, implies, for instance,

"...how can I have different weight on the Moon ... I'm the same person here or there ... I will not change by the fact that I'm on Moon".

(a pupil of the 9th grade)

Although the majority of pupils recognize the existence of an interaction force at small distances (they indicate the force of the magnet on the iron nail) and contact forces (they indicate the force exercised by the boy when kicking the ball) some don't recognize the existence of interaction at a great distance (they don't mention the force of gravity on the apple. The reasons for the fall of the apple are for instance... "the apple falls because there is wind" ... or "the apple falls because it is ripe".
Just a few pupils don't draw the vector weight towards the center of the Earth. However most of them show difficulty with the symbolic representation, (e.g. the extremity of the arrow is drawn at the surface of the Earth meaning by this the link between Earth and the object).

Almost all the pupils associated force with motion and velocity (e.g. if a body has velocity in this direction there has to be a force in this direction).

The great majority of children chose the option (in question 11) suggesting that the upper car would be pulled down the hill with a smaller force than the other because it is farther from the Earth. It shows the lack of the notion of relativity between the decrease in weight and the height through which the object is raised.
QUESTIONNAIRE FOR THE STUDENT TEACHERS

1. What does "teaching physics" mean to you?

2. Compare your view of what is "teaching physics" before and after the course.
   
   2.1 Do you find any difference? 
   
   Yes [ ] No [ ]

   2.2 If you do, try to explain the difference.

   2.3 If do not, try to explain the reasons for the fact.

3. Do you feel confident in your capacity to develop in your future pupils' scientific capacities, attitudes and process skills which you consider important aims for the physics teaching?

   Yes [ ] No [ ]

   3.1 If you do, say how much by ticking the appropriate column
   (1 stands for "very low"; 5 for "very high")

   1 2 3 4 5

   3.2 If you do not, try to explain why not.

   3.3 If you do not, try to explain what you can do in the future to overcome your difficulties.

4. Did you find it difficult to progress through the course?

   Yes [ ] No [ ]
4.1 If you found it difficult, say how much.
   (1 stands for "very easy"; 5 for "very difficult")

4.2 If you found it difficult, try to identify the causes of difficulty, by ticking where appropriate:
   a) faulty preparation in knowledge of theory of learning and teaching
   b) faulty scientific preparation
   c) insufficient time for preparation
   d) lack of support from teacher
   e) lack of support from instructional resources

   If you found any other causes, try to describe them.

5. Do you feel that what you learned during the course will be relevant to your professional life?
   Yes No

5.1 If you do, explain why

5.2 If you do, say how much.
   (1 stands for "not relevant"; 5 for "extremely relevant")

5.3 If you don't, explain why not
6. If you find any improvement in your skills for teaching according to the model of teaching/learning whose purpose is to develop the "scientific-like aspects" of students;

a) try to identify what helped the development of that skill. Tick the column 0 in case the item did not help you at all.

b) then try to decide how much each item helped you by ticking the appropriate column.

(N stands for non-applicability)

6.1 to perceive what I had to do in order to achieve the aims I stated for my teaching

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6.2 to prepare and perform teaching activities

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6.3 to assess my teaching activities in the pre-active and interactive phases, as a means to improve my next teaching experience

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6.4 to prepare and perform teaching activities integrating solutions for improvement on the basis of previous assessment

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6.5 to receive feedback during the whole process of development of my teaching skills

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6.6 to be encouraged in my efforts to learn the teaching skills appropriate for the implementation of the model

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6.7 to be encouraged to analyse the problems and explore imaginative ways of tackling the problems

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7. Make a general comment on your experience:
APPENDIX 11

DATA RELATING TO STUDENT TEACHERS' PERCEPTIONS OF THEIR OWN LEARNING EXPERIENCE

Note: The student teachers' answers were not rephrased; they are translated into English in the best way to avoid distorting their meaning.

1. What does "Teaching Physics" mean to you?

$S_1$ - "To foster enjoyment of physics. To develop and stimulate a certain number of "abilities" that we think are important. To help the pupils' integration in society. Specially to develop in them social habits, such as the skill of communicating. To contribute to a better understanding of the world and nature".

$S_2$ - "Is to help in the understanding of the world around us leading us to the causes of events"

$S_3$ - "Teaching physics must be a way of developing in pupils capacities, attitudes and skills, which allow them to have a better understanding and a better integration in the world".

$S_4$ - "It is to help pupils to understand the world around them and to develop in pupils capacities, attitudes and skills".

$S_5$ - "In a broad sense it is to help pupils to develop all the capacities and skills we believe are important for them and possible to achieve through physics teaching. In a strict sense it is to help pupils to understand the world around them and to help them to adopt personal stances on technological progress and on its social and philosophical consequences".

$S_6$ - "It is to make the understanding of physical phenomena easy, helping pupils to develop their mental structure in order to do their own thinking".

$S_7$ - "Teaching physics is to give opportunities to pupils in order to foster their interest in learning physics, helping them in their learning and research".

$S_8$ - "Teaching physics is providing pupils with situations which help their development as a whole through physics content. For me this development as a whole implies the development of scientific "abilities" as much as possible".
"For me 'teaching physics' is to help the development in pupils of scientific "abilities" (e.g. communicating, predicting etc.). It is to start teaching from ideas pupils already hold, helping them to clarify them and if necessary helping them to develop those ideas to more scientific one".

"For me 'teaching physics' is to be sure and confident in scientific knowledge, mastering it in order to be able to help pupils to develop the scientific "abilities" which I consider important".

"Teaching physics is to help pupils to understand the surrounding world in a better way, developing in them "abilities" which will help them to act in their future life in a more scientific way".

"it is to help the development in pupils of scientific capacities through the interpretation of everyday phenomena. It is also providing pupils with opportunities to disclose their ideas, their doubts and their problems, leading them to progress in their intellectual and cognitive development".

"For me 'teaching physics' is a great opportunity one has to help others to understand and interpret everyday phenomena; it is also to help pupils to develop "abilities" which are important not only for the development of pupils in a scientific way but also, and more important, for their development as human beings".

2. Compare your view of 'What is teaching physics' before and after the course.

2.1 - Do you find any difference?  

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2.2 - If you do, try to explain the difference.

"I'm convinced, now, that being a physics teacher can turn out to be an interesting profession. More important, it is possible to lead pupils to the discovery of physics by themselves and therefore to help them to progress in their intellectual and cognitive development".

"Before the course, 'to teach physics' was, for me, to convey knowledge which we can get in books without seeing the link between that knowledge and the reality around us, memorized knowledge, formulas and definitions. Now I can see that link".
S₃ - "I feel that it is very difficult to explain, since the change took place slowly, so it looks as if at this moment I'm unable to compare, although I find differences."

S₄ - "At the beginning I had a very traditional view of teaching. I mean, for me, teaching was only the transmission of content. The task of the teacher was to "give" the subject matter."

S₅ - "Before this course I had the notion of what 'teaching physics' shouldn't be, but I didn't know what it should be. Now I know what it must be."

S₆ - "Before the course I had never thought that through physics one could achieve aims such as, scientific thinking, creativity, critical thinking and many more. Now I know that this is possible and very possible!".

S₇ - "I think that, concerning our expectations on 'teaching physics', something has changed after the course. We understand, at last, that 'teaching physics' isn't a matter of transmitting or explaining physics knowledge, but, it is a matter of stimulating, guiding and helping pupils' evolution in their physics learning."

S₈ - "The idea I got, after the experience provided by this course, is that instead of speaking of teachers it would be more correct to speak of supervisors. My concept of 'teacher' is of one who teaches centred on himself and by supervisor I mean one who teaches starting from the learner's knowledge, by helping him."

S₉ - "Before the course I conceived 'teaching physics' in the same way that I had been taught. Now I understand it in the way I mentioned above. I think that through physics teaching the scientific "abilities" we considered important can be developed in pupils if we teach within the same approach that we have been trying to experiment with."

S₁₀ - "Until this learning experience I didn't know 'why' to teach physics. Now I think I know it. Now I see teaching as a means to help the development of the pupils."

S₁₁ - "Now I have become conscious of the importance of teaching."

S₁₂ - "Throughout the course I discovered a much more interesting and stimulating way of teaching physics that the one I had been taught. I discovered that it is always possible to relate physics content to everyday phenomena. Maybe it is more difficult, but I got the idea that pupils will more interested in learning if teaching is centered on them and not seen as a transmission of knowledge."
S_{13} - "The difference is that before the course I saw physics teaching concerned only with the teaching of physics content, but now I see it not only as a means to help pupils to understand it but also to help them to develop as people".

2.3 - If you do not, try to explain the reasons for the fact.
No answer.

3. Do you feel confident in your capacity to develop in your future pupils scientific capacities, attitudes and process skills ... ?

Yes | No
---|---
13 | 0

3.1 - If you do, say how much by ticking the appropriate column
(1 stands for "very low"; 5 for very high)

S_{1} - 4; S_{2} - 3; S_{3} - 1; S_{4} - 3; S_{5} - 4; S_{6} - 4; S_{7} - 3; S_{8} - 4;
S_{9} - 4; S_{10} - 3; S_{11} - 5; S_{12} - 5; S_{13} - 4.

3.2 - If you do not, try to explain why not.
No answer.

3.3 - If you do not, try to explain what can you do in the future to overcome your difficulties.
No answer.

4. Did you find difficult to progress through the course?

Yes | No
---|---
4 | 9

4.1 - If you found it difficult, say how much.
(1 stands for "very easy"; 5 for "very difficult")

S_{2} - 4; S_{3} - 3; S_{6} - 3; S_{7} - 3; S_{8} - 4; S_{9} - 2; S_{11} - 3;
S_{12} - 4; S_{13} - 3.
4.2 - If you found it difficult, try to identify the causes of difficulty, by ticking where appropriate.

\[ S_2 - b); \quad S_3 - b) \text{ and } c); \quad S_6 - b); \quad S_7 - a), b) \text{ and } c); \quad S_8 - b) \text{ and } c); \]
\[ S_9 - b), c) \text{ and } e); \quad S_{11} - b) \text{ and } c); \quad S_{12} - a) \text{ and } b); \quad S_{13} - b) \text{ and } c). \]

5. Do you find that what you learned during the course will be relevant to your professional life?

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5.1 - If you do, explain why.

\[ S_1 - "Because I got aware of my own difficulties although I feel I'm able to overcome them. Thus I'm sensitized to pupils own difficulties and I'm much more prepared to help them". \]

\[ S_2 - "Because it will help me to teach in a more efficient way". \]

\[ S_3 - "Although I feel it is more difficult to teach according to this model, and the results only can be seen after a long period, what I learned will have influence on my professional life". \]

\[ S_4 - "Because it changed my perspective toward teaching". \]

\[ S_5 - "Because this approach to physics teaching is much more interesting and I feel this is the way that it's worth while teaching". \]

\[ S_6 - "Because teaching physics according to this model is much more interesting and of course it will have influence on my professional life". \]

\[ S_7 - "Because I think this learning experience gave us something which was missing throughout the previous years of the degree: interest in teaching physics and its practice". \]

\[ S_8 - "Due to opportunities for reflecting first, I was helped to see teaching as something different. Thus, a priori, I'm aware of problems I never thought could emerge during teaching". \]

\[ S_9 - "It will be relevant because not only it helped me to face teaching in a new perspective, but it also made me aware of some of my own deficiencies concerning scientific knowledge and the way I express myself. I think that all of us need to work hard in this field in order to acquire confidence to teach within this approach". \]
S10 - "Because it 'opened my eyes' to certain problems, already mentioned, that
I wasn't aware of".

S11 - "I think this course helped me to become conscious of my own difficulties
and also to realize how important teachers' behaviour is".

S12 - "Because it helped me to discover a more interesting way of teaching which
will make me feel more stimulated to teach and confident because I think
I will be able to do it".

S13 - "I think the experience I had in this course is of great importance in my
professional life because even during the short period it took, it helped us
a great deal to be aware of our role as teachers in the development of our
pupils". I also think that this course should be taught earlier and for a longer
period.

5.2 - If you do, say how much.

S1 - 5; S2 - 2; S3 - 4; S4 - 4; S5 - 4; S6 - 5; S7 - 4; S8 - 5;
S9 - 4; S10 - 4; S11 - 4; S12 - 5; S13 - 5.

5.3 - If you don't, explain why not.

No answer.

6. If you find any improvement in your skills for teaching according to the model
... try to identify what helped you to develop them ....

---

Points 6.1

Points 6.2
7. Make a general comment on your learning experience.

S₁ - "In a broad sense it was very interesting. As a fundamental feature it allowed me to rethink a great number of views related to my way of being, of acting and knowing. The reality is clear in my mind of being at the end of a degree: sieves of smaller and smaller mesh, sure, but just sieves through which the bits of knowledge pass, precisely because our university knowledge is an amount of perfectly colloidal fragments".

S₂ - "From the beginning of the course until the end, I consider that progress occurred, though sometimes I felt some decline in the relations with pupils. Nevertheless, I found my learning experience good in the way that it made me look more directly at problems involved in the process of teaching and learning, not only in physics but towards everything which is related to education in general. On the other hand, this experience taught me that there are a large number of edges to be polished. Thus it gave me an awareness of the necessity of effort towards an improvement and a deepening in various
issues related to teaching. Not only about content but about what can be achieved through content. It also showed me the necessity of paying more attention to the pupils' psychology during the different phases of their learning". 

S₃ - "I think that this course was very useful because besides helping me to become aware of several problems, it faced me with some situations which I had never thought of. Sometimes I felt myself very depressed. Nevertheless I was duly encouraged which made me feel better. I find the result very positive. I think I achieved a great deal with this course".

S₄ - "I think that my learning experience in this course was positive and now I know the way I want to teach. It gave me confidence concerning my future activity".

S₅ - "It was different from what I had during my own learning. It gave me an awareness of problems which can arise in my professional life. It gave me self-confidence. It solved many problems. It aroused others".

S₆ - "What I can say is that before the course I thought that teaching was a very difficult task and I felt very little confidence in my capacities for teaching. Now I find that teaching isn't such a difficult task and that it is an interesting activity for those who wish to accomplish it".

S₇ - "I think that this learning experience was very useful. Even though our work hadn't been the best, or even though we couldn't be able to get the most of the opportunities provided, I think it was really important to get a new perspective on teaching. That is an important thing, considering our future".

S₈ - "As can be easily elicited from the analysis of my answers to this questionnaire, this learning experience helped me to face the teaching/learning process in a totally different way. Now it is up to me to make the choice between the traditional teaching (which is definitely out of the question) and this new perspective on teaching and learning. It also helped me to become aware of problems brought about by this new perspective. Summing up, it was worthwhile".

S₉ - "I think that this experience was very useful because it helped me to re-acquire my self-confidence. I think that this happened not only with me but also with my colleagues. I think that this self-confidence has been reduced by the way we have been taught. In this course I learned (I think) to view physics teaching in a new perspective. It made me rethink my own way of learning, my own way of interpreting phenomena. Not only to study for passing exams but to
study for understanding the basic concepts, to progress in my cognitive development and to have enough confidence in my scientific background in order to teach within this new approach. The course allowed me to become acquainted with other teaching methods different from the traditional one and to look at pupils in a different way, looking them as beings in development. In my point of view this course should take a full academic year. Thus we could have more time to put into practice our ideas and to test them".

S10 - "Despite being a short experience I enjoyed it because I think that I identified myself with the aims proposed at the beginning of the course. On the other hand I became aware of the responsibility of teaching others, the effort teachers are asked of both in the scientific and pedagogical area. I consider this experience highly positive, the most important of my school life. This is because it was here that I identify myself with this way of teaching. Summing up, it was through this experience that I knew what physics teaching is about".

S11 - "I think this course helped me to be aware of what physics teaching should be about. Now I see teaching in a different way, although it seems to me that the teaching experience I had is a bit unreal".

S12 - "I think it was in this course that I discovered what teaching really is. In my first performance I made many mistakes but in the second one I feel I was able to improve my performance based on reflection on previous experiences and I think that I could achieve everything I proposed to achieve in a better way. It was a useful experience also because it helped me to be aware of my deficiencies in the scientific and pedagogical areas".

S13 - "I think this course was very useful. Despite the weakness of my performances I think they helped me to be conscious of my own difficulties as well as why and how I should teach in my future life. It is my opinion that this kind of course should be taught earlier in order to help student teachers to reflect on their future activity, on the best strategies to help the development of their future pupils and to help them to get positive attitudes towards physics".
**APPENDIX 12**

**SCHEDULE FOR SELF-PERCEPTION OF THE DEVELOPMENT OF SCIENTIFIC "ABILITIES"**

Compare your "abilities" before and after the course and say "how much" they were developed, ticking the appropriate column.

(0 stands for "there wasn't"; 1 "very few", ... 5 "very high")

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### C. Scientific Process Skills

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<tr>
<td>C₂</td>
<td>formulating hypotheses</td>
<td></td>
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</tr>
<tr>
<td>C₃</td>
<td>designing, planning and performing experiences</td>
<td></td>
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<tr>
<td>C₄</td>
<td>recording, organizing and interpreting data</td>
<td></td>
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<tr>
<td>C₅</td>
<td>manipulating</td>
<td></td>
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<tr>
<td>C₆</td>
<td>communicating</td>
<td></td>
<td></td>
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<tr>
<td>C₇</td>
<td>predicting</td>
<td></td>
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<tr>
<td>C₈</td>
<td>inferring</td>
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</tbody>
</table>

### D.

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
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</tr>
</thead>
<tbody>
<tr>
<td>D₁</td>
<td>to be aware of my personal frameworks in scientific observation</td>
<td></td>
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<td></td>
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<tr>
<td>D₂</td>
<td>to progress in my intellectual development</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>D₃</td>
<td>to progress in my cognitive development</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>D₄</td>
<td>to develop positive attitudes towards physics</td>
<td></td>
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<tr>
<td>D₅</td>
<td>to appreciate science as an activity of interest for the common person</td>
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</tbody>
</table>
APPENDIX 13

Data relating to Student Teachers' Perceptions of their Development of Scientific "Abilities"

Fig. 1 - Histogram showing S1's self-perception

Fig. 2 - Histogram showing S2's self-perception

Fig. 3 - Histogram showing S3's self-perception
Fig. 4 - Histogram showing $S_4$'s self-perception

Fig. 5 - Histogram showing $S_5$'s self-perception

Fig. 6 - Histogram showing $S_6$'s self-perception

Fig. 7 - Histogram showing $S_7$'s self-perception
Fig. 8 - Histogram showing $S_g$'s self-perception

Fig. 9 - Histogram showing $S_g$'s self-perception

Fig. 10 - Histogram showing $S_{1g}$'s self-perception
Fig. 11 - Histogram showing $S_{11}$'s self-perception

Fig. 12 - Histogram showing $S_{12}$'s self-perception

Fig. 13 - Histogram showing $S_{13}$'s self-perception
APPENDIX 14

Task analysis, transcript, analysis and discussion of a lesson performed by S2

(third lesson on "Force and Mass").
(content of the lesson: . the weight of a body and its variation with latitude and altitude . spring balances)
### A. Statement of the aims of the lesson in terms of pupils' development of "abilities"

Through the contents of this lesson pupils should be helped to develop (see App. 7):

- $A_3$
- $C_1$
- $C_4$
- $C_6$

### B. Statement of the objectives of the lesson in terms of pupils' learning

After the lesson pupils should be able to:

1. explain the change of a body's weight with the place where it is located
2. describe a spring balance
3. measure weights with a spring balance
4. explain the working of a spring balance

### C. Analysis of the lesson aims and objectives to establish the link between them

Through (1) pupils can be helped to develop $A_3$, $C_4$, and $C_6$

Through (2) pupils can be helped to develop $C_1$ and $C_6$

Through (3) pupils can be helped to develop $C_4$ and $C_5$

Through (4) pupils can be helped to develop $C_1$ and $C_6$

### D. Decision on type of:

- **a)** pupils' activities
- **b)** nature of presentation
- **c)** nature of feedback to be provided
- **d)** evaluation

- a). participation in a class discussion
  - manipulation of measuring instruments
  - recording and organizing data
- b). pupils will be presented with a table showing data relating to body weight and mass in different countries and latitudes. A discussion based on that data shall be conducted.
  - pupils will be presented with spring balances and asked to describe them and measure forces with them
- c). not mentioned
- d). not mentioned
2 - TRANSCRIPT AND ANALYSIS OF THE LESSON PERFORMED BY $S_2$

In the following each contribution is numbered consecutively. The source being indicated by S.T. for student teacher and $P$ for pupil contributions, i.e. any pupil. Various pupils contributions at the same time, $P_3$, and occasionally different pupil contributions are indicated by $P_1$, $P_2$, etc.

<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. S.T.</strong> Let's start the lesson OK? what did we talk about in the last lesson?</td>
<td></td>
</tr>
<tr>
<td><strong>2. P</strong> about mass</td>
<td></td>
</tr>
<tr>
<td><strong>3. S.T.</strong> why did we say &quot;mass is a characteristic of a body&quot;? &quot;Sónia&quot;</td>
<td>$S_2$ is using a textbook utterance</td>
</tr>
<tr>
<td><strong>4. $P_3$</strong> (all speaking at the same time)</td>
<td></td>
</tr>
<tr>
<td><strong>5. S.T.</strong> I said &quot;Sónia&quot;!</td>
<td></td>
</tr>
<tr>
<td><strong>6. $P_3$</strong> what ... what is the question?</td>
<td></td>
</tr>
<tr>
<td><strong>7. S.T.</strong> why is mass a characteristic of a body and not the weight?</td>
<td></td>
</tr>
<tr>
<td><strong>8. P</strong> because the weight varies</td>
<td></td>
</tr>
<tr>
<td><strong>9. S.T.</strong> because de weight varies ... and what about the mass?</td>
<td>$S_2$ should ask what the pupil means by that, what is his understanding of the phenomena. Instead she takes it for granted and goes ahead</td>
</tr>
<tr>
<td><strong>10. $P_3$</strong> it's invariable ...</td>
<td></td>
</tr>
<tr>
<td><strong>11. S.T.</strong> the mass is invariable .... it doesn't change from place to place .... while .... weight is variable .... mass isn't. &quot;Paulo&quot; can you think of a current situation in which you can feel this fact? ... that your weight is variable?</td>
<td>$S_2$ talks very quickly. She states facts without the concern of knowing what pupils understand about them. Asking this question she is confusing the pupil</td>
</tr>
</tbody>
</table>

Aims

(Inferre
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
<th>Aims (Inference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. P</td>
<td>Miss ... when ....</td>
<td></td>
</tr>
<tr>
<td>13. S.T.</td>
<td>see if you remember any situation of day-to-day life in which you can see that your weight varies</td>
<td>And she shows that herself has no clear ideas about the problem of weight's variation</td>
</tr>
<tr>
<td>14. P₈</td>
<td>(too much noise)</td>
<td>This noise is not caused by pupils discussing about the problem posed but because their interest about the issue is not aroused</td>
</tr>
<tr>
<td>15. P</td>
<td>.... when one goes in a car ....... I don't know .......</td>
<td></td>
</tr>
<tr>
<td>16. S.T.</td>
<td>when one goes in a car ...?</td>
<td></td>
</tr>
<tr>
<td>17. P</td>
<td>.... the weight of the body ..... I cannot explain ..</td>
<td></td>
</tr>
<tr>
<td>18. S.T.</td>
<td>in that situation do you feel lighter or heavier</td>
<td>She insists on the mistake</td>
</tr>
<tr>
<td>19. P</td>
<td>lighter</td>
<td></td>
</tr>
<tr>
<td>20. S.T.</td>
<td>for instance ... have you ever been in those things in luna parks</td>
<td></td>
</tr>
<tr>
<td>21. P₁</td>
<td>... yes</td>
<td></td>
</tr>
<tr>
<td>22. P₂</td>
<td>which ones?</td>
<td></td>
</tr>
<tr>
<td>23. P₈</td>
<td>(all speaking but not related to the lesson)</td>
<td></td>
</tr>
<tr>
<td>24. S.T.</td>
<td>be quiet .... (she speaks so quickly that it is impossible to transcribe) .... and for example ... other situation .... ..... and this you must have already experienced it .... a person swimming in a pool .......</td>
<td>The first situation (utterance 20) wasn't clarified. Nobody understands what she wanted but they don't show signs of interest. She is referring to another situation but doesn't go on with the idea</td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>25. $P$ when we are swimming .....</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. $P_S$ everybody talking at the same time</td>
<td>Most of the pupils are not paying attention</td>
<td></td>
</tr>
<tr>
<td>27. $P$ Miss when we are walking in water ... for instance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. $S.T.$ what do you feel when you are moving in the water?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. $P$ the weight increases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30. $S.T.$ there is a resistance offered by the water to the movement</td>
<td>Instead of asking what is the pupil's idea she advances an explanation</td>
<td></td>
</tr>
<tr>
<td>31. $P$ and I also feel my weight bigger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32. $S.T.$ but that is because the resistance of water to the movement</td>
<td>This utterance reinforces the pupils' wrong idea about his weight getting bigger because he walks in the water</td>
<td></td>
</tr>
<tr>
<td>33. $P_S$ everybody is speaking ..... but $S_2$ continues talking without noticing that</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34. $S.T.$ ..... while .. when you are moving in the air ..... it's easier because air offers little resistance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35. $P_S$ everybody is speaking ... only very few are listening to the teacher</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36. $P$ Miss ... just one question</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37. $S.T.$ when you are in a car in movement on a road there are some special situations in which you even feel .....</td>
<td>She didn't hear the pupil .. it seems that she is only concerned to cover the content of the lesson. She shows again her confusion when relating this situation with the weight's variation</td>
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<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>38. ( P )</td>
<td>when we cross a bridge ...</td>
<td></td>
</tr>
<tr>
<td>39. ( S.T. )</td>
<td>... and when you pass a slope on a road ...</td>
<td></td>
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<tr>
<td>40. ( P_1 )</td>
<td>... I don't know what a slope is</td>
<td></td>
</tr>
<tr>
<td>41. ( P_2 )</td>
<td>something that comes up and down</td>
<td></td>
</tr>
<tr>
<td>42. ( S.T. )</td>
<td>when you go up and go down ... and more?</td>
<td></td>
</tr>
<tr>
<td>43. ( P )</td>
<td>and on curves ... no?</td>
<td></td>
</tr>
<tr>
<td>44. ( P_3 )</td>
<td>(too much noise)</td>
<td></td>
</tr>
<tr>
<td>45. ( S.T. )</td>
<td>..... and when there is a big building ...... we don't use stairs ....</td>
<td></td>
</tr>
<tr>
<td>46. ( P )</td>
<td>we go by lift</td>
<td></td>
</tr>
<tr>
<td>47. ( S.T. )</td>
<td>inside the lift do we feel that our weight varies?</td>
<td></td>
</tr>
<tr>
<td>48. ( P_3 )</td>
<td>yes ..</td>
<td></td>
</tr>
<tr>
<td>49. ( S.T. )</td>
<td>if ... (so quickly spoken that's impossible to understand) ..... so ... pay attention .... what do you feel when the elevator starts going up .... and when it stops?</td>
<td></td>
</tr>
<tr>
<td>50. ( P_3 )</td>
<td>(too much noise)</td>
<td></td>
</tr>
<tr>
<td>51. ( P )</td>
<td>and also in airplanes ... when they go .....</td>
<td></td>
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</table>

- Again she has taken apparent weight by the phenomenon of variation of weight
- These two pupils are near the tape recorder and their conversation is being recorded. \( S_2 \) doesn't note that they are having a parallel conversation
- Her confusion is again disclosed
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S.T.</strong> .... the airplanes when they pass through the so called air well</td>
<td>She continues talking without paying attention to the noise. Closed-questions requiring from pupils only one or two words</td>
</tr>
<tr>
<td><strong>P_3</strong> (too much noise)</td>
<td></td>
</tr>
<tr>
<td><strong>P_1</strong> in the airplanes what?</td>
<td></td>
</tr>
<tr>
<td><strong>P_2</strong> in the air-well</td>
<td></td>
</tr>
<tr>
<td><strong>P_1</strong> oh! yes we feel a thing in the stomach!</td>
<td></td>
</tr>
<tr>
<td><strong>P_3</strong> (everybody is talking ...)</td>
<td></td>
</tr>
<tr>
<td><strong>S.T.</strong> so .... if you stay the same person .... your number of particles doesn't change ... and the type of particles doesn't change also ... is it the mass which changes in those situations?</td>
<td></td>
</tr>
<tr>
<td><strong>P_3</strong> no ....</td>
<td></td>
</tr>
<tr>
<td><strong>S.T.</strong> is it the weight?</td>
<td></td>
</tr>
<tr>
<td><strong>P_1</strong> yes ..... it is the weight</td>
<td>This pupil gives a clue for the right interpretation of the phenomenon but S_2 doesn't pay attention to him</td>
</tr>
<tr>
<td><strong>P_2</strong> it's the sensation</td>
<td></td>
</tr>
<tr>
<td><strong>S.T.</strong> it is the weight!... you have a sensation of increase or decrease of weight ... so you have a sensation of variation of weight</td>
<td>She is herself making a confusion between apparent weight and weight and is leading the pupils to a wrong conclusion</td>
</tr>
<tr>
<td><strong>P</strong> the weight varies</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td>65. $P_s$ (too much noise)</td>
<td></td>
</tr>
<tr>
<td>66. S.T. on the other hand .... you have already heard about latitude and altitude in geography .......</td>
<td>$S_2$ is mixing the two phenomena reinforcing the confusion in pupils' head</td>
</tr>
<tr>
<td>67. $P_s$ yes ....</td>
<td></td>
</tr>
<tr>
<td>68. $P_1$ the weight varies with latitude</td>
<td></td>
</tr>
<tr>
<td>69. S.T. what is that? .... what do you mean by latitude?</td>
<td>The question demands only a low level of thinking</td>
</tr>
<tr>
<td>70. $P_1$ .... well .. latitude .... is up to the north ....</td>
<td></td>
</tr>
<tr>
<td>71. $P_2$ in relation to the equator</td>
<td></td>
</tr>
<tr>
<td>72. S.T. but ... when we move along the ...</td>
<td>She doesn't stimulate the pupil to clarify his idea losing an opportunity for helping him to develop the skill of communicating</td>
</tr>
<tr>
<td>73. $P_1$ the equator .....</td>
<td></td>
</tr>
<tr>
<td>74. $P_2$ the parallel .....</td>
<td></td>
</tr>
<tr>
<td>75. $P_3$ the meridian .....</td>
<td></td>
</tr>
<tr>
<td>76. S.T. .... along .... the meridian ....</td>
<td>$S_2$ says the &quot;right&quot; sentence without any clarification</td>
</tr>
<tr>
<td>77. $P_1$ oh! yes the weight gets bigger</td>
<td></td>
</tr>
<tr>
<td>78. $P_2$ that's true</td>
<td></td>
</tr>
<tr>
<td>79. $P_s$ (all speaking .... impossible to transcribe)</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
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</tr>
<tr>
<td><strong>80. S.T.</strong> you know ... the earth isn't exactly spherical ..... it is slightly flattened on the poles .. so the polar radius .. or better the distance between the poles and the centre of the earth ....</td>
<td>She never tries to keep order .. it looks as if she doesn't notice the noise. She acts as a transmitter of information. She is not concerned with the achievement of the aims she stated for the lesson.</td>
</tr>
<tr>
<td><strong>81. P</strong> it is smaller than the distance between the centre of the earth and the equator</td>
<td></td>
</tr>
<tr>
<td><strong>82. S.T.</strong> therefore the polar radius is smaller than the equator radius .... the latitude of a body is measured along the meridian ..... latitude means .....</td>
<td></td>
</tr>
<tr>
<td><strong>83. P</strong> .... but ... now is this geography .... or physics?</td>
<td>This utterance shows the lack of inter-disciplinarity that pupils are used to</td>
</tr>
<tr>
<td><strong>84. S.T.</strong> when we move all along a meridian we are changing the latitude of the body .... it varies ..... being larger at the poles .... (she speaks very quickly) ..... varying from the equator to the poles</td>
<td></td>
</tr>
<tr>
<td><strong>85. P₁</strong> the larger the distance ... the smaller the force</td>
<td>All these utterances from 85 to 91, illustrate a parallel conversation caught by the tape recorder while S₂ continues to talk.</td>
</tr>
<tr>
<td><strong>86. P₂</strong> so ... at the equator a person is lighter than at the poles</td>
<td>It is simultaneous with utterance 82 after which S₂ goes near to the OVH projector to project a transparency</td>
</tr>
<tr>
<td><strong>87. P₁</strong> ... yes</td>
<td></td>
</tr>
<tr>
<td><strong>88. P₂</strong> ... so it means ... that one goes to the poles ..... one arrives there fatter</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>------------</td>
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</tr>
<tr>
<td><strong>89.</strong> P₁</td>
<td>look here (he is reading the book) .... the variation of the weight .... the weight of a body increases as long as it is going to be transported from the equator to the poles ... the weight is increasing</td>
</tr>
<tr>
<td><strong>90.</strong> P₂</td>
<td>... so we get fatter when going to the poles</td>
</tr>
<tr>
<td><strong>91.</strong> P₁</td>
<td>it looks like</td>
</tr>
<tr>
<td><strong>92.</strong> S.T.</td>
<td>as long as we move towards the poles .... (pointing to the transparency) ...... and here I would like to ask &quot;Lúcia&quot; .... which is from these places the one which has ... between these three .... the one which has a greater latitude</td>
</tr>
<tr>
<td><strong>93.</strong> P₁</td>
<td>Brussels</td>
</tr>
<tr>
<td><strong>94.</strong> P₂</td>
<td>is the weight increasing Miss?</td>
</tr>
<tr>
<td><strong>95.</strong> P₃</td>
<td>yes ... it is</td>
</tr>
<tr>
<td><strong>96.</strong> P₄</td>
<td>the weight increases with latitude</td>
</tr>
<tr>
<td><strong>97.</strong> S.T.</td>
<td>you have here in this table .. some places and the respective latitudes .... and I'm asking ... which place .. from these ... has greater latitude</td>
</tr>
<tr>
<td><strong>98.</strong> P₁</td>
<td>Canada</td>
</tr>
<tr>
<td><strong>99.</strong> P₂</td>
<td>S. Francisco</td>
</tr>
<tr>
<td>100. S.T.</td>
<td>S. Francisco? .... does S. Francisco has larger latitude than any of the others?</td>
</tr>
<tr>
<td>101. P_s</td>
<td>no ... no</td>
</tr>
<tr>
<td>102. S.T.</td>
<td>then ... if the latitude varies from zero to ninety degrees which one has larger latitude .... the one with zero degrees or the one with 90?</td>
</tr>
<tr>
<td>103. P</td>
<td>90 ....</td>
</tr>
<tr>
<td>104. S.T.</td>
<td>then .. here ... between this and this .. which one has larger latitude?</td>
</tr>
<tr>
<td>105. P_s</td>
<td>Brussels</td>
</tr>
<tr>
<td>106. P_1</td>
<td>but there are there two cities with the same latitude</td>
</tr>
<tr>
<td>107. P_s</td>
<td>yes ... there are</td>
</tr>
<tr>
<td>108. S.T.</td>
<td>but ... I asked ... from those three ..... tell one with latitude larger than other</td>
</tr>
<tr>
<td>109. P</td>
<td>Brussels</td>
</tr>
<tr>
<td>110. S.T.</td>
<td>... if you notice .... the weight is ..... in what units? &quot;Alice&quot; ....</td>
</tr>
<tr>
<td>111. P_1</td>
<td>in grammes</td>
</tr>
<tr>
<td>112. P_2</td>
<td>in grammes</td>
</tr>
<tr>
<td>113. P_s</td>
<td>grammes? (laughing)</td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>114. ( P_s ) gramme-force</td>
<td></td>
</tr>
<tr>
<td>115. S.T. it is in gramme-force ... if we notice S. Francisco is at a smaller latitude than Brussels .... nevertheless the body's weight is bigger at S. Francisco or at Brussels?</td>
<td>Again she says the &quot;last word&quot;, the &quot;right&quot; one without asking pupils who talked about grammes what they mean by that. Pupils need only to read what is written in the table to answer the teacher's question</td>
</tr>
<tr>
<td>116. ( P_s ) Brussels</td>
<td></td>
</tr>
<tr>
<td>117. S.T. Brussels</td>
<td></td>
</tr>
<tr>
<td>118. ( P_1 ) of course</td>
<td></td>
</tr>
<tr>
<td>119. ( P_2 ) but why is it? ....</td>
<td></td>
</tr>
<tr>
<td>120. S.T. at Brussels the body's weight is ...</td>
<td>She doesn't listen to the doubts of the pupil</td>
</tr>
<tr>
<td>121. ( P_s ) bigger</td>
<td></td>
</tr>
<tr>
<td>122. ( P_1 ) smaller</td>
<td></td>
</tr>
<tr>
<td>123. ( P_2 ) bigger</td>
<td></td>
</tr>
<tr>
<td>124. S.T. bigger ... and it is also ... where the latitude is ...?</td>
<td>( S_2 ) is asking very closed questions which don't demand high levels of thinking</td>
</tr>
<tr>
<td>125. ( P_1 ) bigger</td>
<td></td>
</tr>
<tr>
<td>126. ( P_2 ) smaller</td>
<td></td>
</tr>
<tr>
<td>127. ( P_s ) bigger!!</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transcript</td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>128.</td>
<td>S.T. in which the latitude is bigger right? .. if we consider even here ... two bodys .. at the poles .. at the equator ... in Lisbon ... the latitude of the bodies ... is it bigger at the poles or at the equator?</td>
</tr>
<tr>
<td>129.</td>
<td>P₃ at the poles</td>
</tr>
<tr>
<td>130.</td>
<td>S.T. at the poles the latitude is bigger and ... so .. we can see that the mass of the body no. 1 which is unvariable ... it is always the same at each place ..... however ... can you tell ... how the weight is varying?</td>
</tr>
<tr>
<td>131.</td>
<td>P₁ it is increasing with ...</td>
</tr>
<tr>
<td>132.</td>
<td>P₂ it increases with ...</td>
</tr>
<tr>
<td>133.</td>
<td>P₃ .... it increases when .... it goes up ... (laughing)</td>
</tr>
<tr>
<td>134.</td>
<td>S.T. that is ... relative to the poles ... or relative to the equator?</td>
</tr>
<tr>
<td>135.</td>
<td>P it is bigger at the poles and ....</td>
</tr>
<tr>
<td>136.</td>
<td>S.T. it is bigger at the poles than at the ....</td>
</tr>
<tr>
<td>137.</td>
<td>P₃ equator</td>
</tr>
<tr>
<td>138.</td>
<td>S.T. the latitude is bigger at the poles ... at the equator is smaller ... so you are already able to tell me ... how does the weight varies with the latitude of the body</td>
</tr>
<tr>
<td>139.</td>
<td>P₃ (all speaking at the same time)</td>
</tr>
<tr>
<td>140.</td>
<td>S.T. I only want to hear you &quot;Pedro&quot;</td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>141. P</strong> as the body is going up from the equator to the poles it increases ....</td>
<td><em>S₂ doesn't stimulate the pupil to express himself correctly. Instead she makes closed questions which don't provide opportunities for the development of pupil's skill of communicating</em></td>
</tr>
<tr>
<td><strong>142. S.T.</strong> so ... the weight is increasing with? ....</td>
<td></td>
</tr>
<tr>
<td><strong>143. P₁</strong> latitude</td>
<td></td>
</tr>
<tr>
<td><strong>144. S.T.</strong> .... with the latitude ... you can write down ..... the weight increases with the latitude</td>
<td></td>
</tr>
<tr>
<td><strong>145. P₁</strong> the weight varies .... varies ... or would vary?</td>
<td><em>She is so concerned with covering the content of the lesson that she doesn't even listen to pupils' doubts</em></td>
</tr>
<tr>
<td><strong>146. S.T.</strong> now ... I'm asking you .. as we go away from equator towards the poles ... if the latitude is increasing ..... the distance to the center of the earth is still the same?</td>
<td></td>
</tr>
<tr>
<td><strong>147. P₃</strong> no ....</td>
<td></td>
</tr>
<tr>
<td><strong>148. P</strong> it's decreasing</td>
<td></td>
</tr>
<tr>
<td><strong>149. S.T.</strong> it's decreasing .... so ... when the latitude increases .. the weight also increases with the decreasing of the distance to the centre ....</td>
<td><em>S₂ doesn't ask why the distance is decreasing taking for granted its understanding</em></td>
</tr>
<tr>
<td><strong>150. P</strong> of the earth</td>
<td></td>
</tr>
<tr>
<td><strong>151. S.T.</strong> are you not yet seeing it? ... as I walk towards the poles ....</td>
<td></td>
</tr>
<tr>
<td><strong>152. P₁</strong> .. but .... if the earth is spherical</td>
<td><em>This pupil couldn't understand why the distance to center of the earth is decreasing as the latitude increases</em></td>
</tr>
<tr>
<td></td>
<td>Transcript</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>153</td>
<td>$P_2$ it is flat at the poles</td>
</tr>
<tr>
<td>154</td>
<td>S.T. ... please pay attention .... as I go away from the equator .. you have already said that the latitude is ...</td>
</tr>
<tr>
<td>155</td>
<td>$P$ increasing</td>
</tr>
<tr>
<td>156</td>
<td>S.T. ... it is increasing .... you already said ...... that the weight is also increasing</td>
</tr>
<tr>
<td>157</td>
<td>$P_3$ and the distance to the centre decreases</td>
</tr>
<tr>
<td>158</td>
<td>S.T. ... and the distance to the centre decreases ... you there &quot;Paulo&quot; stop with that .... &quot;Ravara&quot; how does the distance to the centre varies from the equator to the poles?</td>
</tr>
<tr>
<td>159</td>
<td>$P$ ... (laughing) (he is completely absent-minded) .... if it increases .... (laughing)</td>
</tr>
<tr>
<td>160</td>
<td>$P_3$ (laughing)</td>
</tr>
<tr>
<td>161</td>
<td>S.T. how does the distance to the centre of the earth vary ... when I move from the equator towards the poles?</td>
</tr>
<tr>
<td>162</td>
<td>$P$ .... it decreases</td>
</tr>
<tr>
<td>163</td>
<td>S.T. it decreases ... so (she writes on the blackboard) ...... the weight of body also varies with the distance to the centre of the earth. (While she is writing .... the majority of pupils are talking about things that have nothing to do with the lesson. Two girls are playing &quot;battle ships&quot;</td>
</tr>
</tbody>
</table>
Let's see now the variation of the weight with another quantity you have already studied in geography ... the altitude of a body? ....

<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>164. <strong>P</strong> the altitude of a body? ...</td>
<td>Again the same inaccuracy &quot;The altitude of a body&quot;</td>
</tr>
<tr>
<td>165. <strong>S.T.</strong> yes ....</td>
<td>She doesn't clarify the pupils' doubts</td>
</tr>
<tr>
<td>166. <strong>P</strong> the larger the altitude the lesser the weight</td>
<td></td>
</tr>
<tr>
<td>167. <strong>S.T.</strong> if you look at here (she points the OVH transparency) we have here two places with the same altitude ... and another with a different one ... you can see how does the weight vary with altitude</td>
<td></td>
</tr>
<tr>
<td>168. <strong>P</strong> it's bigger ... (everybody is speaking impossible to transcribe)</td>
<td></td>
</tr>
<tr>
<td>169. <strong>S.T.</strong> &quot;Lidia&quot; can you tell me?</td>
<td></td>
</tr>
<tr>
<td>170. <strong>P</strong> as the altitude increases ... the weight also increases</td>
<td></td>
</tr>
<tr>
<td>171. <strong>P</strong> no ..... no</td>
<td>In 172 <strong>P</strong> is calling his peers' attention to the two pupils playing &quot;battle ships&quot;. <strong>S</strong> didn't notice any one of the things</td>
</tr>
<tr>
<td>172. <strong>P</strong> look those two playing ..</td>
<td></td>
</tr>
<tr>
<td>173. <strong>S.T.</strong> tell me ... what happens when you move from a place at 110 m of altitude to a place at 1880 m?</td>
<td></td>
</tr>
<tr>
<td>174. <strong>P</strong> the weight decreases</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>175. S.T.</td>
<td>the weight decreases .... thus the weight increases with latitude ... and .. with altitude?</td>
</tr>
<tr>
<td>176. P_s</td>
<td>it increases ... it decreases ...</td>
</tr>
<tr>
<td>177. S.T.</td>
<td>it decreases ... on the other hand ... just as you saw here ... decreasing the altitude ... what varies? ...... relative to ..... what varies?</td>
</tr>
<tr>
<td>178. P</td>
<td>relative to altitude?</td>
</tr>
<tr>
<td>179. S.T.</td>
<td>no ... to the variation of altitude how does the distance to the centre of earth varies?</td>
</tr>
<tr>
<td>180. P</td>
<td>..... it increases</td>
</tr>
<tr>
<td>181. S.T.</td>
<td>... the distance to the centre of the earth increases as we go upwards from the crust of the earth .... the distance to the centre of the earth increases also .... whereas with the latitude .... look as we get away from equator towards the poles .... the distance decreases .... here (pointing to table on the OVH) the distance is increasing ... and this is already pointed here ... thus the weight varies with the latitude ... and with the altitude and that implies .... I mean .... it is already in here ... I mean .... the weight varies with the distance to the centre of the earth precisely with the altitude and with the latitude of the place ......... you can see here .... more values ......</td>
</tr>
</tbody>
</table>

S_2 reinforces the answers "decreases" without a clarification of the pupils who said "increases"

The only demanded skill is the reading of tables and its interpretation

S.T. summarizes the conclusions draw until now

C_4
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>you also talked about another quantity which can vary the bodies' weight ..... you have been told that the bodies' weight varies with the planet on which it is ... you were told that the body's weight was smaller in the Moon than on earth ..... so ..... the body's weight varies also ..... with?</td>
<td></td>
</tr>
<tr>
<td>182. P</td>
<td>its mass</td>
</tr>
<tr>
<td>183. S.T.</td>
<td>how could it be? .... and with the planet .. if the body is the same .... its mass is the same .. only the planet is different ....</td>
</tr>
<tr>
<td>184. P_s</td>
<td>(everybody speaking)</td>
</tr>
<tr>
<td>185. S.T.</td>
<td>say you there .....</td>
</tr>
<tr>
<td>186. P</td>
<td>the distance between the planet and the earth varies</td>
</tr>
<tr>
<td>187. S.T.</td>
<td>the distance from the planet to the earth? The answer given by the pupil (186) is consistent with the conclusions drawn before. Not asking the pupils an explanation she is unable to help him to progress in his cognitive development in a constructivist view</td>
</tr>
<tr>
<td>188. P_s</td>
<td>(everybody speaking)</td>
</tr>
<tr>
<td>189. S.T.</td>
<td>may I speak?</td>
</tr>
<tr>
<td>190. P_s</td>
<td>yes ... you may ...</td>
</tr>
<tr>
<td>191. S.T.</td>
<td>you know that the planets are in their orbits ..... and there are interaction forces among them ... however .... a body on the Moon ... is it influenced by the gravity of the earth?</td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
</tr>
</tbody>
</table>
| 192. $P_s$ | .... no ...
| | ... yes ....
| | ... no ....
| | ... it can be .... |
| 193. S.T. | no ... the body's weight on the Moon .. "João" you are always talking .... the body's weight isn't due to the force that the earth exerts on it .... but to the force exerted by the Moon ... it was because of this that in the last lesson .... I told you ....... can I say a body's weight is the force with which the earth attracts it? |
| 194. $P_s$ | no .... no |
| 195. S.T. | if ... the body is on Jupiter or Mars ...... it isn't the earth ... the body is the same ... what varies .... isn't the distance to the earth ... but the planet ... attention it is the only thing that is varying |
| 196. $P_s$ | (the majority of pupils are totally disinterested ...... talking among themselves and not paying attention to what's going on in the lesson) |
| 197. S.T. | ... when the planet is different .... consequently ...... we have a different mass from the mass of the earth .... and that is going to make the body's weight on the earth .. look here at the table ... body 1 has 8,15 when on the Moon ... while on any place on earth its weight is .... bigger or smaller? |
| 198. $P_s$ | bigger ...
| | smaller .... |

This explanation doesn't clarify pupils' understanding about the phenomenon

Nobody claims about the teacher statement that "the distance to the centre of the earth doesn't vary". Opportunity for the development of critical mind hasn't been provided. Pupils are too disinterested to be critical

She continues to talk not aware of pupils disinterest
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>199. S.T.</strong>... bigger ... and that means that ... where is the force of gravity bigger?</td>
<td>Again she reinforces the &quot;right&quot; answer without asking for an explanation by the pupils who answered differently</td>
</tr>
<tr>
<td><strong>200. P</strong> on earth ....</td>
<td></td>
</tr>
<tr>
<td><strong>201. S.T.</strong> on earth ..... on earth the gravity is bigger than on the moon ..... and that is precisely because the variation of masses .... the mass of the moon (she writes on the blackboard) is</td>
<td></td>
</tr>
<tr>
<td><strong>202. P</strong> do we need to know that?</td>
<td></td>
</tr>
<tr>
<td><strong>203. S.T.</strong> no ... it's only for you to see how the bodies' weights vary with the mass of planets ... while the mass of earth is $5.976 \times 10^{24}$ ... as you see the mass of earth is bigger than the mass of moon .. the mass of Jupiter is about 302.3 times the mass of earth then I will ask &quot;António&quot; where has a body bigger weight .. on Jupiter or on earth?</td>
<td></td>
</tr>
<tr>
<td><strong>204. P</strong> ... on earth</td>
<td></td>
</tr>
<tr>
<td><strong>205. P</strong> (laughing)</td>
<td></td>
</tr>
<tr>
<td><strong>206. S.T.</strong> .... well ... let's see .. when we talked about earth and moon .. you said that the body's weight was bigger on the earth because the earth has a mass ....</td>
<td></td>
</tr>
<tr>
<td><strong>207. P</strong> smaller ...</td>
<td></td>
</tr>
<tr>
<td><strong>208. P</strong> bigger (laughing)</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>209. S.T.</td>
<td>bigger or smaller than the mass of the moon?</td>
</tr>
<tr>
<td>210. P_s</td>
<td>bigger ... bigger ..</td>
</tr>
<tr>
<td>211. S.T.</td>
<td>bigger .. so here .. you have .. the bigger the mass of the planet the bigger the weight of the body .. if I move from earth to Jupiter .. how does the weight vary?</td>
</tr>
<tr>
<td>212. P</td>
<td>... it increases</td>
</tr>
<tr>
<td>213. S.T.</td>
<td>the weight increases ... the weight increases ... if we measure the weight of a body on the earth and on Jupiter .. its weight on Jupiter is much bigger ....</td>
</tr>
<tr>
<td>214. P</td>
<td>because the mass is bigger</td>
</tr>
<tr>
<td>215. S.T.</td>
<td>because the mass of Jupiter is bigger ... it wasn't the mass of the body that varied ... it was the mass of the planet under consideration ..... the weight varies also .... with what?</td>
</tr>
<tr>
<td>216. P_s</td>
<td>with the mass of the planets .... (the majority of the pupils are disinterested from what's going on in the lesson) ..........</td>
</tr>
<tr>
<td>217. S.T.</td>
<td>.... well ... I want now .. that &quot;João&quot; who has been talking all the time .... I want him to tell me .... if I move from the base of the mountain of &quot;Estrela&quot; to the top of the mountain how does my weight vary?</td>
</tr>
<tr>
<td>218. P</td>
<td>it decreases</td>
</tr>
<tr>
<td>219. S.T.</td>
<td>why does it decreases?</td>
</tr>
</tbody>
</table>

It is the second time on the whole lesson she asks why
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>220. P</td>
<td>because the weight varies with the altitude</td>
</tr>
<tr>
<td>221. S.T.</td>
<td>the weight varies with the altitude and with the latitude .... but ... in this case what did vary? ..... once you don't know either the altitude or the latitude ..... what did increase there?</td>
</tr>
<tr>
<td>222. P</td>
<td>(silence)</td>
</tr>
<tr>
<td>223. P_s</td>
<td>(some speaking)</td>
</tr>
<tr>
<td>224. S.T.</td>
<td>it's &quot;João&quot; who should answer ..... look I didn't give any values of latitude or altitude ..... what did vary there?</td>
</tr>
<tr>
<td>225. P</td>
<td>(silence)</td>
</tr>
<tr>
<td>226. S.T.</td>
<td>related to the centre of the earth .... what did vary? ... it varies with the latitude and with altitude right ... it's true ... but more concretely .. say it ..... the distance .....</td>
</tr>
<tr>
<td>227. P</td>
<td>the distance to the centre of the earth increased</td>
</tr>
<tr>
<td>228. S.T.</td>
<td>the distance to the centre of the earth increased ..... if the distance to the centre of the earth increased ... the weight of the body .....?</td>
</tr>
<tr>
<td>229. P</td>
<td>decreased</td>
</tr>
<tr>
<td>230. S.T.</td>
<td>the altitude increases .... increasing the altitude ..... the distance to the centre of the earth increases ..... the weight of the body decreases ....... for instance when you move from the base of a mountain to the top ... what does vary also there?</td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>231. P</td>
<td>.... from the base of the mountain upwards ....... the distance .....</td>
</tr>
<tr>
<td>232. S.T.</td>
<td>the distance from the centre of the earth also varies ... how? .... decreasing or increasing?</td>
</tr>
<tr>
<td>233. P</td>
<td>increasing</td>
</tr>
<tr>
<td>234. S.T.</td>
<td>increasing ... if the distance to the centre of the earth increases ... the weight ..... decreases ......... is that clear? ... do you know now .... what makes the variation of the weight of a body?</td>
</tr>
<tr>
<td>235. P₃</td>
<td>yes ... yes ..</td>
</tr>
<tr>
<td>236. S.T.</td>
<td>now .. at the same place .. to the same place on earth .. let's see again body 1 (referring to the table) and body 2</td>
</tr>
<tr>
<td>237. P₃</td>
<td>(almost all the pupils are talking about other subjects rather than on the lesson subject)</td>
</tr>
<tr>
<td>238. S.T.</td>
<td>I'm asking &quot;Arnaldo&quot; ... tell me ... the weight of body 1 in Lisbon ... how much is it?</td>
</tr>
<tr>
<td>239. P₁</td>
<td>49.0</td>
</tr>
<tr>
<td>240. P₂</td>
<td>49.6</td>
</tr>
<tr>
<td>241. P₃</td>
<td>0.6 ...</td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td>242. S.T.</td>
<td>in Lisbon it is 49.6 ... and its mass?</td>
</tr>
<tr>
<td>243. P_s</td>
<td>... one ... one</td>
</tr>
<tr>
<td>244. P</td>
<td>the mass of body 1 .....</td>
</tr>
<tr>
<td>245. S.T.</td>
<td>it's five</td>
</tr>
<tr>
<td>246. P_s</td>
<td>of yes ... it's five</td>
</tr>
<tr>
<td>247. S.T.</td>
<td>and its weight in Lisbon? ... how much is it?</td>
</tr>
<tr>
<td>248. P_s</td>
<td>48.9 ... 9.8 ....</td>
</tr>
<tr>
<td>249. S.T.</td>
<td>and its mass?</td>
</tr>
<tr>
<td>250. P_s</td>
<td>it's one ...</td>
</tr>
<tr>
<td>251. S.T.</td>
<td>&quot;Arnaldo&quot; ...?</td>
</tr>
<tr>
<td>252. P_1</td>
<td>what do you want Miss?</td>
</tr>
<tr>
<td>253. P_2</td>
<td>the mass</td>
</tr>
<tr>
<td>254. S.T.</td>
<td>what do I want? ... if you have been paying attention ... you would know ... these two relations $\frac{p_1}{m_1}$ and $\frac{p_2}{m_2}$ ... what do you see in them? ... are they equal?...</td>
</tr>
<tr>
<td>255. P_s</td>
<td>(too much noise)</td>
</tr>
<tr>
<td></td>
<td>(the bell rings .... the lesson finished).</td>
</tr>
</tbody>
</table>
3. Discussion

To complement the analysis made during the transcript of the lesson, an attempt will be made to find out how did the student teacher S$_2$ guide the interaction towards the achievement of the stated aims.

Two aspects will be considered: i) the nature; ii) the content of the interaction.

i) The nature of the interaction

The approach chosen by S$_2$ for the interaction of the unit of "Force and Mass" was not based on the information gathered through the diagnostic questionnaire.

From the beginning of the lesson S$_2$ tried to promote a class discussion but she was unable to guide it in order to rise the pupils' interest on it. Some reasons for this fact can be advanced.

Since the study of the unit did not start from what pupils already knew, from the conceptions and meanings for words they already held, their interest was not fostered. Their ideas were not challenged and thus they showed no signs of interest in participating in the discussion. Evidence of this was produced by observation and associated notes.

Most of the pupils were talking to each other about subjects not related to the lesson's. Others were playing "battle ships". Most of the time, S$_2$ did not notice neither of the situations. When such situations were noticed she was unable to handle them (e.g. from utterances 159 to 193).

The more frequent mode of interaction followed the pattern

<table>
<thead>
<tr>
<th>Opening (by teacher)</th>
<th>Answering (by pupils)</th>
<th>Follow-up (by teacher)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a question</td>
<td>a response</td>
<td>evaluation and/or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>comment</td>
</tr>
</tbody>
</table>

In this particular lesson the follow-up was mainly a reinforcement of the "right" answer without any attempt to investigate the ideas underlying the "wrong" answers. Instances of this situation are illustrated in the following sequence of utterances:63 to 76; 110 to 130; 175 to 181; 191 to 193; 197 to 203; 238 to 242.)

The nature of the interaction did not provide opportunities for
inter-pupil discussion in which the whole class could participate. The inter-pupil discussions taking place were isolated and parallel to the teacher discourse. An example of this is given by the sequence 85 to 91. In the conversation, one of the difficulties found through the diagnostic questionnaire was disclosed: the difficulty in distinguishing between the concept of mass and the concept of weight: "... the weight increases when we go towards the poles ... so we get there fatter ...". This view rested untouched because no opportunities were provided by S2 for an overt discussion between pupils. It was apparent her greater concern to cover the lesson plan than to listen to pupils' ideas.

Although S2 used an interaction based on questioning, she used, all the time, convergent and factual questions, not demanding high level of thinking and allowing no elaborated answers (one or two words or very short sentences). This form of interaction does not foster pupils' curiosity, interest and motivation. Neither does it challenge pupils intuitive ideas.

According to the task analysis of the pre-active phase, the aims intended to be achieved were: to help pupils to develop the capacity of critical-mindedness, the skills of observing, recording and interpreting data, manipulating (measuring instruments) and communicating. From the analysis of the lesson transcript no opportunities were found in which these "abilities" could be developed. S2's performance did not allow for this. Throughout the interaction a concern to cover the topic was apparent, being the flow of knowledge fully controlled by the student teacher. Nevertheless, only objective (1) was approached.

Only the skill of interpreting tables could have been developed, though the skill needed was of very low level of demanding.

The interaction was very noisy not because the pupils' participation was desorganized, as happened during other lessons analysed, but because the majority of the pupils were talking among themselves about subjects different from the lesson subject.

The nature of the interrelationship between S2 and the pupils was very cold and distant. She acted as she was interested only in getting, at the end of the lesson, people saying "how does the weight vary with the latitude and with the altitude" rather than helping youngsters to develop their "scientific-like aspects".

The pupils acted accordingly. They were distant from the teacher and from the subject of the lesson. The majority of them showed signs of absent-mindedness.
Talking about this situation, after the lesson, $S_2$ commented:

"I didn't enjoy the lesson .. I don't know what they (the pupils) have ... they don't seem interested in this ... really this subject isn't very interesting .... but anyway .. I'm not happy with this .." 

ii) The content of the interaction

In the previous lessons, the concepts of force and weight, as $S_2$ said, were already explored. Her presentation of the content of this lesson followed closely the pattern suggested by the textbook chosen for the 9th grade by the school. In that pattern no account has been given to the pupils' intuitive ideas. Thus the approach taken did not go to the encounter of those ideas.

During the lesson a situation occurred in which it could be noticed the difference between "teachers' science" ans "scientists' science". I would rather talk about "student teachers' science" because it reveals a great lack of reflection on the situations presented. This happened when $S_2$ asked the pupils to present situations in which they could feel that their weights were varying. $S_2$'s confusion between the two concepts, "weight" and "apparent weight" led her to reinforce the pupils' misunderstanding of the situation presented (sequence 11 to 63) and conveyed the idea that the weight of a body varies at the same place on earth depending on the milieu where it is. Similar mistakes have been found in some textbooks related to the concept of "imponderability".

Conclusion

A priori, the nature of the interaction could allow for an approach to the teaching of the lesson's content fostering the achievement of the stated objectives and aims. But it required from $S_2$ a completely different performance. Firstly, she should have used the information gathered about her pupils' alternative conceptions as the starting point for the discussion and for guiding it. Secondly, she should present the phenomena under study in a challenging way, providing situations that could challenge pupils' ideas, presenting anomalous situations that could bring those ideas into conflict. Thirdly, she should explore in a better and more useful way some of the opportunities provided for developing scientific process skills. When using the table, she should provide opportunities for helping the development of high level skills. For example, she should help the pupils to infer, from the data presented on the table, the factors on which the weight depends.
Summing up: the lesson was conducted in a conventional way. The teacher's role being a transmitter instead of a facilitator one. The implications of this for the class environment, pupils' attitudes and teacher's feeling were well elicited from the analysis of the lesson transcript.
APPENDIX 15

Task analysis, transcript and analysis of a lesson performed by S5

(the first lesson on "Optics")
(content of the lesson: "light and its properties")
## 1 - Task Analysis of the Pre-Active Phase of the First Lesson on Optics Performed by S5

| A. Statement of the aims of the lesson in terms of pupils' development of "abilities" | B. Statement of the objectives of the lesson in terms of pupils' learning | C. Analysis of the lesson aims and objectives to establish the link between them | D. Decision on type of:  
  a) pupils activities  
  b) nature of presentation  
  c) nature of feedback to be provided  
  d) evaluation |
|---|---|---|---|
| Through the contents of this lesson pupils should be helped to (see App. 7):  
  A2  
  A3  
  C1  
  C6  
  C4  
  C7  
  D1 | After the lesson pupils should be able to:  
  . identify light as a source of energy  
  . hold the model of light propagation in space  
  . explain how does light move  
  . explain the meaning of beam of light | All the objectives are appropriate for the achievement of the aims proposed | a) discussion participation  
  b) group discussion based on the information gathered through the diagnostic questionnaire  
  c) teacher's verbal and non-verbal feedback  
  . teacher encourages pupils' participation  
  . peers' feedback  
  d) through checking pupils' ability to participate in group discussion, to apply learning in new situations |
2 - TRANSCRIPT AND ANALYSIS OF THE LESSON PERFORMED BY S₅

In the following each contribution is numbered consecutively. The source being indicated by S.T. for student teacher and pupil contributions, i.e. any pupil. Various pupils contributions at the same time, P₅, and occasionally different pupil contributions are indicated by P₁, P₂, etc.

<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
<th>Ain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. S.T.</td>
<td>Today we are going to discuss some of the questions of the diagnostic test ... for instance .... what happens to green plants when placed in the dark?</td>
<td>S₅ is concerned with elucidating lesson's purposes. She asks a question to the whole class encouraging pupils' discussion.</td>
</tr>
<tr>
<td>2. P₁</td>
<td>they wither away and die .. they need to carry the photosynthesis .... and for that they need sunlight ... otherwise they will die.</td>
<td></td>
</tr>
<tr>
<td>3. P₂</td>
<td>not necessarily the sunlight</td>
<td></td>
</tr>
<tr>
<td>4. S.T.</td>
<td>why?</td>
<td>S₅ pushes the pupil to clarify his comment.</td>
</tr>
<tr>
<td>5. P</td>
<td>what is needed is light ... any kind of light</td>
<td></td>
</tr>
<tr>
<td>6. S.T.</td>
<td>well ... so what happens during the photosynthesis?</td>
<td>The S.T., S₅, didn't explore the last comment and returns to the first question.</td>
</tr>
<tr>
<td>7. P₅</td>
<td>..... (silence) ...........</td>
<td></td>
</tr>
<tr>
<td>8. S.T.</td>
<td>you there .. &quot;Vasco&quot; ....</td>
<td>S₅ encourages one particular pupil naming him</td>
</tr>
<tr>
<td>9. P₅</td>
<td>........ (silence) ................</td>
<td></td>
</tr>
<tr>
<td>10. S.T.</td>
<td>does anybody know?</td>
<td>She stimulates pupils' participation.</td>
</tr>
<tr>
<td>11. P₅</td>
<td>(some pupils talking at the same time)</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>------------</td>
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</tr>
<tr>
<td>12. \textbf{P}_1 \text{ what is photosynthesis? ...}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. \textbf{P}_2 \text{ but in what sense?}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. S.T. \text{ well what happens during the photosynthesis}</td>
<td>Pupils asking for a clarification of the question .... \textbf{S}_5 answering with the same utterance</td>
<td></td>
</tr>
<tr>
<td>15. \textbf{P} \text{ it is ... er ... (laughing) when the sap comes up in the plant ... there is also ... sunlight and carbon dioxide ... and on the other side the sap with food comes down ...}</td>
<td>The pupil shows a great difficulty in expressing himself</td>
<td></td>
</tr>
<tr>
<td>16. S.T. \text{ the sap with food comes down? ... What do you mean by that?}</td>
<td>\textbf{S}_5 asks for a clarification ....... but she didn't give opportunity to the pupil to clarify and to express himself in a better way, because she asks immediately another question that shifts the direction of the discussion</td>
<td></td>
</tr>
<tr>
<td>17. \text{why is it light necessary?}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. \textbf{P}_1 \text{ without light it wouldn't be possible ... the light is one of the essential components for the realization of the photosynthesis}</td>
<td>This pupil has an idea but he is unable to explain it. \textbf{S}_5 lost an opportunity to help him to develop his capacity of communication and self-confidence. The others' laughs could have inhibited this pupil. \textbf{S}_5 is more concerned with the control of the class</td>
<td></td>
</tr>
<tr>
<td>19. \textbf{P}_2 \text{ I think it has the function of an oven ....}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. \textbf{P}_5 \text{ ....... (everybody laughing) ...}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. S.T. \text{ what?}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. \textbf{P}_5 \text{ ....... (everybody laughing) ...}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. S.T. \text{ well ... if plants are in the dark ... there is no sunlight falling on the plants .... but ...... look they continue to have ... because they are into a flower pot with water and earth ... they continue to have food ... so why can they realize the photosynthesis if there is no light?}</td>
<td>\textbf{S}_5 returns to the main problem without investigating what the pupil had in mind when he made utterance 19. \textbf{S}_5 reinforces the intuitive ideas some pupils have about the plants obtaining their food from environment, rather than manufacturing it internally</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>24. P</td>
<td>This utterance shows the unclear ideas that the pupil has about the process of photosynthesis</td>
<td></td>
</tr>
<tr>
<td>25. S.T.</td>
<td>S5 tries to focus on the role of the light perhaps in an attempt to clarify ideas</td>
<td></td>
</tr>
<tr>
<td>26. P</td>
<td>S5 asks for clarification</td>
<td></td>
</tr>
<tr>
<td>27. S.T.</td>
<td>Asking a question without naming a pupil S5 lost the control of the class and it pushed her to advance towards the topic of energy which wasn't spoken until now</td>
<td></td>
</tr>
</tbody>
</table>
| 28. P      | She probably caught this answer (in \( H_2 \) and \( O_2 \)) from some pupil nearby but she returns to the main question without a clarification of the "in \( H_2 \) and \( O_2 \)"
<p>| 29. S.T.   | |
| 30. P      | |
| 31. S.T.   | |
| 32. P      | |
| 33. S.T.   | |
| 34. P      | |
| 35. P      | |</p>
<table>
<thead>
<tr>
<th></th>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>S.T. there are chemical reactions</td>
<td>Although $S_5$ is encouraging pupils' participation, that is done in a disorganized way and not in a helpful one for the development of the skills of interpreting and communicating</td>
</tr>
<tr>
<td>37</td>
<td>P the plants capture carbon and release oxygen</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>S.T. they release oxygen .... yes ... and ....</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>P .... and we breath oxygen and release carbon dioxide</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>S.T. right ... so the plants release oxygen ... well what happens? ..... the energy of sunlight gets into the plants .......... this helps the plants to carry out the photosynthesis ... as you said ..... during the photosynthesis some chemical reactions take place ... and ... which is the energy change that takes place?</td>
<td>She asks for an interpretation of the phenomena in terms of change of energy</td>
</tr>
<tr>
<td>41</td>
<td>P during the photosynthesis?</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>S.T. yes ... can you say it &quot;Sardo&quot;?</td>
<td>She is encouraging this pupil to interpret the phenomenon</td>
</tr>
<tr>
<td>43</td>
<td>$P_S$ ..... (general babble) ......</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>S.T. please could you speak loudly so everybody can listen?</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>P (inaudible)</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>$P_S$ (too much noise)</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>P I'm not listening anything</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
<td></td>
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<tr>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>48. S.T. speak louder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>49. P (still inaudible)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50. S.T. SPEAK LOUDER ... could you come to the blackboard please</td>
<td>She couldn't control the class and decided to send the pupil to the blackboard</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51. S.T. please draw a diagram showing the energy changes that take</td>
<td></td>
<td></td>
</tr>
<tr>
<td>place during photosynthesis ... (During this situation the pupil and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S₅ talk to each other near the blackboard leaving the rest of the class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>out of the conversation). The pupil writes on the blackboard</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52. P [energy from sunlight → chemical energy]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>53. S.T. so there are some chemical reactions there is a change of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...... what? of what kind of energy?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>54. P chemical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55. S.T. then what conclusions can we draw from all this? ......</td>
<td>S₅ makes a synthesis of what have been said ...... she draws the conclusion by herself</td>
<td></td>
</tr>
<tr>
<td>we can draw the conclusion that light is luminous energy which in this</td>
<td></td>
<td></td>
</tr>
<tr>
<td>case is going to be changed into chemical energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>56. S.T. Now tell me .... why are there no green plants at approx. 120</td>
<td>She calls for an interpretation which could lead to another evidence for</td>
<td></td>
</tr>
<tr>
<td>m under the sea?</td>
<td>drawing the conclusion &quot;light is a source of energy&quot;</td>
<td></td>
</tr>
<tr>
<td>57. P₁ because after 120 m the light starts disappearing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>58. P₂ .... the sea doesn't let the light get through</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
59. P₃ .... there is light but its intensity is weak

60. S.T. the intensity is weak .... what happens ..... (she draws on the blackboard) we have here the sea surface and here the sun ... what happens to the sun rays ..... what happens to the light?

In insisting in questioning, S₅ is concerned with helping the development of skills of interpreting and communicating

61. P the light starts to get into the water ..... but the rays are not strong enough in order to get into the bottom of the sea ... because the water is going ......

62. S.T. what does the water do?

She encourages the pupil to finish her interpretation

63. P .... I think it is going to absorb some of the light

64. S.T. it is going to absorb some of the light ..... so .... what conclusion can you draw from that?

65. P ... the water absorbs light

66. S.T. the water absorbs light ...

Reinforcing

67. P and not only (other pupil)

68. S.T. so?

She encourages pupils discussion

69. Pₛ (a discussion takes place between some pupils but it was impossible to transcribe)

70. S.T. ... well the energy from the sun when getting into the the water ... what is the water going to do?

She stimulates pupils' process of thinking
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>71. P</td>
<td>it is absorbing energy</td>
</tr>
<tr>
<td>72. S.T.</td>
<td>yes .. and at about 120 m there is no more luminous energy and because of that there is no green plants because there is no luminous energy</td>
</tr>
<tr>
<td>73. P</td>
<td>... but the water is going to reflect the light ....</td>
</tr>
<tr>
<td>74. S.T.</td>
<td>the water is going to reflect the light ... so what happens?</td>
</tr>
<tr>
<td>75. P</td>
<td>I can't explain</td>
</tr>
<tr>
<td>76. S.T.</td>
<td>can you come here to the backboard and try to explain to us what happens .. you said that the water is going to reflect the light</td>
</tr>
<tr>
<td>77. P₁</td>
<td>yes it is going to reflect the light ..... but not all the light</td>
</tr>
<tr>
<td>78. P₂</td>
<td>there are some rays that get into the water and other are reflected</td>
</tr>
<tr>
<td>79. S.T.</td>
<td>so some get into and other are reflected .... what happens?</td>
</tr>
<tr>
<td>80. P</td>
<td>I think that's a wrong theory</td>
</tr>
<tr>
<td>81. S.T.</td>
<td>what? ... is it a wrong theory ... what do you mean by that?</td>
</tr>
<tr>
<td>82. P₃</td>
<td>(laughing) .... it isn't ..........</td>
</tr>
<tr>
<td>83. P</td>
<td>.... why should they be reflected?</td>
</tr>
</tbody>
</table>

Again she makes the synthesis of what had been said

She encourages the pupil to explain his view by means of a iconic representation

She is a bit lost which is shown all along this sequence (from 79. to 89.)
<table>
<thead>
<tr>
<th></th>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>84</td>
<td>S.T.  <em>when you are near a smooth surface of water can't you see your image on the water?</em></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>P   <em>yes I can</em></td>
<td></td>
</tr>
<tr>
<td>86</td>
<td>S.T. <em>so ... what happens?</em></td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>Pₜ (<em>laughing</em>)</td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>S.T. <em>what happens besides reflection?</em></td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>Pₜ (<em>silence</em>)</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>S.T. <em>when the ray gets into? ....</em></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>P   (<em>silence</em>)</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>S.T. <em>what is the consequence of this reflection of light?</em></td>
<td><em>She stimulates pupils' thinking</em></td>
</tr>
<tr>
<td>93</td>
<td>P₁  <em>there is a loss of light's intensity getting into the water</em></td>
<td></td>
</tr>
<tr>
<td>94</td>
<td>P₂  <em>there is a waste of energy</em></td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>S.T. <em>a waste of energy that goes to ....</em></td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>P   <em>to the air</em></td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>S.T. <em>yes ... have you ever tried to light a cigarette with a magnifying glass?</em></td>
<td><em>She is asking for more evidence on light being a source of energy</em></td>
</tr>
<tr>
<td>98</td>
<td>Pₜ  <em>... (everybody speaking at the same time) ....</em></td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>P   <em>it is easy with a solar-lighter</em></td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
<td></td>
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<tr>
<td>------------</td>
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<td></td>
</tr>
<tr>
<td><strong>100. S.T.</strong></td>
<td>what happens in the solar-lighter?</td>
<td></td>
</tr>
<tr>
<td><strong>101. P</strong></td>
<td>the light falls on the magnifier .... the sun rays are all concentrated into one point ...... the luminous energy focusses on the cigarette and it lights .. because when the light falls only on one point ......</td>
<td></td>
</tr>
<tr>
<td><strong>102. S.T.</strong></td>
<td>come here (to the blackboard) to make a drawing showing what you are saying</td>
<td></td>
</tr>
<tr>
<td><strong>103. P</strong></td>
<td>(the pupil goes to the blackboard and draws something like this)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the sunbeams fall on the magnifier which concentrates them on the point of the cigarette</td>
<td></td>
</tr>
<tr>
<td><strong>104. S.T.</strong></td>
<td>does everybody agree with this?</td>
<td></td>
</tr>
<tr>
<td><strong>105. P₁</strong></td>
<td>I agree</td>
<td></td>
</tr>
<tr>
<td><strong>106. P₂</strong></td>
<td>I don't</td>
<td></td>
</tr>
<tr>
<td><strong>107. P₃</strong></td>
<td>(all speaking nobody is listening to anybody)</td>
<td></td>
</tr>
<tr>
<td><strong>108. S.T.</strong></td>
<td>please don't speak all at the same time. One at a time</td>
<td></td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>This pupil is answering to teacher's question 97. The question of the solar-lighter wasn't explored</td>
<td></td>
</tr>
<tr>
<td></td>
<td>She encourages the pupil to express himself through drawings</td>
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<tr>
<td></td>
<td>Calling for criticism</td>
<td></td>
</tr>
<tr>
<td></td>
<td>She shows some difficulty in controlling the discussion</td>
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<td></td>
<td>Transcript</td>
<td>Analysis</td>
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</tr>
<tr>
<td>109.</td>
<td>P₁</td>
<td>I don't agree .. he drew the sunbeams convergent and they aren't .. they are divergent</td>
</tr>
<tr>
<td>110.</td>
<td>P₂</td>
<td>but don't you see .. the magnifier makes them convergent</td>
</tr>
<tr>
<td>111.</td>
<td>P₃</td>
<td>(all speaking at the same time)</td>
</tr>
<tr>
<td>112.</td>
<td>S.T.</td>
<td>please don't speak at the same time .. tell me .. do you agree with this drawing?</td>
</tr>
<tr>
<td>113.</td>
<td>P₃</td>
<td>(all speaking at the same time)</td>
</tr>
<tr>
<td>114.</td>
<td>P</td>
<td>.... I don't know I never tried it</td>
</tr>
<tr>
<td>115.</td>
<td>S.T.</td>
<td>come here ... near the window (it was a sunny day) does anybody have a cigarette?</td>
</tr>
<tr>
<td>116.</td>
<td>P₃</td>
<td>(laughing ...) yes ... yes</td>
</tr>
<tr>
<td>117.</td>
<td>P</td>
<td>I have got one ....... here it is Miss (the pupil near the window holds the magnifier and the cigarette and tries to light it)</td>
</tr>
<tr>
<td>118.</td>
<td>S.T.</td>
<td>so tell me what is .. needed .. in order to light it?</td>
</tr>
<tr>
<td>119.</td>
<td>P₃</td>
<td>(meantime everyone is giving instructions to the peer near the window)</td>
</tr>
<tr>
<td>120.</td>
<td>S.T.</td>
<td>what is needed in order to light it?</td>
</tr>
<tr>
<td>121.</td>
<td>P₁</td>
<td>the rays of the sun should fall on the top of the cigarette</td>
</tr>
<tr>
<td></td>
<td>Transcript</td>
<td>Analysis</td>
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</tr>
<tr>
<td>122.</td>
<td>$P_2$ they need to fall on perpendicularly</td>
<td></td>
</tr>
<tr>
<td>123.</td>
<td>$P_3$ oh ... in this way it's impossible ... not even tomorrow</td>
<td></td>
</tr>
<tr>
<td>124.</td>
<td>S.T. why do you say ... not even tomorrow?</td>
<td></td>
</tr>
<tr>
<td>125.</td>
<td>$P$ because in that way .. it .. is not going to work</td>
<td></td>
</tr>
<tr>
<td>126.</td>
<td>$P_s$ (laughing)</td>
<td></td>
</tr>
<tr>
<td>127.</td>
<td>S.T. what must happen on the magnifier in order to get the maximum of energy?</td>
<td>She didn't ask for a clarification on the part of the pupil and continues</td>
</tr>
<tr>
<td>128.</td>
<td>$P$ it must be in the direction of the sun</td>
<td></td>
</tr>
<tr>
<td>129.</td>
<td>S.T. but what did you say that should happen here on the magnifier?</td>
<td></td>
</tr>
<tr>
<td>130.</td>
<td>$P_s$ it's lighted ...... yes ... there is smoke</td>
<td></td>
</tr>
<tr>
<td>131.</td>
<td>$P_s$ let me see it! let me see it!</td>
<td></td>
</tr>
<tr>
<td>132.</td>
<td>$P_s$ ... eh ...... er ...... (laughing)</td>
<td></td>
</tr>
<tr>
<td>133.</td>
<td>$P$ Miss can I extinguish it?</td>
<td></td>
</tr>
<tr>
<td>134.</td>
<td>S.T. yes you can</td>
<td></td>
</tr>
<tr>
<td>135.</td>
<td>$P$ what a pity! ... what a waste of cigarettes!</td>
<td>The atmosphere of the class is relaxed and friendly</td>
</tr>
<tr>
<td>136.</td>
<td>$P_s$ (laughings)</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
<td>Aim (Infer.)</td>
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<tr>
<td>137. S.T.</td>
<td>so can you tell me what happened?</td>
<td>She is seeking for an interpretation</td>
</tr>
<tr>
<td>138. $P_1$</td>
<td>the sun rays</td>
<td></td>
</tr>
<tr>
<td>139. $P_2$</td>
<td>the sun rays are parallel aren't they?</td>
<td></td>
</tr>
<tr>
<td>140. S.T.</td>
<td>yes they are parallel and when falling on a convergent magnifier what happens?</td>
<td>She advances the effect of the magnifier saying convergent</td>
</tr>
<tr>
<td>141. $P$</td>
<td>they are being concentrated just on one point</td>
<td></td>
</tr>
<tr>
<td>142. S.T.</td>
<td>yes ... and by the fact they are being concentrated just on one point what happens?</td>
<td></td>
</tr>
<tr>
<td>143. $P$</td>
<td>there is a large amount of energy on that point and so it was possible to light the cigarette</td>
<td></td>
</tr>
<tr>
<td>144. S.T.</td>
<td>yes ... the energy was concentrated on a point so there was a great amount of energy and what happened to the cigarette?</td>
<td>Repeating the pupil utterance she is reinforcing him</td>
</tr>
<tr>
<td>145. $P$</td>
<td>it was lighted</td>
<td></td>
</tr>
<tr>
<td>146. S.T.</td>
<td>why?</td>
<td></td>
</tr>
<tr>
<td>147. $P$</td>
<td>because there was energy</td>
<td></td>
</tr>
<tr>
<td>148. S.T.</td>
<td>luminous energy?</td>
<td></td>
</tr>
<tr>
<td>149. $P$</td>
<td>luminous energy was transformed into thermal energy</td>
<td>Without being told pupils are constructing knowledge</td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>150. S.T.</td>
<td>so based on this case .. can you say now why in fiction films .... like Buck Roger's the laser ray is used as the &quot;death ray&quot; ...... the one which destroys everything? You &quot;Paulo&quot; can you comment on that?</td>
<td></td>
</tr>
<tr>
<td>151. P₁</td>
<td>... well .... that is fiction ... it doesn't happen in reality ....</td>
<td></td>
</tr>
<tr>
<td>152. P₃</td>
<td>(a big discussion took place between pupils about fiction .... impossible to transcribe)</td>
<td></td>
</tr>
<tr>
<td>153. P₂</td>
<td>I never studied that ... but ..... I'm now thinking that the laser ....</td>
<td></td>
</tr>
<tr>
<td>154. S.T.</td>
<td>tell me do you know what a laser is?</td>
<td></td>
</tr>
<tr>
<td>155. P₁</td>
<td>it's a beam</td>
<td></td>
</tr>
<tr>
<td>156. P₂</td>
<td>I think a laser is a beam of energy .... I mean concentrated energy ... I mean a laser is a beam with a great amount of energy</td>
<td></td>
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<tr>
<td>157. P₃</td>
<td>is it that?</td>
<td></td>
</tr>
<tr>
<td>158. S.T.</td>
<td>well first of all a laser is an apparatus which emits light ... light from a laser ... when we say laser light we mean light ... light from a laser</td>
<td></td>
</tr>
<tr>
<td>159. P₁</td>
<td>but isn't it ... concentration of energy?</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td><strong>160. P₂</strong> I think that it is a concentration of energy... and that what you are talking... about destroying everything... I mean... if a... beam of energy... a very concentrated one comes towards me it is going to destroy me because I cannot receive such energy in my body...... I will be destroyed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>161. P₃</strong> but that is a bit exaggerated... because... well sometimes... it is a piece of iron and it doesn't happen... let's say it can happen but only slowly... the iron can start being melted by the energy...</td>
<td></td>
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<tr>
<td><strong>162. P₄</strong> it depends on the intensity</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>163. P₃</strong> yes it depends on the laser intensity</td>
<td></td>
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<tr>
<td><strong>164. S.T.</strong> what happens with the laser is something similar... you there... what is your name?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>165. P</strong> me...? &quot;Artur&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>166. S.T.</strong> &quot;Artur&quot;... what were you talking about?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>167. P₁</strong> I was saying...... the laser is a kind of tube of Zn or other special material wrapped in a flash lamp... and when switched on...... there is a concentration of energy which gets out by one side</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>168. P₂</strong> please......!! change it into normal words....</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>169. P₅</strong> (laughing)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Analysis*:

It is her 7th lesson on this class and as she has other classes she still doesn't know all the pupils' names.
<table>
<thead>
<tr>
<th></th>
<th>Transcript</th>
<th>Analysis</th>
<th>Aims (Inference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>170.</td>
<td>S.T. well ... actually what happens?</td>
<td>She asks for a clarification but some disruptive situations unable her to follow the consequences of question 170</td>
<td></td>
</tr>
<tr>
<td>171.</td>
<td>Miss. he is teasing me</td>
<td></td>
<td></td>
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<tr>
<td>172.</td>
<td>S.T. be quite ... the meaning of laser in English is &quot;light amplification stimulate ....&quot;</td>
<td></td>
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<tr>
<td>173.</td>
<td>P please could you talk in portuguese!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>174.</td>
<td>P (laughing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>175.</td>
<td>S.T. well ... it is amplified light ... well the light is amplified ... it happens ... well practically what happens is the same that takes place in the magnifier ... but .... with a great amount of energy there is a great concentration of energy and that is the cause of all the damages the laser makes</td>
<td>She can't explain what a laser is</td>
<td></td>
</tr>
<tr>
<td>176.</td>
<td>let's talk about other thing</td>
<td>The question is aimed at disclosing pupils' ideas about light and sources of light</td>
<td>D1</td>
</tr>
<tr>
<td>177.</td>
<td>can you tell me where is there light in this room?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>178.</td>
<td>P (all speaking at the same time)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>179.</td>
<td>S.T. ... what? .. say it ... I can't hear you</td>
<td></td>
<td></td>
</tr>
<tr>
<td>180.</td>
<td>P in every place</td>
<td>She encourages others to express their own ideas</td>
<td>D1</td>
</tr>
<tr>
<td>181.</td>
<td>S.T. in every place ... are there other opinions?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>182.</td>
<td>P1 Miss ... there is light in every place but with different intensities .. if we look behind that desk there is less light than here because ....</td>
<td></td>
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<tr>
<td></td>
<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>183.</td>
<td>$P_2$ well ... the intensity varies ......</td>
<td></td>
<td></td>
</tr>
<tr>
<td>184.</td>
<td>$P_3$ it depends on the places</td>
<td>Another pupil comes to help the peer</td>
<td></td>
</tr>
<tr>
<td>185.</td>
<td>S.T. why?</td>
<td>Asking for an interpretation</td>
<td>C</td>
</tr>
<tr>
<td>186.</td>
<td>P (all speaking at the same time)</td>
<td>The pupil shows a great difficulty to express himself</td>
<td></td>
</tr>
<tr>
<td>187.</td>
<td>P if for instance the window is opened there is more light ... if the light comes directly from the windows ...... the sun ... has more intensity than if it comes already .. broken ... for instance if it strikes something .... it comes broken ...</td>
<td>$S_5$ doesn't ask for a clarification ..... she lost an opportunity to help the development of the skill of communitive in this pupil</td>
<td></td>
</tr>
<tr>
<td>188.</td>
<td>S.T. why?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>189.</td>
<td>P because it is direct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>190.</td>
<td>S.T. it is direct ... the light comes from the sun and falls on here ...</td>
<td>She stimulates pupils' thinking</td>
<td>C</td>
</tr>
<tr>
<td>191.</td>
<td>P it has more energy than after being reflected .. after being reflected the energy is less .... isn't it?</td>
<td></td>
<td></td>
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<tr>
<td>192.</td>
<td>S.T. it is less ... why? .. what happens when the light is reflected?</td>
<td></td>
<td></td>
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<tr>
<td>193.</td>
<td>P some energy is absorbed</td>
<td></td>
<td></td>
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<tr>
<td>194.</td>
<td>S.T. it is absorbed by whom?</td>
<td></td>
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<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>195.</td>
<td>P by the object</td>
<td></td>
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<tr>
<td>196.</td>
<td>S.T. yes by the object on which it is falling..... so there is light in all the room and there is more in some places than in others</td>
<td>She synthesizes the issue about light and sources of light</td>
<td></td>
</tr>
<tr>
<td>197.</td>
<td>S.T. what is the difference between the sun and this table?</td>
<td>The question isn't very clear</td>
<td></td>
</tr>
<tr>
<td>198.</td>
<td>P related to light?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>199.</td>
<td>S.T. yes</td>
<td></td>
<td></td>
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<tr>
<td>200.</td>
<td>P₃ ... (all speaking at the same time)</td>
<td></td>
<td></td>
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<tr>
<td>201.</td>
<td>P₁ the sun is a source of energy</td>
<td></td>
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</tr>
<tr>
<td>202.</td>
<td>P₂ and the table is illuminated because the sunlight is falling on it ... because the source of energy is supplying energy to the table</td>
<td></td>
<td></td>
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<tr>
<td>203.</td>
<td>S.T. well ... so what does the sun have that the table doesn't have ..... you &quot;Fátima&quot; say it ...</td>
<td>Asking for attributes and non attributes of the concept to be learned</td>
<td></td>
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<tr>
<td>204.</td>
<td>P (other pupil) Miss .. proper energy</td>
<td></td>
<td></td>
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<tr>
<td>205.</td>
<td>S.T. so you are saying the table doesn't have proper energy?</td>
<td></td>
<td></td>
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<tr>
<td>206.</td>
<td>P₃ ... no it hasn't it has potential energy</td>
<td></td>
<td></td>
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<tr>
<td>207.</td>
<td>P but it hasn't luminous energy</td>
<td></td>
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<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>208</td>
<td>S.T. so the sun has luminous energy</td>
<td>It looks as she didn't hear the utterance 206</td>
<td></td>
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<tr>
<td>209</td>
<td>P yes .... it is stocked</td>
<td></td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>S.T. the sun emits light</td>
<td>(Two pupils were talking to each other)</td>
<td></td>
</tr>
<tr>
<td>211</td>
<td>S.T. ... you there .... what are you talking about?</td>
<td>can you put your problems to the class?</td>
<td></td>
</tr>
<tr>
<td>212</td>
<td>P .... well he was trying to confuse me</td>
<td></td>
<td></td>
</tr>
<tr>
<td>213</td>
<td>P₃ (laughing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>214</td>
<td>P₁ I was saying potential energy and he was saying stocked energy ......</td>
<td>and I said stocked energy is potential energy ...</td>
<td></td>
</tr>
<tr>
<td>215</td>
<td>P₂ it is not</td>
<td></td>
<td></td>
</tr>
<tr>
<td>216</td>
<td>P₃ (laughing)</td>
<td>(the inter-pupil discussion continues but it is impossible to transcribe)</td>
<td></td>
</tr>
<tr>
<td>217</td>
<td>S.T. well let's not talk about it now</td>
<td></td>
<td></td>
</tr>
<tr>
<td>218</td>
<td>the sun emits light ..... that is what we are talking about now ... you</td>
<td>Probably she didn't want to shift the subject of the lesson and intentionally didn't clarify 214.</td>
<td></td>
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<tr>
<td></td>
<td>said the sun emits light ... and what about the table?</td>
<td></td>
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<tr>
<td>219</td>
<td>P₃ ... (all together) it receives light</td>
<td></td>
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<td></td>
<td>Transcript</td>
<td>Analysis</td>
<td>Aims (Inferred)</td>
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<tr>
<td>220</td>
<td>S.T. it receives light .. can you give other examples of objects that emit light?</td>
<td>She asks for specific examples of the concepts of luminous and illuminated bodies</td>
<td>C₁.C₄</td>
</tr>
<tr>
<td>221</td>
<td>P₁ the torch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>222</td>
<td>P₂ lamps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>P₃ the lighter</td>
<td></td>
<td></td>
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<tr>
<td>224</td>
<td>P₄ candles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>225</td>
<td>S.T. yes .. and objects which don't emit light ............ which receive light?</td>
<td>She is helping pupils to distinguish between examples and non-examples of the concept to be learned</td>
<td></td>
</tr>
<tr>
<td>226</td>
<td>P ... the wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>227</td>
<td>S.T. yes ... more</td>
<td></td>
<td></td>
</tr>
<tr>
<td>228</td>
<td>P₅ .... the glass the wood the rubber the floor the iron</td>
<td></td>
<td></td>
</tr>
<tr>
<td>229</td>
<td>P₁ I think the iron emits light</td>
<td>Pupils feel at ease to put forward their ideas</td>
<td></td>
</tr>
<tr>
<td>230</td>
<td>S.T. what? .... iron emits light? when?</td>
<td>She is confused</td>
<td></td>
</tr>
<tr>
<td>231</td>
<td>P₁ when it is being cut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>232</td>
<td>S.T. does it emit light when ... being cut? .... how can you prove that?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>233</td>
<td>P₁ I don't know (laughing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
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<tr>
<td>234. (P_2) it doesn't emit ... it reflects light</td>
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<tr>
<td>235. (P_3) Miss, in the case of a mirror ... the mirror receives light and reflects it ... isn't it ... can it be considered as a reflector or as ... as an object which receives and at the same time an object which emits?</td>
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<tr>
<td>236. (P_4) yes the mirror emits light</td>
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<tr>
<td>237. (P_5) ... no ... it receives light</td>
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<tr>
<td>238. S.T. well ... now we are interested in those bodies with proper light ... the ones emitting light because they have light on themselves ... the case of the sun ...</td>
<td>The difficulties she shows on controlling the discussion don't allow her to explore some pupils' views</td>
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<tr>
<td>239. (P) ..... the stars</td>
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<tr>
<td>240. (P_s) (laughing) ... the stars</td>
<td></td>
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<tr>
<td>241. (P) what do you think the sun is? ..... (laughing)</td>
<td>She turns to the point raised by one pupil which isn't still clarified</td>
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<tr>
<td>242. S.T. there are few luminous bodies ....... the majority of bodies are illuminated ... but you there ..... can you think of a way to prove that iron emits light</td>
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<tr>
<td>243. (P) if we cut iron ... it emits light</td>
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<tr>
<td>244. (P_s) (laughing)</td>
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<tr>
<td>245. S.T. for instance if you could cut iron in a dark room would you be able to see it?</td>
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<tr>
<td>246. (P) I don't know ... I never saw it</td>
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<td>Aims (Inferred)</td>
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<tr>
<td>247. $P_s$</td>
<td>(some confusion ... all speaking)</td>
<td></td>
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<tr>
<td>248. S.T.</td>
<td>if we would be in a completely dark room and switched on a torch what should happen?</td>
<td>She asks for an interpretation</td>
<td></td>
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<tr>
<td>249. $P$</td>
<td>there was light in every place</td>
<td></td>
<td></td>
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<tr>
<td>250. S.T.</td>
<td>we could see the light ...... there was propagation of light .. so if we would cut iron what should happen?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>251. $P_s$</td>
<td>we could see nothing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>252. $P$</td>
<td>Miss .. in a dark room if we rub two little sticks they emit light</td>
<td>Through all this sequence (from 253 to 269) there were too many things in the air but nothing was left clarified</td>
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<tr>
<td>253. S.T.</td>
<td>so what happens there?</td>
<td></td>
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<tr>
<td>254. $P_1$</td>
<td>well if we rub two sticks they emit light</td>
<td></td>
<td></td>
</tr>
<tr>
<td>255. $P_2$</td>
<td>even the primitive men knew that (laughings)</td>
<td></td>
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<tr>
<td>256. S.T.</td>
<td>so ... what happens there in terms of energy?</td>
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<tr>
<td>257. $P$</td>
<td>it is chemical energy</td>
<td></td>
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<tr>
<td>258. S.T.</td>
<td>is it?</td>
<td></td>
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<tr>
<td>259. $P$</td>
<td>I think so .. chemical energy transformed into luminous energy</td>
<td></td>
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<tr>
<td>260. S.T.</td>
<td>chemical energy from what?</td>
<td></td>
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<tr>
<td>261. $P_1$</td>
<td>I think it's heat energy</td>
<td></td>
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<td>262. ( P_2 ) heat?</td>
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<tr>
<td>263. ( P_3 ) yes .. because if we touch the sticks they are hot</td>
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<tr>
<td>264. ( P_4 ) oh yes .... that's true</td>
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<tr>
<td>265. ( P_s ) (all speaking at the same time)</td>
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<tr>
<td>266. ( P ) I think it is due to friction</td>
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<tr>
<td>267. ( S.T. ) due to friction?</td>
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<tr>
<td>268. ( P ) yes .. due to friction ... a spark ... is drawn from the sticks</td>
<td></td>
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<tr>
<td>269. ( S.T. ) yes there is heat energy and then luminous energy .... that is what happens</td>
<td>Many ideas were left unclarified</td>
<td></td>
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<tr>
<td>270.</td>
<td>well ... so as we have seen there are two kinds of objects .. luminous and illuminated .. the first ones emit light and the others emit light only when they receive it first ... they are not self luminous</td>
<td>She makes the synthesis</td>
<td></td>
</tr>
<tr>
<td>271. ( S.T. ) now let's go back to the example ... when we switch on a torch in a dark room what does happen?</td>
<td>She now approaches the model &quot;light propagates in space&quot;</td>
<td>( D_1 )</td>
<td></td>
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<tr>
<td>272. ( P ) there is light in the room</td>
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<tr>
<td>273. ( P_s ) (all speaking at the same time)</td>
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<tr>
<td>274. ( P ) I think there is light only where the light from the torch falls on and not in every place in the room</td>
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<tr>
<td>275. $P_3$ no yes I think so I don't agree</td>
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<tr>
<td>276. $P_1$ oh! Miss ... in the place where the light of the torch falls on there is more light</td>
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<tr>
<td>277. $P_2$ there is light only where the light of the torch falls on</td>
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<tr>
<td>278. $P_3$ I think in this case the torch makes the role of the sun .... the torch is the source of luminous energy .... but the intensity of the torch light may not be enough to illuminate the whole room</td>
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<tr>
<td>279. S.T. for instance ... if this room was completely dark and we put the lights on ...</td>
<td></td>
<td>She asks for a clarification</td>
<td></td>
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<tr>
<td>280. $P$ there would be light in all the room ...</td>
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<tr>
<td>281. S.T. so .. why do you say that's different in the case of the torch?</td>
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<tr>
<td>282. $P$ it's only one small lamp</td>
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<tr>
<td>283. $P_3$ (inaudible)</td>
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<tr>
<td>284. $P$ the torch is less powerfull</td>
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<tr>
<td>285. S.T. is less powerfull ... it has less intensity</td>
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<tr>
<td>286. $P$ with the torch the room is more in the dark</td>
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<td><strong>287. S.T.</strong> but is there any difference between switching on a torch or a lamp like that (pointing to the lamps hanging from the ceiling)?</td>
<td>Asking for clarification</td>
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<tr>
<td><strong>288. P_s</strong> (all together) yes there is</td>
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<tr>
<td><strong>289. P_1</strong> the lamp has more intensity</td>
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<tr>
<td><strong>290. P_2</strong> Miss it is because the way the light gets out is different in both cases .. lamp or torch</td>
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<tr>
<td><strong>291. S.T.</strong> is it?</td>
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<tr>
<td><strong>292. P_1</strong> yes ... with the torch we point it ... and the light gets out aligned ... while with a lamp ... &quot;bch&quot; ...</td>
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<tr>
<td><strong>293. P_2</strong> it's like the sun</td>
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<tr>
<td><strong>294. P_s</strong> (all speaking at the same time)</td>
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<tr>
<td><strong>295. S.T.</strong> in the case of the lamp ..... the light diverges in every direction</td>
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<tr>
<td><strong>296. P</strong> ..... the torch no ....... the torch makes .........</td>
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<tr>
<td><strong>297. S.T.</strong> what does the torch? ..... say it &quot;Rut&quot;</td>
<td>She encourages the pupil to express himself</td>
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<tr>
<td><strong>298. P_1</strong> the torch has a kind of mirror ... I don't know how to explain</td>
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<tr>
<td><strong>299. P_2</strong> the torch has a glass which makes the light scattering about</td>
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<tr>
<td>300. $P_3$ no ... what happens is that when the lamp of the torch is switched on the light goes in every direction but as it has a mirror it makes the light converging and it gives that looking ....</td>
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<tr>
<td>301. $P_S$ (all speaking at the same time)</td>
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<td>302. $P$ it depends on the slit through which the light spreads out</td>
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<tr>
<td>303. S.T. that's why when we switch on the light in a room ...... it propagates in every direction ... and we can see all the objects when we switch on a light</td>
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<tr>
<td>304. does the light move?</td>
<td>$S_5$ moves to another question in an attempt to ascertain that the model &quot;light propagates in space&quot; is held by all pupils</td>
<td>$D_1$</td>
<td></td>
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<tr>
<td>305. $P_S$ yes ... it moves .. it moves</td>
<td></td>
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<tr>
<td>306. S.T. why? ... how can we observe that?</td>
<td>She asks for a justification</td>
<td>$D_1$</td>
<td></td>
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<tr>
<td>307. $P_1$ for instance ... in a glass .. the glass has small holes .. and the light for passing from one side to the other through the glass it has to move ........ to go through those holes</td>
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<tr>
<td>308. $P_2$ I think he is expressing in a very bad way!</td>
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<tr>
<td>309. $P_S$ (all speaking at the same time)</td>
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<tr>
<td>310. S.T. what were you trying to say &quot;Vasco&quot;?</td>
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<td>Aims (Inferre)</td>
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<tr>
<td>311.</td>
<td>P</td>
<td>all the matter has empty spaces .... I don't know how to explain ...</td>
<td></td>
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<tr>
<td>312.</td>
<td>S.T.</td>
<td>well ... you said that the light moves ... how can you design an experiment or some way in which this can be proved?</td>
<td>She moves on without an attempt to help the pupil to clarify his views and asks for a design of an experiment to prove what had been said</td>
</tr>
<tr>
<td>313.</td>
<td>P1</td>
<td>for instance with a torch</td>
<td></td>
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<tr>
<td>314.</td>
<td>P2</td>
<td>with a light ray</td>
<td></td>
</tr>
<tr>
<td>315.</td>
<td>S.T.</td>
<td>with a torch ... how?</td>
<td>She pushes the pupil to continue designing the experiment</td>
</tr>
<tr>
<td>316.</td>
<td>P1</td>
<td>if I point it ...... if I switch on the torch ..... the light strikes the blackboard</td>
<td></td>
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<tr>
<td>317.</td>
<td>P2</td>
<td>and if I put my hand on the way .. it doesn't reach the backboard</td>
<td></td>
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<tr>
<td>318.</td>
<td>S.T.</td>
<td>so ... if we do that (she switches on a torch and points it towards the blackboard) the light is falling on there ... then it moves from here to there and if I put my hand here (she puts her hand on the way) it only moves from here to here ... so does it mean that between the torch and the blackboard there is light?</td>
<td>She insists in investigating which model of light pupils hold</td>
</tr>
<tr>
<td>319.</td>
<td>P8</td>
<td>yes ... there is ... there is</td>
<td></td>
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<tr>
<td>320.</td>
<td>P</td>
<td>well yes and no .. it's a kind of invisible light ..... we don't see it because ....</td>
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<td>Aims</td>
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<tr>
<td>321. $P_s$ (all speaking at the same time)</td>
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<tr>
<td>322. $P$ if the teacher puts some chalk powder ..... everybody will see the light</td>
<td>The pupil plans an experiment to prove the existence of light</td>
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<tr>
<td>323. S.T. why?</td>
<td>She asks for an interpretation</td>
<td>$C_4$</td>
<td></td>
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<tr>
<td>324. $P$ ... because the light is reflected by the particles of the chalk powder</td>
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<tr>
<td>325. S.T. very well</td>
<td>She reinforces positively</td>
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<tr>
<td>326. $P_s$ (all speaking at the same time)</td>
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<tr>
<td>327. S.T. have you ever seen ... sometimes when one window is open ... just a little ... and there is dust ... what does happen?</td>
<td>She asks for an interpretation in a different situation</td>
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<tr>
<td>328. $P_1$ we see just a beam of light</td>
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<tr>
<td>329. $P_2$ I have never seen that! ...</td>
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<tr>
<td>330. S.T. then you can try to see it, OK?</td>
<td>She stimulates the observation outside classroom</td>
<td>$A_2$</td>
<td></td>
</tr>
<tr>
<td>331. S.T. well ... so we have already seen that light moves and it moves in all directions .... now in each direction how does it propagate?</td>
<td>Considering the last point clarified she moves toward the next objective</td>
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<tr>
<td>332. $P$ in a straight line</td>
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<tr>
<td>333. S.T. (addressing to a pupil who is absent minded) &quot;Ana&quot; what did I ask?</td>
<td>She detects a pupil disinterested in the discussion</td>
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<tr>
<td><strong>334. P</strong></td>
<td>the directions through which light propagates</td>
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<tr>
<td><strong>335. S.T.</strong></td>
<td>so answer that</td>
<td></td>
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<tr>
<td><strong>336. P</strong></td>
<td>in all directions (another pupil answering)</td>
<td></td>
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<tr>
<td><strong>337. S.T.</strong></td>
<td>it is &quot;Ana&quot; who is going to answer</td>
<td></td>
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<tr>
<td><strong>338. P</strong></td>
<td>I don't know</td>
<td></td>
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<tr>
<td><strong>339. S.T.</strong></td>
<td>have you been understanding the lesson?</td>
<td></td>
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<tr>
<td><strong>340. P</strong></td>
<td>yes .... more or less</td>
<td></td>
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<tr>
<td><strong>341. S.T.</strong></td>
<td>why more or less?</td>
<td></td>
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<tr>
<td><strong>342. P</strong></td>
<td>because you are always making questions and I don't know the answers</td>
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<tr>
<td><strong>343. S.T.</strong></td>
<td>well I'm trying that you reach the conclusions through questions .....</td>
<td></td>
<td>She tries to motivate this particular pupil to enter in the discussion</td>
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<tr>
<td></td>
<td>why does the light propagate in all directions?</td>
<td>A₂, A₃</td>
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<td></td>
<td>what was the example given which proves that light propagates in all directions?</td>
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<tr>
<td><strong>344. P₁</strong></td>
<td>I don't know</td>
<td></td>
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<tr>
<td><strong>345. P₂</strong></td>
<td>if we were in a dark room and somebody switched on the light ...... the whole room would be illuminated which shows that it propagates in all directions</td>
<td>Other pupil explains to his peer</td>
<td></td>
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<tr>
<td><strong>346. S.T.</strong></td>
<td>do you agree?</td>
<td>A₃</td>
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<tr>
<td>347. P</td>
<td>yes .... because we can see all the objects in the room</td>
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<tr>
<td>348. S.T.</td>
<td>yes ... then there is light in all directions and in each direction how does the light propagate?</td>
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<tr>
<td>349. P₂</td>
<td>(silence)</td>
<td></td>
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<tr>
<td>350. S.T.</td>
<td>how does the light move in each direction?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>351. P</td>
<td>(the same pupil who was distracted) (she speaks but in a very low voice)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>352. S.T.</td>
<td>can you speak louder?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>353. P₁</td>
<td>(she speaks but still very low)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>354. P₂</td>
<td>what is she saying Miss?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>355. S.T.</td>
<td>you ought to speak louder because as you see they can't hear you down there</td>
<td></td>
<td></td>
</tr>
<tr>
<td>356. P₁</td>
<td>the light falls on objects and because of that we can see them</td>
<td>This pupil isn't following the discussion and she repeats what she had heard from another peer (347)</td>
<td></td>
</tr>
<tr>
<td>357. P₂</td>
<td>it's not that ... I think light propagates in a straight line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>358. S.T.</td>
<td>how can we prove that?</td>
<td>She stimulates pupils thinking</td>
<td></td>
</tr>
<tr>
<td>359. P</td>
<td>with a torch .... it's easy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>360. S.T.</td>
<td>how?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
<td>Aims (Inferre)</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>361. $P_1$ no need for a torch .... for instance .... what we did when we lighted the cigarette .. with the magnifier .. when one puts the cigarette ... the light must come in straight lines ... because if it came in curves the rays wouldn't get to the same point</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>362. $P_2$ no ... that doesn't prove anything ... it may not come in a straight line but it can fall on as well in the cigarette ...... it can come in zig-zag and light the cigarette</td>
<td></td>
<td>$A_3$</td>
<td></td>
</tr>
<tr>
<td>363. $P_s$ (a great inter-pupils discussion, very enthusiastic but impossible to transcribe)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>364. S.T. so ... what does happen when having light falling on the wall down there ... I put my hand on the way?</td>
<td>She asks for a synthesis of the discussion</td>
<td>$C_4$</td>
<td></td>
</tr>
<tr>
<td>365. $P_s$ the shadow of the hand can be seen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>366. $P_1$ the hand doesn't let the light pass through</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>367. $P_2$ .... it shows that the light travels in straight line</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>368. $P_s$ (a very lively discussion takes place impossible to transcribe)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>369. S.T. good ... then as a homework you are going to think about fiction or comic films in which you can see the light of a laser and next lesson I will ask for an explanation</td>
<td>She is stimulating the development of critical mindedness</td>
<td>$A_2$, $A_3$</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>370. P</td>
<td>oh ... that's easy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>371. P</td>
<td>(all speaking at the same time)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(the bell rings and the lesson finishes).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(-584-)
APPENDIX 16

Task analysis, transcript and analysis of a lesson performed by S6

(the first lesson on "Force, Weight and Mass")
(content of the lesson: introduction to the concept of mass)
**1 - Task Analysis of the Pre-Active Phase of the First Lesson on the Unit of "Force and Mass" Performed by S6**

| A. Statement of the aims of the lesson in terms of pupils' development of "abilities" | B. Statement of the objectives of the lesson in terms of pupils' learning | C. Analysis of the lesson aims and objectives to establish the link between them | D. Decision on type of:
|---|---|---|---|
| Through the contents of this lesson pupils should be helped to develop (see App. 7): | After the lesson pupils should be able to: | Throughout the discussion opportunities should be provided for the development of the "abilities" stated | a) pupils activities
b) nature of presentation
c) nature of feedback to be provided
d) evaluation |
| $A_3$ | (1) - differentiate the concept of "mass" from the concept of "volume" | | a) participation in a class discussion |
| $A_6$ | (2) - differentiate "mass" from the material from which a body is made of | | b) class discussion based on the findings emerged from the diagnostic questionnaire |
| $C_1$ | (3) - define "mass" | | c) teacher verbal and non-verbal feedback
| $C_3$ | | | peers' feedback |
| $C_6$ | | | d) based on the way pupils participate in the discussion |
| $D_1$ | | | |
2 - TRANSCRIPT AND ANALYSIS OF THE LESSON PERFORMED BY S₆

In the following each contribution is numbered consecutively. The source being indicated by S.T. for student teacher and P pupil contributions, i.e. any pupil. Various pupils contributions at the same time, Pₛ, and occasionally different pupils contributions are indicated by P₁, P₂, etc..

<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
<th>Aims (Inferred)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. S.T.</td>
<td>Today I would like to start the lesson by asking what do you mean by mass of a body</td>
<td>S₆ is concerned with disclosing pupils' intuitive ideas about the concept of &quot;mass&quot;</td>
</tr>
<tr>
<td>2. Pₛ</td>
<td>(all speaking at the same time)</td>
<td></td>
</tr>
<tr>
<td>3. S.T.</td>
<td>please .. just one .... you &quot;Isabel&quot; what do you mean by mass?</td>
<td>It is interesting to note this pupil's behaviour. She is trying to certificate if she ought to 'know' any specific definition which might be already given. This is her first thought instead of trying to explicit her own meaning for the word</td>
</tr>
<tr>
<td>4. P</td>
<td>mass ... is ... (to her peers) ...... have we ever talked about it?</td>
<td>With this utterance S.T. encourages the pupils to think by themselves and to give their own idea of &quot;mass&quot;</td>
</tr>
<tr>
<td>5. Pₛ</td>
<td>(laughing)</td>
<td></td>
</tr>
<tr>
<td>6. S.T.</td>
<td>what do you mean by &quot;mass&quot;?.. you must have already thought about it .... haven't you?</td>
<td></td>
</tr>
<tr>
<td>7. P₁</td>
<td>..... well ... let me think ... mass .. is what makes up a body ... it's its constitution</td>
<td>All these answers are coherent with the findings of the analysis of the diagnostic questionnaire</td>
</tr>
<tr>
<td>8. P₂</td>
<td>I think it is the matter of the body ...</td>
<td></td>
</tr>
<tr>
<td>9. P₃</td>
<td>I also think that ......</td>
<td></td>
</tr>
<tr>
<td>10. P₄</td>
<td>for me it's the shape of the body</td>
<td></td>
</tr>
<tr>
<td>11. P₅</td>
<td>I don't agree with that ....</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>---</td>
<td>------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>12.</td>
<td>S.T.</td>
<td>you don't agree ... why?</td>
</tr>
<tr>
<td>13.</td>
<td>P5</td>
<td>I think ... it is the quantity of matter contained in a body</td>
</tr>
<tr>
<td>14.</td>
<td>P6</td>
<td>yes</td>
</tr>
<tr>
<td>15.</td>
<td>P2</td>
<td>Miss ... what's the difference between quantity of matter and what makes up a body?</td>
</tr>
<tr>
<td>16.</td>
<td>P3</td>
<td>what makes up a body isn't its mass ....... it has something to do with mass .... but</td>
</tr>
<tr>
<td>17.</td>
<td>P3</td>
<td>(all giving their ideas at the same time)</td>
</tr>
<tr>
<td>18.</td>
<td>S.T.</td>
<td>once at each time ... I'm going to write on the blackboard your answers and then we will discuss them ....... first ...</td>
</tr>
<tr>
<td>19.</td>
<td>P</td>
<td>mass is the material that makes up a body</td>
</tr>
<tr>
<td>20.</td>
<td>S.T.</td>
<td>... (writing on the blackboard) ... well .. second .. mass is ...</td>
</tr>
<tr>
<td>21.</td>
<td>P</td>
<td>the quantity of substance of a body</td>
</tr>
<tr>
<td>22.</td>
<td>S.T.</td>
<td>.... yes ... is there any other?</td>
</tr>
<tr>
<td>23.</td>
<td>P</td>
<td>mass is the quantity of matter that makes up the body</td>
</tr>
<tr>
<td>24.</td>
<td>S.T.</td>
<td>O.K. .. so that is the third one .. any more?</td>
</tr>
<tr>
<td>25.</td>
<td>P</td>
<td>mass is the matter of the body</td>
</tr>
</tbody>
</table>

S.T. stimulates the discussion

S6's intention is to get a registration of the various pupils' ideas about mass so they can be discussed further

S6 is encouraging pupils to give their own alternative conceptions about mass
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>26. S.T.</td>
<td>I'm writing that also ... more?</td>
</tr>
<tr>
<td>27. P₁</td>
<td>I think ... it's the third one ... it is the quantity of matter that makes up a body</td>
</tr>
<tr>
<td>28. P₂</td>
<td>no ... no .. it's the substance of the body</td>
</tr>
<tr>
<td>29. P₃</td>
<td>no ... it's the quantity of substance</td>
</tr>
<tr>
<td>30. P₄</td>
<td>oh ... yeah! I agree with that</td>
</tr>
<tr>
<td>31. P₅</td>
<td>... may be ... it's that one the first one ... the quantity ...</td>
</tr>
<tr>
<td>32. P₆</td>
<td>... may be ...</td>
</tr>
<tr>
<td>33. P₇</td>
<td>... and ... what about you Miss? ... what do you think that mass is?</td>
</tr>
<tr>
<td>34. P₈</td>
<td>(laughing)</td>
</tr>
<tr>
<td>35. S.T.</td>
<td>well ... I want to hear your ideas</td>
</tr>
<tr>
<td>36. P₈</td>
<td>(all speaking at the same time)</td>
</tr>
<tr>
<td>37. S.T.</td>
<td>once at each time ... &quot;Teresa&quot; .. you .... please .... the others raise hands when wanting to talk</td>
</tr>
<tr>
<td>38. P₁</td>
<td>well ... I think ... quantity is related to volume</td>
</tr>
<tr>
<td>39. P₂</td>
<td>I think volume has nothing to do with mass</td>
</tr>
<tr>
<td>40. P₃</td>
<td>that's true ....</td>
</tr>
</tbody>
</table>

This gives an idea of the atmosphere of the interaction; relaxed and friendly

S₆ is concerned in keeping order, reminding the rules for participation

During this conversation it can be seen how pupils have different meanings for the concept of mass and how the strategy used by S₆ allows for a free expression of these meanings
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>41. P2</td>
<td>I can occupy a certain volume and other person occupy exactly the same ... or other object occupy exactly the same volume ... and we can have different masses</td>
</tr>
<tr>
<td>42. P4</td>
<td>of course ...</td>
</tr>
<tr>
<td>43. P5</td>
<td>no ... no ... if two objects occupy the same volume they have the same mass</td>
</tr>
<tr>
<td>44. P6</td>
<td>impossible ..... how can a very big wardrobe have the same mass as me? (laughing)</td>
</tr>
<tr>
<td>45. P5</td>
<td>(all speaking at the same time ... impossible to transcribe)</td>
</tr>
<tr>
<td>46. S.T.</td>
<td>one at each time ... you there ... &quot;Maria&quot; .. what do you think?</td>
</tr>
<tr>
<td>47. P1</td>
<td>I think that the volume is related to the shape of the body</td>
</tr>
<tr>
<td>48. P2</td>
<td>of course!</td>
</tr>
<tr>
<td>49. P1</td>
<td>and ... it is .. the shape of the body is the volume .. it's its volume ..</td>
</tr>
<tr>
<td>50. P2</td>
<td>... and then! .... isn't the mass related to its volume?</td>
</tr>
<tr>
<td>51. P3</td>
<td>no it has nothing to do with the volume</td>
</tr>
<tr>
<td>52. P4</td>
<td>uhm! I don't agree with that!</td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>53. $P_5$ so .. are you saying that the wardrobe can have the same mass as me?</td>
<td>(She is referring to the diagnostic questionnaire)</td>
</tr>
<tr>
<td>54. $P_4$ no ... it's not the same mass ...</td>
<td>The confrontation of pupils' ideas between them, per se, allows for a development toward the scientific ones</td>
</tr>
<tr>
<td>55. $P_s$ (all speaking at the same time ... impossible to transcribe)</td>
<td></td>
</tr>
<tr>
<td>56. S.T. look here ... some of you answered saying that &quot;the mass is the size or the volume of the body&quot;</td>
<td></td>
</tr>
<tr>
<td>57. $P_s$ (all speaking)</td>
<td></td>
</tr>
<tr>
<td>58. $P_1$ ... I said that ... the mass was the volume ... but .. now I think I'm changing ideas ... I'm not so sure about it ... no mass isn't the same as volume ...</td>
<td></td>
</tr>
<tr>
<td>59. S.T. can you show to your colleagues that mass isn't the same as volume?</td>
<td></td>
</tr>
<tr>
<td>60. $P_1$ .. for instance if we have two bodies made of iron .. with exactly the same size ... no ... let's think .. one of iron and another of wood ... exactly with the same size ..... same shape ... they occupy the same space .. the same volume ... but the mass is different ...</td>
<td></td>
</tr>
<tr>
<td>61. $P_s$ .... different ... yes .. yes</td>
<td></td>
</tr>
<tr>
<td>62. $P_1$ ... yes .... and so .. volume has nothing to do with mass ......</td>
<td></td>
</tr>
</tbody>
</table>
63. S.T. has the mass something to do with weight?  

Before going to the problem of "mass and weight" she should lead the discussion in order to a better clarification of the problem "mass and volume"

D1

64. P_3 no .. no yes .... yes

65. P_1 I think mass has something to do with weight

66. P_2 no ..... no

67. P_3 may be it has something to do with the quantity of matter ...

68. P_4 what? .. the quality of matter? ....

69. P_3 (a very lively discussion takes place, impossible to transcribe)

70. S.T. you there .. "Ana" ... "Isabel" is saying that the quality of mass has something to do with weight ...

S.T. stimulates the discussion

A3 C1

71. P_1 I don't think so .... because if you have a block of iron weighting 1 Kg ...

P_1 is addressing to her peer "Isabel"

72. P_2 ... and cotton wool

73. P_1 yes ... cotton wool ... we need a bigger volume of cotton wool to get the same ... the same weight

74. P_3 (all speaking at the same time impossible to transcribe)

75. P I'm speaking in quantity not in quality
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>76. $P_3$ (all speaking ...)</td>
<td></td>
</tr>
<tr>
<td>77. $P_1$ oh! ... Miss I think mass has nothing to do with weight ... because ... for instance ... I can weight the same as a piece of iron ... but we have different mass ... isn't it?</td>
<td>The view that mass is the material is again disclosed in this utterance</td>
</tr>
<tr>
<td>78. $P_2$ that's true ...</td>
<td></td>
</tr>
<tr>
<td>79. $P_3$ .... no .. but don't you see .... mass isn't the material that makes up a body!</td>
<td>The discussion between pupils help them to develop critical mindedness, the skill of communicating and progress in their cognitive development</td>
</tr>
<tr>
<td>80. $P_3$ (big discussion between pupils impossible to transcribe)</td>
<td></td>
</tr>
<tr>
<td>81. S.T. well ... let's clear up ideas ... first of all we are going to see if mass is the material from which a body is made up ....... if it is the existent matter in the body ... or quantity of substance and ... etc. .... and then ... we are going to see if mass and weight are the same thing ... OK?</td>
<td>She recognizes here that the problem of identification of mass with material still remains which makes her to draw back to the problem</td>
</tr>
<tr>
<td>82. $P$ can I go there to explain my idea?</td>
<td>This illustrates how pupils feel at ease in participating</td>
</tr>
<tr>
<td>83. S.T. yes you can</td>
<td></td>
</tr>
<tr>
<td>84. $P_1$ what is she going to do?</td>
<td></td>
</tr>
<tr>
<td>85. $P_2$ oh! Miss is she going to say .. which one of those sentences is the correct one?</td>
<td>Acting like this $S_6$ is showing to the pupils that what they think is important for the development of the lesson and encourages pupils to talk</td>
</tr>
<tr>
<td>86. S.T. well .. let's see what she is going to tell us</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transcript</td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>87</td>
<td>( P_1 )  well ... I have here .... one stick of chalk .. and if I have two sticks ... the quality of mass is the same ... but the quantity of mass is going to be different and in consequence the weight is also going to be different</td>
</tr>
<tr>
<td>88</td>
<td>( P_2 )  ... so ... how can you prove that the mass isn't the same although the weight is different?</td>
</tr>
<tr>
<td>89</td>
<td>( P_1 )  ah! ... er! ....</td>
</tr>
<tr>
<td>90</td>
<td>( P_3 )  (a very lively discussion takes place, impossible to transcribe)</td>
</tr>
<tr>
<td>91</td>
<td>S.T.  ... well .. &quot;João Paulo&quot; ... first ... let's see if mass is some of the things written on the blackboard?</td>
</tr>
<tr>
<td>92</td>
<td>( P_1 )  it's the second one</td>
</tr>
<tr>
<td>93</td>
<td>( P_2 )  it's the last one</td>
</tr>
<tr>
<td>94</td>
<td>( P_3 )  it's the third one</td>
</tr>
<tr>
<td>95</td>
<td>( P_3 )  it's the second it's the last ....</td>
</tr>
<tr>
<td>96</td>
<td>S.T.  I said &quot;João Paulo&quot;.. is &quot;João Paulo&quot; everybody's name? ... let's see ... &quot;João Paulo&quot; how could we prove if the first hypothesis is true or false ... &quot;the mass is what makes up a body&quot;</td>
</tr>
<tr>
<td>97</td>
<td>( P )  I said that ... but I was thinking ... what I wanted  to say was that the body is formed by a certain matter ..</td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>98.  $P_2$  yes ... and it can be made ... for instance ... from iron or wood ... and that is what makes up the body ... it is the material of the body</td>
<td></td>
</tr>
<tr>
<td>99.  $P_3$  ... and in consequence of that ... the mass will be different if the material is different</td>
<td>She rewords the pupil's idea to help for a clarification</td>
</tr>
<tr>
<td>100. S.T.  ... then for you .. the material from which the body is made is its mass ... is that true?</td>
<td></td>
</tr>
<tr>
<td>101. $P_s$  ... it is  yes  .. no  (all speaking at the same time)</td>
<td></td>
</tr>
<tr>
<td>102. S.T.  but my question is this .... how can we prove if this is true</td>
<td>(The first sentence)</td>
</tr>
<tr>
<td>103. $P_1$  well ... Miss .. it is not wrong .. but it is not completed</td>
<td></td>
</tr>
<tr>
<td>104. S.T.  suppose I say &quot;the mass is the material from which the body is made&quot;</td>
<td></td>
</tr>
<tr>
<td>105. $P_1$  it's alright</td>
<td></td>
</tr>
<tr>
<td>106. $P_2$  it's true</td>
<td></td>
</tr>
<tr>
<td>107. S.T.  is it true?</td>
<td></td>
</tr>
<tr>
<td>108. $P_1$  I think so</td>
<td></td>
</tr>
<tr>
<td>109. $P_2$  but it isn't complete</td>
<td></td>
</tr>
<tr>
<td>110. $P_3$  I'm not understanding anything</td>
<td>This utterance conveys the conflict faced by pupil's intuitive ideas</td>
</tr>
<tr>
<td>Transcription</td>
<td>Analysis</td>
</tr>
<tr>
<td>---------------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>111. P_S</strong></td>
<td>(all speaking)</td>
</tr>
<tr>
<td><strong>112. S.T.</strong></td>
<td>... again .. my question is this .. how can we prove that it is true?</td>
</tr>
<tr>
<td><strong>113. P_S</strong></td>
<td>(silence)</td>
</tr>
<tr>
<td><strong>114. P_1</strong></td>
<td>... if we put together all the chalk powder which I have here ... and if I make a stick of chalk .... I know that .. that is what makes up ...</td>
</tr>
<tr>
<td><strong>115. P_2</strong></td>
<td>the body ..</td>
</tr>
<tr>
<td><strong>116. P_1</strong></td>
<td>yes ... the stick of chalk ... all the powder makes up the body ... and the constitution was the chalk powder</td>
</tr>
<tr>
<td><strong>117. S.T.</strong></td>
<td>and what conclusion about mass can you draw from that?</td>
</tr>
<tr>
<td><strong>118. P</strong></td>
<td>... I can draw the conclusion that the stick of chalk is made up by the chalk powder ... which is its mass</td>
</tr>
<tr>
<td><strong>119. S.T.</strong></td>
<td>then ... if I have in my right hand one stick of chalk and in my left hand another stick of chalk .. the material of these two sticks are equal .. right?</td>
</tr>
<tr>
<td><strong>120. P_S</strong></td>
<td>yes ... they are ... yes</td>
</tr>
<tr>
<td><strong>121. P_1</strong></td>
<td>yes ... they have the same mass</td>
</tr>
<tr>
<td><strong>122. P_2</strong></td>
<td>no ...</td>
</tr>
<tr>
<td><strong>123. P_3</strong></td>
<td>yes ...</td>
</tr>
</tbody>
</table>

_She stimulates pupils' thinking_

_S.T. encourages the pupil to draw the conclusion_

_The pupil's conclusion is consistent with his meaning of "mass"_
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>124. ( P_4 )</td>
<td>..... uhum!</td>
</tr>
<tr>
<td>125. ( P_5 )</td>
<td>... well at a first look ... their masses seem equal ....</td>
</tr>
<tr>
<td>126. S.T.</td>
<td>... so .. If the mass is the material which makes up the stick ... If I have one or ten sticks ... the mass of one is the same as the mass of ten?</td>
</tr>
<tr>
<td>127. ( P_8 )</td>
<td>no ... no yes it is yes ..</td>
</tr>
<tr>
<td>128. ( P_4 )</td>
<td>I think ... yes ... because if the material is the same</td>
</tr>
<tr>
<td>129. ( P_5 )</td>
<td>what is different is the quantity of mass</td>
</tr>
<tr>
<td>130. S.T.</td>
<td>so according to that definition &quot;mass is what makes up a body&quot; ... If I have one stick of chalk or ten sticks we have the same mass .. in each case?</td>
</tr>
<tr>
<td>131. ( P_1 )</td>
<td>yes ... because the material is the same</td>
</tr>
<tr>
<td>132. ( P_8 )</td>
<td>no ... I don't agree yes .. it is! ... I think so</td>
</tr>
<tr>
<td>133. ( P_1 )</td>
<td>no ... it must be related to the weight</td>
</tr>
<tr>
<td>134. ( P_2 )</td>
<td>shut up ... this has nothing to do with weight ....</td>
</tr>
<tr>
<td>135. S.T.</td>
<td>look here ... we have here a beam balance .. it compares masses</td>
</tr>
<tr>
<td>136. ( P_3 )</td>
<td>yes</td>
</tr>
</tbody>
</table>

Her intention seems to get pupil's idea in conflict which can lead to a cognitive development in a constructivist perspective

It is apparent the identification of mass with the material which makes up the body

Aim: (Inference)
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>137. S.T.</td>
<td>... so if I put one stick in one of the plates and two in the other what will happen?</td>
</tr>
<tr>
<td>138. P₄</td>
<td>it will not be balanced</td>
</tr>
<tr>
<td>139. S.T.</td>
<td>let's ... (she puts the chalks on the plates) ... so what conclusions can we draw?</td>
</tr>
<tr>
<td>140. P₅</td>
<td>two sticks weight more</td>
</tr>
<tr>
<td>141. S.T.</td>
<td>... well ... we are still talking about mass ..</td>
</tr>
<tr>
<td>142. P₆</td>
<td>the masses are different</td>
</tr>
<tr>
<td>143. P₇</td>
<td>the mass of the two sticks is bigger</td>
</tr>
<tr>
<td>144. P₈</td>
<td>no ... the mass .. should be the same ... they are made up by the same material</td>
</tr>
<tr>
<td>145. P₉</td>
<td>... but don't you see that the balance isn't balanced ...</td>
</tr>
<tr>
<td>146. S.T.</td>
<td>well according to this first definition for mass ... just written here ... to have one or two sticks made up of the same material we should have the same mass</td>
</tr>
<tr>
<td>147. P₁₀</td>
<td>yes ...</td>
</tr>
<tr>
<td>148. S.T.</td>
<td>but ... as you see .. the beam balance ... which compare masses ... shows us that this definition ... is it true or false?</td>
</tr>
<tr>
<td>149. P₁₁</td>
<td>... (silence)</td>
</tr>
</tbody>
</table>

This answer is consequent with everyday experience although it is inconsistent with some pupils' ideas about the concept of mass.

She provides situations in which pupils' ideas can be in conflict.

This evidences the resistance of the intuitive idea.

In this inter-pupil interaction this pupil is helping her peer to progress in her cognitive development.

She is pushing pupils for an interpretation of an observation.
<table>
<thead>
<tr>
<th>Transcript</th>
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</tr>
</thead>
<tbody>
<tr>
<td>150. ( P_1 ) it's false</td>
<td></td>
</tr>
<tr>
<td>151. ( P_2 ) ... but ... with that balance we measure weights ....</td>
<td></td>
</tr>
<tr>
<td>152. S.T. This beam balance compares masses ... where is there more mass? She is unable to clarify the doubt shown by the last pupil (151)</td>
<td></td>
</tr>
<tr>
<td>153. ( P_3 ) on that side ... of course</td>
<td></td>
</tr>
<tr>
<td>154. S.T. so two sticks of chalk have more mass than one .. She sums up the result of the measurement</td>
<td></td>
</tr>
<tr>
<td>155. ( P_4 ) (all speaking at the same time)</td>
<td></td>
</tr>
<tr>
<td>156. ( P_5 ) I still think they have the same mass</td>
<td></td>
</tr>
<tr>
<td>157. S.T. so .. you are saying .. the mass of two sticks is the same as the mass of one?</td>
<td></td>
</tr>
<tr>
<td>158. ( P_6 ) it's the same .... because they are made of the same material This pupil still persists with her intuitive idea</td>
<td></td>
</tr>
<tr>
<td>159. ( P_7 ) it's the same in quality ... but in quantity ...... it's different ...</td>
<td></td>
</tr>
<tr>
<td>160. ( P_8 ) ... no ..........</td>
<td></td>
</tr>
<tr>
<td>161. ( P_9 ) ... but the balance .... it isn't balanced ......</td>
<td></td>
</tr>
<tr>
<td>162. ( P_{10} ) (all speaking .... big discussion between pupils taking place)</td>
<td></td>
</tr>
<tr>
<td>163. ( P_1 ) Miss can I speak?</td>
<td></td>
</tr>
<tr>
<td>164. S.T. yes</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
</tr>
</tbody>
</table>
| 165. \( P_1 \) 
... I think that the mass is the same because the sticks are made of the same thing ... but ... it is obvious that the two sticks have more ... |
| 166. \( P_2 \) 
more quantity of that material |
| 167. \( P_3 \) 
but the question isn't about quantity or quality .... it's about mass |
| 168. \( P_4 \) 
yes ... and the mass is different in both cases |
| 169. \( P_5 \) 
no ... it's equal .... |
| 170. S.T. 
... well ... let's think ..... according to this sentence here ... we would say that one chalk has the same mass as two ... because they are made of the same material |
| 171. \( P \) 
... so .. the sentence is false |
| 172. S.T. 
now ... the beam balance which compares masses ..... what does it indicate? |
| 173. \( P_1 \) 
... that the sentence is false |
| 174. \( P_s \) 
(all speaking) |
| 175. \( P \) 
but ... that indicates quantity ... |
| 176. S.T. 
quantity of what? .... the balance compares masses |
| 177. \( P_1 \) 
... but .... Miss what is that of "comparing"? |
| 178. \( P_2 \) 
it compares the quantity of mass |
<table>
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</tr>
</thead>
<tbody>
<tr>
<td>179. S.T.</td>
<td>what is comparing masses?</td>
<td>She returns the question (177) to the class</td>
</tr>
<tr>
<td>180. P</td>
<td>I think the balance .... compares quantities of mass</td>
<td></td>
</tr>
<tr>
<td>181. P₂</td>
<td>(big discussion .... impossible to transcribe)</td>
<td></td>
</tr>
<tr>
<td>182. P</td>
<td>I'm very confused</td>
<td></td>
</tr>
<tr>
<td>183. S.T.</td>
<td>well .. we are trying to find out what is mass .... if we still don't know what mass is ... we cannot understand when you speak about quantity of mass ... so what do you mean by mass?</td>
<td></td>
</tr>
<tr>
<td>184. P</td>
<td>mass is the substance of a body</td>
<td></td>
</tr>
<tr>
<td>185. S.T.</td>
<td>is it the substance? it's what it is made of?</td>
<td></td>
</tr>
<tr>
<td>186. P₂</td>
<td>(silence)</td>
<td></td>
</tr>
<tr>
<td>187. S.T.</td>
<td>well .. let's sum up ... from the beginning ... according to this sentence the mass of a body is the material from which a body is made up .. I have here two chalk sticks which are made of the same material .. so according to this sentence .... the mass of one or the mass of two sticks is the same</td>
<td>She repeats the situation in a new attempt to help some pupils to change their intuitive ideas to a more scientific one</td>
</tr>
<tr>
<td>188. P₁</td>
<td>according to that sentence it should be the same but this is not true</td>
<td></td>
</tr>
<tr>
<td>189. P₂</td>
<td>... right ... it's false</td>
<td></td>
</tr>
<tr>
<td>190. P₂</td>
<td>.. yes ... that's false</td>
<td></td>
</tr>
<tr>
<td>191. P₁</td>
<td>yes ... we saw that when you put them on the balance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transcript</td>
<td>Analysis</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>192</td>
<td>$P_2$ everybody should see that</td>
<td>Pupils are allowed to discuss between them their ideas</td>
</tr>
<tr>
<td>193</td>
<td>$P_3$ it's obvious</td>
<td></td>
</tr>
<tr>
<td>194</td>
<td>$P_s$ (all speaking)</td>
<td></td>
</tr>
<tr>
<td>195</td>
<td>$P$ ... you don't go to the fish market to see those balances so .. you don't understand noting</td>
<td></td>
</tr>
<tr>
<td>196</td>
<td>$P_s$ (laughing)</td>
<td></td>
</tr>
<tr>
<td>197</td>
<td>S.T. so ... we all agree that the first sentence is false ....... mass isn't the material from which the body is made of</td>
<td></td>
</tr>
<tr>
<td>198</td>
<td>$P_s$ yes ... right</td>
<td></td>
</tr>
<tr>
<td>199</td>
<td>S.T. now let's see the other sentence ... mass is the quantity of substance which makes up a body</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>$P_1$ it's wrong</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>$P_2$ wrong? .... prove me that it's wrong</td>
<td></td>
</tr>
<tr>
<td>202</td>
<td>$P_1$ because I think so ..</td>
<td></td>
</tr>
<tr>
<td>203</td>
<td>$P_2$ that doesn't prove anything</td>
<td></td>
</tr>
<tr>
<td>204</td>
<td>$P_3$ the substance ... means quality</td>
<td></td>
</tr>
<tr>
<td>205</td>
<td>$P_4$ .. the quality doesn't say nothing .. it has nothing to do with mass because we can have two objects ... for instance one of iron and one of wood ..... the quality is different but .. they can have both the same mass .. it has nothing to do with quality</td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>206. <em>P₂</em></td>
<td>it has ... it must have ...</td>
<td></td>
</tr>
<tr>
<td>207. <em>P₃</em></td>
<td>(all speaking at the same time)</td>
<td></td>
</tr>
<tr>
<td>208. <em>S.T.</em></td>
<td>just one person speaking at each time!</td>
<td></td>
</tr>
<tr>
<td>209. <em>P</em></td>
<td>it's logic that there are different qualities of mass ... ..... but from the point of view of the concept of mass the quality has nothing to do with it .. because .. being iron .. or wood .. or meat ... or bones (laughing) ..... it is always mass</td>
<td></td>
</tr>
<tr>
<td>210. <em>P₅</em></td>
<td>(laughing) .. a big discussion takes place impossible to transcribe</td>
<td></td>
</tr>
<tr>
<td>211. <em>P₁</em></td>
<td>.... but ... I think that is true ... mass is the quantity of substance or ... material ... or matter which makes up a body ...... it's because this that the two sticks have more mass than one .. they have more quantity of chalk powder</td>
<td></td>
</tr>
<tr>
<td>212. <em>S.T.</em></td>
<td>everybody agrees with &quot;Maria&quot;?</td>
<td></td>
</tr>
<tr>
<td>213. <em>P₃</em></td>
<td>.... yes ... that's true I think so</td>
<td></td>
</tr>
<tr>
<td>214. <em>S.T.</em></td>
<td>OK .... so .. let's see if we can find a way to prove if mass and volume are the same thing or different things</td>
<td></td>
</tr>
<tr>
<td>215. <em>P₁</em></td>
<td>for me it is the same thing</td>
<td></td>
</tr>
<tr>
<td>216. <em>P₂</em></td>
<td>I think it's different</td>
<td></td>
</tr>
</tbody>
</table>

It looks that everybody now has no more doubt about mass being the quantity of material that makes up a body

She shifts now towards another idea emerged from the diagnostic questionnaire — mass = volume

\[ D₁ \]
<table>
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</thead>
<tbody>
<tr>
<td>217. S.T.</td>
<td><em>well... a great number of answers to the questionnaire say that mass is the same as the volume</em></td>
</tr>
<tr>
<td>218. P</td>
<td>no... no... they are different</td>
</tr>
<tr>
<td>219. Pₚ</td>
<td>(all speaking)</td>
</tr>
<tr>
<td>220. S.T.</td>
<td><strong>... look here... I have here two balls of the same volume...</strong></td>
</tr>
<tr>
<td>221. P₁</td>
<td>yes... but if one is made of wood and the other made of plastic their masses must be different</td>
</tr>
<tr>
<td>222. Pₚ</td>
<td>yes...</td>
</tr>
<tr>
<td>223. S.T.</td>
<td>(puts the balls on the plates of the balance)... which one has a bigger mass?</td>
</tr>
<tr>
<td>224. Pₚ</td>
<td><strong>... the one made of wood</strong></td>
</tr>
<tr>
<td>225. P₁</td>
<td>no... the mass should be the same they have the same volume</td>
</tr>
<tr>
<td>226. Pₚ</td>
<td>(all speaking)</td>
</tr>
<tr>
<td>227. S.T.</td>
<td><strong>... look here... you know that this balance compares masses... if when I put the two balls on each plate of the beam the balance is unbalanced... what conclusion can you draw?</strong></td>
</tr>
<tr>
<td>228. P₁</td>
<td>the masses are different</td>
</tr>
<tr>
<td>229. P₂</td>
<td><strong>... but the volume occupied by them is equal</strong></td>
</tr>
</tbody>
</table>

**Evidence of the resistance of the intuitive ideas although the facts observed are in opposition of these ideas**

**She asks for conclusions based on evidence**

C₈
<table>
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<tbody>
<tr>
<td>230. $P_3$</td>
<td>yes ... it is the mass that is different</td>
</tr>
<tr>
<td>231. S.T.</td>
<td>so ... the first conclusion that can be drawn is that mass isn't the material from which the body is made up ... and the second is that mass isn't the volume of the body ... is that clear?</td>
</tr>
<tr>
<td>232. $P_3$</td>
<td>yes ... yes</td>
</tr>
<tr>
<td>233. S.T.</td>
<td>so what should mass be?</td>
</tr>
<tr>
<td>234. $P_1$</td>
<td>well ... for me it is the quantity of matter that's make up the body</td>
</tr>
<tr>
<td>235. $P_2$</td>
<td>... quantity ... what is this ... is it the number .... isn't it?</td>
</tr>
<tr>
<td>236. $P_1$</td>
<td>yes ..</td>
</tr>
<tr>
<td>237. $P_3$</td>
<td>is it Miss? ... so you are going to prove that it is true</td>
</tr>
<tr>
<td>238. $P$</td>
<td>it's already proved</td>
</tr>
<tr>
<td>239. $P_3$</td>
<td>(a lively discussion takes place, impossible to transcribe)</td>
</tr>
<tr>
<td>240. $P$</td>
<td>please Miss I think that isn't correct ... because ... for instance I know that every mass has a certain quantity ... but ... for instance ... having 35 Kg of a mass and having 49 Kg of the same doesn't mean ... it is clear that it is a different quantity but it doesn't mean that it is not the same mass ...</td>
</tr>
<tr>
<td>241. $P_3$</td>
<td>(all speaking)</td>
</tr>
</tbody>
</table>

This pupil still shows the same intuitive idea about "mass"
<table>
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</thead>
<tbody>
<tr>
<td><strong>242. S.T.</strong> &quot;Paula&quot;... look here.. let's see your example.. you are talking about a mass of 35 Kg and another of 49 Kg... it means that the mass of 49 Kg has more quantity of matter... right?</td>
<td>It looks as S6 is losing her patience with this girl</td>
<td></td>
</tr>
<tr>
<td><strong>243. P3</strong> yes... (a big discussion takes place between pupils in which their ideas are confronted with the others')</td>
<td></td>
<td>A3</td>
</tr>
<tr>
<td><strong>244. S.T.</strong> now I want to make another question....</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>245. P2</strong> good</td>
<td></td>
<td>A3</td>
</tr>
<tr>
<td><strong>246. P2</strong> another!</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>247. S.T.</strong>... if I have a body with... one thousand of particles... you all know that a body is made up of particles... isn't it?... and if I have another body... of the same material... supposing that's iron... and have ....... 1100 particles which one do you say that has bigger mass</td>
<td>With this example she is probably making emphasis on pupils' idea about particles making up a body. Her intention seems to be to investigate if the concept of mass is understood</td>
<td>A3</td>
</tr>
<tr>
<td><strong>248. P3</strong> .... the second one</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the one with 1100....</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>249. P</strong> but it doesn't mean they haven't the same mass</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>250. P3</strong> (a big reaction from peers) again! she is still in the same!</td>
<td>This pupil is still holding her intuitive idea about mass</td>
<td></td>
</tr>
<tr>
<td><strong>251. S.T.</strong> look here &quot;Paula&quot; how can they have the same mass if one has less particles than the other? how can they have the same mass?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transcript</td>
<td>Analysis</td>
<td>Aims (Inferred)</td>
</tr>
<tr>
<td>------------</td>
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<td>----------------</td>
</tr>
<tr>
<td>252. P1</td>
<td>.... how can I explain! ... the quantity can be different but they have the same mass because they are made of the same thing</td>
<td></td>
</tr>
<tr>
<td>253. P2</td>
<td>she is thinking about quality!</td>
<td>Other peers are clearing up this pupil's difficulty</td>
</tr>
<tr>
<td>254. P3</td>
<td>she is talking about the material from which the body is made up</td>
<td></td>
</tr>
<tr>
<td>255. S.T.</td>
<td>&quot;Paula&quot; you are using the definition of mass that we all already saw it isn't correct</td>
<td></td>
</tr>
<tr>
<td>256. P5</td>
<td>(all speaking ... impossible to transcribe)</td>
<td></td>
</tr>
<tr>
<td>257. P1</td>
<td>look Miss .... I think that what she is trying to say is that having five bricks piled here and just one there ... because they are all bricks ... both piles have the same mass ... but we have already seen that this isn't true</td>
<td></td>
</tr>
<tr>
<td>258. P2</td>
<td>they are made of the same material but they haven't the same mass</td>
<td></td>
</tr>
<tr>
<td>259. P5</td>
<td>(everybody is trying to explain to &quot;Paula&quot; ... but ... at the same time!)</td>
<td></td>
</tr>
<tr>
<td>260. S.T.</td>
<td>&quot;Paula&quot; are you understanding?</td>
<td></td>
</tr>
<tr>
<td>261. P</td>
<td>oh! Miss I think I already understand .... I think I was confused</td>
<td></td>
</tr>
<tr>
<td>262. S.T.</td>
<td>because you were stuck to an idea of mass that wasn't correct</td>
<td></td>
</tr>
</tbody>
</table>
263. P  yes Miss ... but I think I understand now ..... the material is one thing and the quantity of material in a body is what its mass is

264. S.T.  good ... now another question ... if I have two equal masses ... one occupying two cm³ ... for instance ... one ball occupying two cm³ and another ball occupying less .... and if I put them in the beam balance like this one and ... what do you see?

265. P₁  ... the beam balance is balanced

266. P₂  it means the two masses are equal

267. P₃  yes the masses are equal

268. S.T.  yes they have the same mass although their volumes are different .. what conclusions can you draw about the material they are made up?

269. P₁  one is made of ... plastic ... and the other of iron ....

270. P₂  they are made of different materials

271. S.T.  yes ... we say the smaller ball is denser than the other one because it has the same mass in a smaller volume ... we call density to the mass existing in the unit volume ....

272. P₁  what .. density .. can you repeat?

She is exemplifying what she is saying

She asks for a conclusion based on evidence

S₈ should point out that this pupil couldn't infer what materials were the balls made up

The pupils are writing down what she is saying about density
<table>
<thead>
<tr>
<th>Transcript</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>273. <strong>S.T.</strong> we have here the same mass ... the two balls have the same mass ... but their volumes are different ..... this ball is denser because it has the same mass in a smaller volume</td>
<td><em>At this time she shouldn't advance with this concept, because the class is near the end and she doesn't have time to explore it conveniently</em></td>
</tr>
<tr>
<td>274. <strong>P</strong> the particles are more concentrated</td>
<td></td>
</tr>
<tr>
<td>275 <strong>P_s</strong> (all speaking at the same time)</td>
<td></td>
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<tr>
<td></td>
<td><em>(the bell rings and the lesson finishes).</em></td>
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</tbody>
</table>