CHANGING TEACHERS' PRACTICE:
TOWARDS A CONSTRUCTIVIST METHODOLOGY OF PHYSICS TEACHING.

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THESIS PRESENTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE DEPARTMENT OF EDUCATIONAL STUDIES, UNIVERSITY OF SURREY

1992
To Aristóteles, Leonardo, Bárbara, Socorro and Hermano who shared laughs and tears
ABSTRACT

This study explores the ideas held by physics teachers in relation to teaching and learning, their change due to a reflective process and consequences to their teaching practice.

The theoretical point of view adopted in this thesis considers the active role played by individuals in the construction of knowledge and applies the theoretical framework developed by George Kelly in his Personal Construct Theory. Methodology developed from PCT is used to analyse the learning processes experienced by them.

The data were obtained through case studies conducted with two teachers and two student teachers in the Physics Department at Universidade Católica de Pernambuco, Brazil. Over a period of six months, they participated in a series of workshops and group discussions during which they discussed their views and had contact with others about aspects of the teaching-learning process. At the end of this period, each teacher prepared a teaching sequence which were implemented by both of them during the next semester in an introductory course in Mechanics. They were observed in their classrooms in several occasions, using both new and traditional teaching methods. They were also interviewed using Repertory Grids focussed on teaching-learning process and nature of knowledge, curriculum materials, and teacher's and students' roles in this Mechanics course.

A constructivist model for learning was developed based on the results obtained in this study.

It is suggested that teachers should be aware of their own ideas about the teaching-learning process and be conscious of the links between these ideas and the procedures they adopt in their teaching practice, as well as have contact with other ideas and correlated procedures, in order to evaluate their teaching practice. These may lead to a construction of a new set of ideas. The use of them in the same context where the previous ideas were constructed, together with an analysis of the situation based on internal as well as external information, may then lead to an integration of previous and new ideas which would be reflected in a change in teaching practice.
ACKNOWLEDGEMENTS

This work is the result of years of study and perseverance, when several persons and institutions helped and encouraged me to keep going. At this moment I would like to thank all of them.

I would like to acknowledge the inspiration given by my colleague José Maurício Figueiredo, with whom I discussed the first version of my research plan.

Dr. John Gilbert, my first supervisor, was my first contact at the University of Surrey and I thank him for having invited me to study under his supervision.

Paula, Mike, Khalid, Muhammed, Tony, Dominique and Anne were my colleagues at the university and built a warm environment where we could discuss our ideas and give support to each other.

Pam Denicolo, Pat Cryer and Lewis Elton gave suggestions and 'food for thought' which were very helpful during the development of this study.

The British Council and CNPq - Conselho Nacional de Desenvolvimento Científico e Tecnológico gave me a scholarship which financed part of this work.

My colleagues at Universidade Católica de Pernambuco, the student-teachers and the students, who participated in the development process, opened their minds and hearts to allow my investigation.

Dr. Maureen Pope, my second and final supervisor, was the person who followed the development of this study, giving suggestions, discussing my doubts and guiding me towards a successful conclusion of this work.

Lígia Delacruz, Zélia Girardi and Erik Provan were my friends who shared my problems and difficulties during this long period and supported me with their love and care.

My parents, Hermano and Socorro, incentivated my studies since the beginning of my life and gave me the necessary support, taking care of my children, together with my husband, when I was alone in England.
Finally, I would like to acknowledge the love and patience received from my husband, Aristóteles, and my children, Leonardo and Bárbara, who were always present to encourage me and to give their support. The drawings and the visual presentation of this dissertation were prepared by Aristóteles, Leonardo introduced the changes in the font necessary for improving the quality of the typesetting, and Bárbara helped me in typing parts of this dissertation.

God bless you.
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1.0 - INTRODUCTION

In this chapter I shall make a brief presentation of the problem considered in this study and its objectives. I shall also present the phases of this study and the main results.

The theoretical framework will be presented in Chapter 2, followed by the methodological issues, presented in Chapter 3 and the description of the study in Chapter 4. The general results will be presented in Chapters 5 and 6. The two case studies will be presented in Chapters 7 and 8. Finally, the conclusions will be presented in Chapter 9.

1.1 - CHANGE IN PRACTICE AS A LEARNING PROCESS

The possibility of changing the practice of experienced teachers is the basis for promoting in-service training. This activity may be organized in different ways but generally involves the presentation of new ideas and methods to teachers. Therefore, during in-service training the teachers undergo a learning process which requires the integration of information in their conceptual framework. The expected result of this process is a teaching practice which presents more organization and theoretical coherence.

The demands faced by teachers in these processes are similar to the ones faced by students in physics courses, when they are asked to integrate scientific concepts to their previous ideas. In both cases, the persons involved possess their own theories about the events discussed during the process. They also have in common the demand of applying what they are learning during the process in another context.

Despite the differences between the two processes, the similarities stated above are enough to make an analogy between them. Therefore, the experiences
undergone by teachers in such a process could be used to enable their reflection upon the process undergone by students.

In this study I explored this analogy during a process developed according to the theoretical assumptions of the Personal Construct Theory (Kelly, 1955), with the objective of facilitating teachers' awareness of their theories concerning teaching and learning and their teaching practice.

During the process, the participants made contact with other views about teaching and learning, and had the opportunity of discussing and applying them in their own classrooms.

1.2 - OBJECTIVES OF THE STUDY

Considering the theoretical assumptions used in this process, this study was organized with the objective of answering the following research questions:

- How does teacher's awareness of his/her own implicit theories of teaching and learning enable him/her to evaluate/change his/her teaching practice?

- How does teacher's construct system in relation to curriculum materials interfere in his/her adoption of new teaching methods?

- What aspects of PCT could be used in respect of what aspects of a physics course?

The answers could contribute to the understanding of the changes undergone by teachers during in-service training, as well as to the identification of relevant aspects involved in the changing of teachers' practice. They could also contribute to the understanding of the learning process, considering the parallel made with the case of students in physics courses.

1.3 - DEVELOPMENT OF THE STUDY

This study was organized in two phases: a theoretical one, where the participants' personal theories about teaching and learning were elicited,
discussed and compared with other theories, and a practical one, when these theories were applied in a physics course.

During the first phase, the participants' personal theories were elicited using repertory grids, workshops and group discussions. The repertory grids focused on the teaching-learning process and the nature of knowledge, curriculum materials, teacher's roles and student's roles. The workshops were used to introduce the following themes: nature of scientific knowledge, alternative conceptions, teaching methods, evaluation, curriculum change and instructional process. The group discussions were used to present and discuss other views about the themes introduced during the workshops. A group discussion was used to introduce and discuss the theme "objectives in a course".

During the practical phase, the teachers prepared teaching sequences which were piloted and then used in a mechanics course. The teaching material was discussed in the group and the lessons were observed.

The results obtained in this study emphasized the importance of the context for learning. They also highlighted the necessity of support for teachers who are introducing innovations in their practices. The awareness of their personal theories was another aspect considered necessary for the teachers to change their practice, although it was not sufficient.

In this dissertation I have used he/him to generally refer to the teacher or student, as a reflection of my cultural background, where using the masculine makes the reference general and not related to the sex of the person involved. It is necessary to say that these results could apply indifferently to both sexes.
CHAPTER 2
THEORETICAL FRAMEWORK

2.0 - INTRODUCTION

In this chapter I shall identify the research field in which my work is embedded, and its current theoretical background. I shall also point out some inconsistencies presently found in this background, and suggest their origin.

In section 2.1 I shall discuss teachers' practice and its theoretical basis, and then stress the necessity of adopting a model of learning which is coherent with teachers' epistemological and psychological views. The constructivist approach to knowledge will be introduced, and the theory of Kelly will be suggested as a basis for a model of learning, due to its consistent epistemological and psychological approaches. The main aspects of this theory and its relationship with the work of some recent philosophers of science will also be presented in this section.

In section 2.2 the current uses of constructivist ideas in science teaching will be introduced. I shall start by discussing the problem of alternative conceptions, and shall then identify some inconsistencies in the "learning as conceptual change" approach.

The uses of constructivist ideas in the formation and development of teachers will be presented in section 2.3.

In section 2.4 the learning processes occurring in teacher education and in teacher training will be discussed, and the parallels between them, from a constructivist perspective, will be drawn.

Implications of the adoption of a constructivist perspective of learning will be summarized in section 2.5.
2.1 - CONSTRUCTIVIST APPROACH TO KNOWLEDGE

Teachers' practice, although considered by some as being a craft which is developed through their interaction with students in the classroom, is usually based on a theoretical framework which involves a model of learning. This kind of model has, in turn, its origin in more fundamental aspects: the nature of knowledge and the nature of man.

The nature of knowledge has been discussed in philosophy throughout the ages without agreement being reached. Among other ways of classifying the several theories of knowledge, it is possible to divide them in two groups: passivist and activist.

There is an important demarcation between 'passivist' and 'activist' theories of knowledge. Passivists' hold that true knowledge is Nature's imprint on a perfectly inert mind: mental activity can only result in bias and distortion. The most influential passivist school is classical empiricism. Activists' hold that we cannot read the book of Nature without mental activity, without interpreting them in the light of our expectations or theories.

(Lakatos, 1978, p.104, original emphasis)

One philosophical approach within the passivist group is naive realism. In the Realist's view reality is independent of man and absolute truth can be obtained through accumulation of parts of reality (Pope and Keen, 1981). In the philosophy of science, the passivist group is represented by the empiricists, who believe that knowledge is acquired through observation of reality and is transmitted to man's mind directly by the senses.

Within the activist group it is possible to identify two sub-groups: the conservative and the revolutionary:

...conservative 'activists' hold that we are 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. The idea that we live and die in the prison of our 'conceptual framework' was developed primarily by Kant; pessimistic Kantians thought
that the real world is forever unknowable because of this prison, while optimistic Kantians thought that God created our conceptual framework to fit the world. But revolutionary activists believe that conceptual frameworks can be developed and also replaced by new, better ones; it is we who create our 'prisons' and we can also, critically, demolish them.

(Lakatos, 1978, p.104, original emphasis)

The nature of man is an object of discussion in psychology. The theories about it are informed by theories about the nature of knowledge, and work together with them. This is acknowledged by Lakatos (1978):

Indeed, all brands of justificatlonist theories of knowledge which acknowledge the senses as a source (whether as one source or as the source) of knowledge are bound to contain a psychology of observation.

(Lakatos, 1978, p.98-99, original emphasis)

Among the psychological theories associated with passivist theories of knowledge, there is common acceptance of the Lockean idea that the mind of the individual is a tabula rasa until it is filled with information obtained through the senses. One example of these theories is behaviourism. Teaching methods based on these theories emphasize the way content is presented and pay no attention to students' ideas or their direct influence on the material being studied. Teachers who adopt this perspective expect that students acquire information in the same way as it was presented to them. Repetition is used to enhance the fixation of the content and exercises are used to permit rapid access to the information stored in students' mind.

Psychological theories associated with activist theories of knowledge consider persons as active agents who construct knowledge through interaction with their environment. Due to this emphasis on human construction, these theories are known as CONSTRUCTIVIST. The theories of Piaget (1929, 1930), Kelly (1955), and Ausubel (1968) are examples of this type of theory. Teaching methods based on the first two theories emphasized the active participation of students through their involvement in activities which were designed by the teachers. Students were conducted through a series of experiences considered
relevant by the teachers in order to reach the objectives they had established beforehand.

Although Kelly's theory was published in 1955, it was only in 1979 recommended by the Association for Science Education, in Britain, for consideration as an alternative model of Psychology for its implications for science education (Pope and Gilbert, 1985). A scheme for initial teacher training of physics teachers based on Kelly's theory was developed by Thomaz (1986). This scheme allowed the participants to adopt a constructivist approach to the teaching and learning of physics at secondary school level. It emphasized participants' own models of teaching and gave them the opportunity to try their hypotheses.

Current pedagogical practice in science education, however, is strongly influenced by the empiricist view of science. Alternative perspectives of science, such as those presented by Popper, Kuhn, Lakatos and Feyerabend, although influential in the scientific environment, are beginning to be considered in science courses, but generally in those about history of science. Implications of these theories for science education are restricted to some works in educational research (Zylbersztajn, 1981; Watts and Pope, 1982; Gilbert and Swift, 1985).

This influence from philosophy of science on science education causes some problems when constructivist perspectives are introduced, due to the inconsistency between their philosophical bases. While empiricism considers that knowledge is absorbed by the students, in a passive way, constructivism emphasizes the active role of the students in the construction of knowledge.

Furthermore, since the epistemological position of some constructivist theories is not explicit, it may lead to the design of teaching methods involving contradictory aspects. One example of these problems is observed in the discovery learning approach, which may be seen as an extension of the process approach:

While as a pedagogical approach it acknowledges implicitly, if not explicitly, that learning is an active process, it has not taken adequate account of the influence of the learner's prior knowledge on learning activities...as a pedagogy it...reflects a
view of scientific knowledge as absolute and unproblematic; as 'facts' which are revealed to us if an appropriate method is followed... It attempts to bring together the teaching of the processes of science with the 'transmission' of a certain body of knowledge by giving students opportunities to 'discover' knowledge through investigation.

(Millar and Driver, 1987, p.57)

Kelly's theory, as a basis for designing teaching methods, may have the advantage of making explicit its epistemological position. Thus, it would provide the psychological and epistemological bases for a model of learning which would inform a new pedagogic practice. On the other hand, since the theory is open to reconstruction, as recognized by Kelly himself, and since other influences must be considered in the construction of a teaching method, this study will analyse some steps necessary to develop a constructivist approach to physics teaching based on Kelly's theory.

In the next section I shall present the basic ideas of this theory, as well as some details, in order to stress some implications for teaching. This presentation is considered as a personal view of the theory and does not intend to give a deep analysis of it. Readers who are interested in more details or in other perspectives and applications of this theory, may consult Kelly (1955), Maher (1969), Bannister (1970), and Pope and Keen (1981).

2.1.1 - PERSONAL CONSTRUCT THEORY

The theory developed by George Kelly (1955) is a psychological theory based on an activist view of construction of knowledge, which he called CONSTRUCTIVE ALTERNATIVISM:

People understand themselves, their surroundings and anticipate future eventualities by constructing tentative models and evaluating these against personal criteria as to the successful prediction and control of events based upon the model.

(Pope, 1985, p.4, original emphasis)

This epistemological position stresses the relativity of knowledge, which is personally constructed in accordance with somebody's experiences, and the
possibility of changing it by successive experimentation. It is in direct contrast with accumulative fragmentalism, which is the idea that truth can be collected piece by piece:

\[
\text{While constructive alternativism does not argue against the collection of information, neither does it measure truth by the size of the collection. Indeed it leads one to regard a large accumulation of facts as an open invitation to some far-reaching reconstruction which will reduce them to a mass of trivialities.} \\
\text{(Kelly, 1970, p.2)}
\]

This position highlights the importance of the person as the decision maker and the principal responsible for his ideas or the change of them.

The nature of man adopted by Kelly is expressed by the metaphor *man-the-scientist*. According to this position, men, as scientists, develop personal theories in order to make sense of reality and *anticipate* events. These theories are checked against events which confirm or disconfirm an individual's expectations. It does not mean that events themselves have an intrinsic meaning, nor can they prove whether a construct is true or not, but that personal theories must be seen as hypotheses open to reconstruction.

Kelly's theory is organized as a fundamental postulate and eleven corollaries. Its FUNDAMENTAL POSTULATE states:

\[
\text{A person's processes are psychologically channellized by ways in which he anticipates events.} \\
\text{(Kelly, 1970, p. 9)}
\]

This idea is directly connected to Kelly's root metaphor *man-the-scientist* through the activity of anticipation, which Kelly saw as common to scientists and individual men. It also acknowledges the different ways of approaching the same event.

In terms of teaching methods, this affirmative stresses the necessity of considering the different ways students approach an activity. Depending on their previous ideas, the same activity may be perceived in different ways and that may lead to different conclusions.
The way persons make anticipations is treated in the CONSTRUCTION COROLLARY:

_A person anticipates events by construing their replications_

(Kelly, 1970, p. 11)

In order to construe replications of events a person uses certain characteristics he observes in them. These characteristics, which Kelly called CONSTRUCTS, are the basis to decide if two events are similar or not. If two events may be constructed using the same characteristics, they are considered similar.

It is important to stress that what is similar is the construction of events, not events per se. These are always different but, due to their inherent complexity, it is impossible for a person to consider all aspects involved in them.

This corollary emphasizes the active role of persons in the construction of knowledge. Its main implication for teaching methods is that students will not receive information passively, but will work on it, according to their previous ideas, and reconstruct it. Once they have interacted with some information, the result will be part of their personal knowledge and not a simple reproduction of the information.

The construction of the same event by different persons is considered in the INDIVIDUALITY COROLLARY:

_Persons differ from each other in their construction of events_

(Kelly, 1970, p. 12)

This corollary reinforces the notion that events do not carry an intrinsic meaning but can have different meanings put upon them by persons. It acknowledges, therefore, the development of alternative conceptions as a result of different persons interacting with the same event.

_Each person characteristically evolves, for his convenience in anticipating events, a construction system embracing ordinal relationships between constructs._

(Kelly, 1970, p. 12)
This ORGANIZATION COROLLARY provides some order to the system of constructs. They are considered as organized in a hierarchical way, with some constructs taking precedence over others, that is, being in a superordinate position within the system.

This type of structure allows the co-existence of parallel sets of constructs which can be used in different situations. This may explain the observation that children's ideas are not used consistently across contexts which appear to scientists as being similar (Driver and Oldham, 1986). If the contexts are not perceived as similar by the children, the use of different sets of constructs to analyse them does not constitute an inconsistency. Therefore, the inconsistency exists only in relation to the construct systems of the scientists.

This problem highlights the necessity for the teacher to know how the students organize their ideas. Chi et al. (1981) observed that physics problems were represented differently by students, depending on their expertise. Novices tended to categorize problems according to the surface structure of problems, that is, to the objects referred to in the problem, and to the literal terms used in the problem statement, while more experienced students based their categorization on the major physics principles governing the solution of each problem. In this case, a series of problems which would be considered by the teacher as variations of the same theme, would be considered by the students as a collection of different situations. It is especially important in relation to evaluation and transfer of knowledge to new situations.

An important aspect of this corollary, as acknowledged by Pope (1985), is the use of the term *evolves* to stress that this structure is not static but open to change.

The intrinsic nature of constructs is defined by the DICHOTOMY COROLLARY:

\[ A \text{ person's construction system is composed of a finite number of dichotomous constructs. } \]

(Kelly, 1970, p. 12)

Constructs are not representations or symbols of events, but abstractions which persons construe in their minds to deal with events - either grouping or
making distinctions between them. These abstractions are seen by Kelly as originating from comparison between at least three events. Through this comparison two characteristics are identified – one which applies to two of these events and another which does not apply to them but applies to the third. Thus, these characteristics, which are called poles of the construct, are the basis for establishing similarity and difference at the same time.

Although constructs have a bipolar nature it does not imply that events must be gathered around these poles. On the contrary, the existence of these extremes allows the creation of an array of objects ordered between the poles.

Certainly it is important not to consider a construct as another term for a concept.

(Kelly, 1970, p. 15)

The difference between constructs and concepts is stressed by Kelly, who sees constructs as the result of a double entity choice whereas concepts result from a single entity choice.

Two opposite views are generally used to explain concept formation. On one side, the theory of abstraction, with its origin in Aristotelian thinking, explains that concepts are formed by abstracting certain resemblances among otherwise dissimilar stimuli (Bolton, 1977, p.1). On the other, the subject is supposed to have a hypothesis about some aspects of his environment, and a concept is formed by the validation of this hypothesis. In both cases, either adopting a passivist or an activist view, concepts are formed by a set of characteristics. Thus, if somebody analyses an event in relation to a concept, there are two possible situations: it presents or it does not present the concept. If the concept is used to analyse a set of events, this analysis does not locate the events in relation to each other, but just divides them in two groups: those which present and those which do not present the concept.

The use of constructs, however, allows for differentiation among events, by localizing them in relation to the poles of the constructs. Through this process, it is possible to compare and contrast situations.

In his attempts to anticipate events a person may choose one or another pole of his constructs. The CHOICE COROLLARY states that:
A person chooses for himself that alternative in a dichotomized construct through which he anticipates the greater possibility for the elaboration of his system.

(Kelly, 1970, p. 15)

For Kelly, persons develop the usefulness of their construct systems by consolidating and extending them. To consolidate their construct systems, persons have to know how the constructs are applied to objects and how they are related to each other. To extend them, they have to use them in new situations. In any case, changes are made in their construct systems in order to optimize their application.

This corollary emphasizes the notion that changes come from inside, not from outside. In order to change his behaviour, a person must change his perspective of events. Besides moving from one pole to another to deal with an event, a person sometimes needs to change the construct itself. This occurs because constructs cannot be applied to all types of events.

The RANGE COROLLARY states that:

A construct is convenient for the anticipation of a finite range of events only.

(Kelly, 1970, p. 16)

Here, again, it is necessary to distinguish between constructs and concepts. Constructs are bipolar. Then, when they are used to analyse an event, both poles are considered. The events are grouped according to their positions in respect to these poles. This enables the person to compare and contrast different events. If the characteristics expressed by the poles are irrelevant to some events, the construct is not useful for dealing with them.

A concept, on the other hand, may have several characteristics at the same time. When it is used to analyse events, the result is the separation between those which exhibit the concept and those which do not. In this way, a concept has universal applicability, but its power of discrimination is reduced to inclusion or exclusion.
The FOCUS OF CONVENIENCE of a construct is defined as the *set of objects with which it works especially well* (Kelly, 1970, p.17). A broader set with which a construct works *only reasonably well* is called RANGE OF CONVENIENCE.

This idea of range of convenience is especially important in the case of students' learning. It is related to the fact that students use different approaches to situations considered similar by teachers. In this case, in order to consider these situations as similar, students would need to extend the range of convenience of their constructs.

The way persons change their construct systems is treated by the EXPERIENCE COROLLARY:

> A person's construction system varies as he successively construes the replication of events.

(Kelly, 1970, p. 17)

This corollary is related to Kelly's idea of learning - *It is not something that happens to a person on occasions, it is what makes him a person in the first place* (Kelly, 1955, p. 7).

Learning is not regarded as something special but as a synonym for any psychological process. It is, therefore, the result of a person's attempts to deal with events, that is, of a person's experiences. What Kelly defines as an experience, however, is not a simple encounter with an event, but a *cycle embracing five phases: anticipation, investment, encounter, confirmation or disconfirmation, and constructive revision* (Kelly, 1970, p. 15).

Since events do not have an intrinsic meaning but are given meanings by the person through his constructs, it is possible that two events seen as different by one person appear as the same for another. In this case, what constitutes an experience for one person is a mere repetition for another, since the same constructs were used with both events.

In order to change his construct system a person should actively involve himself in anticipating an event as well as using the new evidences provided by the encounter to revise his constructs.
...the amount of a man's experience is not measured by the number of events with which he collides, but by the investments he has made in his anticipations and the revisions of his constructions that have followed upon his facing up to consequences.

(Kelly, 1970, p. 19)

This statement is especially relevant for teachers who expect that students change their ideas because they have contact with some situation. If they are not prepared for this encounter, if they do not invest in its anticipation and if they do not consider what happens in a critical way, no change will occur. Readiness to learn is not controlled by the teacher, but depends on students only.

An important aspect of this revision is not only the creation of revised constructs, that may be quite isolated in respect to the whole construct system, but the building up of new relations within the system. It can be achieved through the creation of new superordinate constructs to link the revised constructs to the whole structure, or through the development of new structures subordinated to already existent higher order constructs. These constructs, however, may or may not accept new subordinate structures - a characteristic called PERMEABILITY by Kelly.

This limitation to change is treated by the MODULATION COROLLARY:

The variation in a person's construction system is limited by the permeability of the constructs within whose ranges of convenience the variants lie.

(Kelly, 1970, p. 19)

The necessity of linking new ideas to a superordinate one was acknowledged by Ausubel et al. (1978). Their suggestion, however, was to provide this more general idea to the student.

The permeability of constructs does not depend on the building up of logical relations within the system, as stated by the FRAGMENTATION COROLLARY:
A person may successively employ a variety of construction subsystems which are inferentially incompatible with each other

(Kelly, 1970, p. 20)

Although the organization of a person's construct system enables him to lead a coherent existence, it is his system's ability to maintain non-logical relations between constructs that is responsible for the development of his knowledge. This characteristic, found in the development of scientific knowledge (Kuhn, 1970; Feyerabend, 1981), is considered by Kelly as inherent to human psychological processes:

\[
\text{The nice thing about hypotheses is that you don't have to believe them. This, I think, is a key to the genius of the scientific method. It permits you to be inconsistent with what you know long enough to see what will happen.}
\]

(Kelly, 1970a, p. 258)

This kind of inconsistency does not threaten the construct system because it may be ignored through the use of different ranges of convenience. It can be observed in the case of students who use the scientific concepts to solve problems during their science lessons, but are unable to apply them to analyze everyday life situations.

The COMMONALITY COROLLARY states that:

\[
\text{To the extent that one person employs a construction of experience which is similar to that employed by another his processes are psychologically similar to those of the other person.}
\]

(Kelly, 1970, p. 20)

The importance of this corollary is that it acknowledges the possibility of two persons, even having different construct systems, construing some experiences in the same way. It does not imply, however, that the persons have psychologically similar processes because they have experienced the same events. Even if they have undergone different experiences, they may construe them in a similar manner.
One aspect of group work, or simply of life in society, is the possibility of communication between persons. The SOCIALITY COROLLARY states that.

*To the extent that one person construes the construction process of another, he may play a role in a social process involving the other person.*

(Kelly, 1970, p. 22)

Since meaning is something constructed internally, in order to understand each other, persons should not rely just upon behaviour, but go a step further and try to understand the way the other person construes events. It is not necessary that the construction of the other person’s construct system is perfect, but that one tries to recreate it in his own mind.

The iterative process of communicating what somebody has concluded about another person’s perspectives may lead to the development of both of them. This process, however, is not always reciprocal and one person may fail to play a role in the development of the other because he does not invest in the reconstruction of the processes of the other.

The implications of this corollary for teaching practice are paramount. Within the traditional approach to science teaching, students are asked to understand (construe) the construction processes of the teacher. This enables the teachers to develop their ideas, which they generally acknowledge. Despite recognizing the importance, to their own development, of students’ attempts to understand what they try to teach, teachers do not seem to consider that they could enhance students’ development through the same process.

Although I have stressed the importance of Kelly’s ideas for science teaching, their use by teachers will require the fulfilment of some conditions. One of these is to solve the inconsistency between the philosophical bases of these ideas and the ideas contained in the science curriculum. In the next section I shall discuss the influence of philosophy of science on science teaching and the parallels between Personal Construct theory and the work of some recent philosophers of science.
2.1.2 - PHILOSOPHY OF SCIENCE AND PERSONAL CONSTRUCTION OF KNOWLEDGE

As far as science is concerned, the teacher today is no longer a mere purveyor of knowledge. He is an interpreter of his subject, an epistemologist and philosopher of science ... As to the education related disciplines, the teacher acts as a psychologist who applies principles of learning and motivation theories, as well as the findings of developmental psychology and social psychology, to match instruction to the capabilities and needs of his students. He also acts as a sociologist taking into account the community, its needs and its resources.

(Tamir, 1983, p.4)

This vision of teachers seems to me as an ideal which is as yet difficult to find in secondary schools' classrooms. In order to engage in all these activities and, therefore, to completely develop his potentials, a teacher must overcome a series of obstacles. One of these is the inconsistency between the philosophic bases informing his views concerning teaching methods, on one hand, and content, on the other.

At present, the influence of logical-positivism on pedagogic practice is still strong. Among others, two reasons for the success of this philosophic current are considered by Swift (1982). The first one is mainly historical. Logical-positivism may be regarded as an extension of empirical-inductivism, which is "the longest lasting and most influential philosophy of science with respect to modern (post-Renaissance) science" (p.5). The second reason is mainly psychological. Positivistic approaches appear to be similar to those which most people see as the one used to acquire knowledge, that is, through accumulation of fragments of reality. They are also appealing because, since it is a passive way to receive information, persons are not asked to assume responsibility for this process.

Although the work of Kant in the 18th century challenged the idea of an absolute truth, it was after the dissemination of Einstein's theories that this idea was substituted by that of probable truth, truth by consensus, or even that of scientific knowledge being unprovable (Lakatos, 1978).
It is interesting to notice that Einstein's ideas are very difficult to understand and cannot be checked by everyday life experiences. They are generally studied in undergraduate courses of physics, quite superficially, due to the mathematical complexity involved in a complete discussion, and are introduced, even more superficially, in some secondary schools' curricula.

If physics students attending courses in special relativity have problems in understanding and applying some of Einstein's ideas (Hewson, 1982), what can be said about science teachers who make contact with them through the textbooks they use to give their lessons?

According to Swift (1982):

\[ \text{Science, philosophy of science and theories of science-teaching inform each other through interaction - the more interaction the better the match.} \]

(p.7)

The image of science developed by students and teachers is influenced by the implicit philosophy of the curriculum, or "hidden curriculum" (Hodson, 1985). In the case of science curricula used in secondary schools, the content is generally presented as a system of facts, theories and concepts, absolute and unproblematic (Selley, 1981), and concentrates on theories developed up to the last century. It is not surprising, therefore, to find more links with positivism than with more recent philosophies of science.

Another aspect analysed by Swift (1982) is the compatibility between positivism and the ideology of 'cultural transmission', traditionally adopted by western education (Pope and Keen, 1981). According to this ideology, education is seen as an agent to preserve the structure of society, its values and its knowledge.

Since new visions about education and philosophy of science are slowly being introduced in schools, together with new teaching methods, it is necessary to appraise the basic ideas informing all these views in order to construct a common basis which will support all of them. In the next paragraphs I shall argue that it is possible through the use of Kelly's ideas to inform teaching practice.
While inductivism was widely accepted by scientists, non-scientists, teachers and students, there is a lack of consensus in relation to the more recent philosophical perspectives. Recent writers on philosophy of science, although agreeing that induction is inadequate as a description of scientific method, adopt different approaches which vary from Popperian methodology to post-Kuhnian views (Hodson, 1985). In order to consider these different perspectives I shall discuss the basic ideas of Popper, Kuhn, Lakatos and Feyerabend.

2.1.2.1 — THE IDEAS OF POPPER

The work of Popper was the basis for the works of the others. It broke off with inductivism, suggesting that all observations are theory laden and rejecting the view that science progresses by accretion. For him "science consists of the body of, as yet, unfalsified hypotheses" (Donnelly, 1986, p.21). These hypotheses are derived from the scientist's theoretical ideas and not from direct observation.

The problem faced by Popper was the problem of induction. He showed that theories are equally unprovable and improbable (Lakatos, 1978), that is, it is equally impossible to demonstrate that they are true. Therefore, to evaluate theories, he suggested the use of methodological falsificationism, which involves the use of criteria to reject, not to disprove, a theory. These criteria are established by agreement within the scientific community.

The criterion suggested by Popper to distinguish between scientific and non-scientific theories is the existence of an 'empirical basis'. It would be established with the aid of 'observational' statements. These are singular statements made unfalsifiable during a certain time and within a certain context. They are "distinguishable by the fact that there exists at the time a relevant technique such that anyone who has learned it will be able to decide that the statement is acceptable" (Lakatos, 1978, p.106, original emphasis). This demarcation criterion was his attempt to allow experiments to be powerful enough to refute a theory, without overlooking that they are interpreted according to some theories held by the scientists.

Although this criterion is not accepted by other philosophers of science, the basic ideas which gave origin to it, that is, that facts are interpreted by theories and that theories are not disproved by facts, are accepted.
In terms of science teaching, the most important notions present in Popper's work are:

- All observations are theory laden;
- Theories must be seen as tentative;
- Scientific knowledge progresses through critical analysis of theories.

Although these ideas concern epistemology of science and not personal aspects of scientists' development, it is possible to observe that they are compatible with Kelly’s basic epistemological position and even with some of his other ideas.

The emphasis on the theoretical basis of observations acknowledges the constructivist role of the scientist. He is the meaning-maker and, therefore, scientific knowledge is not absolute truth but the result of the construction of reality through the scientist's frameworks. It is in agreement with Kelly’s position of constructive alternativism, which recognizes the possibility of different constructions of the same reality. In terms of science teaching, it emphasizes the importance of students' conceptions prior to their participation in classroom activities.

The other two ideas, that is, that theories must be seen as conjectures and that they should be subjected to critical analysis, are related to the way Kelly suggests personal constructions should be treated — as hypotheses open to reconstruction. In this way, Popper’s idea about progress in science is analogous to Kelly’s idea about personal development. Even the occurrence of what Kelly called hostility, that is, "the continued effort to exhort validational evidence in favour of a type of social prediction which has already been recognized as a failure" (Pope, 1982, p.56), is considered by Popper when he distinguishes the use of auxiliary hypotheses which satisfy certain well-defined conditions to save a theory, from the use of hypotheses which do not. In the first case he considers that there is scientific progress, while in the second, the use of the so called ad hoc hypotheses is considered as a degeneration (Lakatos, 1978). In both cases, however, the objective is to preserve the existent theory and to avoid change.
2.1.2.2 - THE IDEAS OF KUHN

Kuhn adopts a position similar to that of Popper when he rejects a view that science develops by accumulation of bits of truth and also when he acknowledges that facts are not responsible for the replacement of theories. The criterion for this substitution, however, is based on the social and psychological behaviour of scientists instead of, as in the case of Popper, on a logic of discovery.

The progress of science, according to Kuhn, is characterized by the existence of three periods: pre-paradigm, normal science and scientific revolution. During the first period several theories compete with each other and adopt different approaches. At some stage one of these paradigms establishes itself as dominant and is accepted by the scientific community. It is the beginning of the period of normal science.

The term paradigm was used by Kuhn to denote both the set of commitments shared by a scientific community and the “exemplars”. In the first case it was considered as a synonym of “disciplinary matrix”, whose main components would be:

"symbolic generalizations" (e.g. F=ma, V=IR); "beliefs in particular models", either heuristic or ontological, which supply the group with the accepted analogies and metaphors (e.g. electric circuit as a hydrodynamic system, corpuscular or wave model of light); "shared values" (e.g. theories should be accurate in their predictions, theories should be simple); and "exemplars".

(Zylbersztajn, 1982, p.67)

By "exemplars" he meant the solutions of problems which students encounter during their scientific education plus the solutions of technical problems faced by scientists during their careers. The empirical content of scientific knowledge would be centrally placed in these shared examples, which would allow scientists to view the situations in the same gestalt as other members of their specialists' group (Kuhn, 1970).
During periods of "normal science" the scientist acts like a "puzzle solver", that is, the difficulties faced by him challenge only his ingenuity and not the present theory. This commitment to the dominant paradigm is seen by Kuhn as a sign of progress, because it enables the scientist to articulate the paradigm and to identify the points in it which need to be tested.

When the accepted theory fails to support the puzzle-solving tradition, the result is the emergence of a crisis during which "normal science" is replaced by "extraordinary science". In this situation the problems are regarded as anomalies and the limitations of the accepted theory are explored in order to incorporate the anomalous results into the dominant paradigm. At the same time the basic commitments of the paradigm are questioned and the whole process can lead to the emergence of a new paradigm which can solve the anomalies. When there is a shift to a new paradigm, it is said that a "scientific revolution" occurred. The progress of scientific knowledge takes place through cycles of normal and extraordinary science.

...a careful look at the scientific enterprise suggests that it is normal science... rather than extraordinary science which most nearly distinguishes science from other enterprises.  
(Kuhn, 1970a, p. 6)

It seems that an important characteristic of science, according to Kuhn, is the existence of a common knowledge which may be developed by different members of a community sharing its basic ideas. This knowledge may be represented by a common language and common accepted definitions. There is also a dominant theory that articulates this knowledge.

Although Popper considers critical discussion as "the only practical way of expanding our knowledge" (in Kuhn, 1970a, p. 6), Kuhn thinks that it is not science at all and since Hellenistic period, mathematics, astronomy, statics and the geometric parts of optics changed this type of discourse in favour of puzzle solving.

In a sense... it is precisely the abandonment of critical discourse that makes the transition to a science. Once a field has made that transition, critical discourse recurs only at moments of crisis.
when the bases of the field are again in jeopardy ... Only when they must choose between competing theories do scientists behave like philosophers.

(Kuhn, 1970a, p. 6-7)

Despite Popper and Kuhn's disagreement in relation to the precise way science develops, both of them acknowledge the importance, to this development, of critical discourse and adherence to current ideas:

*If we give in to criticism too easily, we shall never find out where the real power of our theories lie.*

(Popper, 1970, p.55)

2.1.2.3 - THE IDEAS OF LAKATOS

For Lakatos, science develops through competition of alternative research programmes. These programmes have three main components: the *negative heuristic* or *hard core*, formed by the basic ideas which are not questioned; the *protective belt*, formed by the "auxiliary hypotheses" which are adjusted or even replaced to stand the tests and defend the hard core; and the *positive heuristic*, formed by the ideas which organize the development of the research programme (Lakatos, 1970).

A research programme is appraised for its *heuristic power*, that is, its capacity of anticipating new facts and of explaining its refutations. For Lakatos, if a research programme is progressive, its empirical content increases. It does not mean, however, that new facts must be immediately observed:

*All we need... is that at least every now and then the increase in content should be seen to be retrospectively corroborated.*

(Lakatos, 1970, p.134, my emphasis)

For Lakatos, theoretical science is relatively autonomous. The problems studied by scientists are determined by the positive heuristic and not by the anomalies. These assume an important role only when the research programme is in a degenerating phase and the positive heuristic is no longer powerful.
Only those scientists have to rivet their attention on anomalies who are either engaged in trial-and-error exercises or who work in a degenerating phase of a research programme when the positive heuristic ran out of steam.

(Lakatos, 1970, p.137)

In both cases the problem is with the theory - lack of it, in the first case, and crisis in it, in the second.

But consistency - in a strong sense of the term - must remain an important regulative principle (over and above the requirement of progressive problemshift); and inconsistencies (including anomalies) must be seen as problems. The reason is simple. If science aims at truth, it must aim at consistency; if it resigns consistency, it resigns truth...On the other hand, this does not mean that the discovery of an inconsistency - or of an anomaly- must immediately stop the development of a programme: it may be rational to put the inconsistency into some temporary, ad hoc quarantine, and carry on with the positive heuristic of the programme.

(Lakatos, 1970, p.143, original emphasis)

This statement recognizes that, although consistency is necessary for the development of knowledge, lack of it is not enough to stop such development. Thus, it emphasizes that empirical evidence does not interfere directly on the development of theories, but may be kept apart “waiting” for the construction of a satisfactory explanation.

The structure proposed by Lakatos for research programmes is compatible with the basic Ideas of Popper and Kuhn, in relation to the theoretical basis of observations and to the power of facts to refute theories. It also acknowledges the importance of critical discourse and adherence to current ideas (in the hard core) for the development of science.

Purely negative, destructive criticism, like 'refutation' or demonstration of an inconsistency does not eliminate a programme. Criticism of a programme is a long and often frustrating process and one must treat budding
programmes leniently. One may, of course, show up the degeneration of a research programme, but it is only constructive criticism which, with the help of rival research programmes, can achieve real successes.

(Lakatos, 1970, p.179, original emphasis)

Besides this compatibility, Lakatos suggests three measures of progress for a research programme: maturity, heuristic power and generality. Maturity measures the unity, integrity and continuity over time of the programme (Watts, 1982). These characteristics are also acknowledged by Kelly as a sign of development of a person's construct system, and are described by the organization corollary, which considers a hierarchical structure giving unity and integrity to the evolving system.

Heuristic power is related to the capacity of anticipating new facts. This capacity, according to Kelly, is linked to the elaboration of a person's construct system, which may happen either through choice of different poles of a construct, or modulation, when new constructs are created in the same range of convenience, or fragmentation, when different ranges of convenience are considered.

The idea of generality is also acknowledged by Kelly in the hierarchical way he considers that construct systems are organized. More general constructs are hierarchically superior to specific constructs and, therefore, have precedence over them.

The major difference between the work of Lakatos and the works of Popper and Kuhn is the emphasis on the co-existence of alternative theories, which compete with each other, and on the time required to abandon one theory and adopt another:

... the idea of instant rationality can be seen to be utopian. But this utopian idea is a hallmark of most brands of epistemology. Justificationists wanted scientific theories to be proved even before they were published; probabilists hoped a machine could flash up instantly the value (degree of confirmation) of a theory, given the evidence; naive falsificationists hoped that elimination at least was the instant result of the verdict of experiment.
Lakatos emphasizes that the idea of instant rationality, or instant learning, is false. For him, science must be construed as a battleground of research programmes rather than of isolated theories (Lakatos, 1970, p. 175).

He presents three different positions to handle inconsistencies in research programs: the conservative position, that suggests halting the programme until inconsistencies are repaired; the anarchist position, that regards inconsistency as "some basic property of nature or an ultimate limitation of human knowledge" (Lakatos, 1970, p. 145); and the rational position, that keeps working on the positive heuristic while trying to solve the inconsistency. Examples of these three positions may be found in the history of science.

This acknowledgement of the existence, and necessity, of alternative perspectives in order to exist growth of scientific knowledge makes Lakatos' position closer to Kelly's. The epistemological position of alternative constructivism considers the production of alternative perspectives as the way persons cope with reality and develop themselves. The hard core suggested by Lakatos seems similar to the core constructs suggested by Kelly: both are fundamental, very resistant to change and at a low level of explication. They are responsible for the basic assumptions which give the support for the development of theories. The protective belt can be seen as similar to the construct system, which is adjusted according to the results of the interaction between the person and his environment. The positive heuristic can be compared with the way persons organize their construct systems in order to predict their behaviour.

2.1.2.4 - THE IDEAS OF FEYERABEND

The work of Feyerabend is based on the idea that observations are theory laden and also that the meanings of the observation languages change as the theories change (Swift, 1982). Therefore, competing theories which give different meanings to all terms used in the field are incommensurable.
His position is compatible with Lakatos' in relation to the existence of alternative theories, but he does not accept the existence of any objective criterion to choose between them. Lakatos opposed the emphasis put by Kuhn and Feyerabend on the psychology of science:

... the psychology of science is not autonomous; for the rationally reconstructed growth of science takes place essentially in the world of ideas, in Plato's and Popper's 'third world', in the world of articulated knowledge which is independent of knowing subjects.

(Lakatos, 1970, pp. 179-180, original emphasis)

Thus, Lakatos' belief in an objective criterion to judge between theories is based on this more fundamental idea of absolute knowledge, independent of knowing subjects.

The position adopted by Feyerabend is closer to that adopted by Kelly, when he considers the problem of dimensionality in knowledge claims, that is, when he considers that meaning depends on context and that there are different ideas involved in the making and testing of scientific knowledge claims (Swift, 1986).

... theories become clear and 'reasonable' only after incoherent parts of them have been used for a long time.

(Feyerabend, 1978, p. 26, original emphasis)

His idea about scientific progress is related to the proliferation of alternative theories and his suggestion for education emphasizes the importance of comparing and contrasting different perspectives:

General education should prepare a citizen to choose between the standards, or to find his way in a society that contains groups committed to various standards but it must under no condition bend his mind so that it conforms to the standards of one particular group.

(in Swift, 1982a, p. 124, original emphasis)
Feyerabend emphasizes the role of the scientist in the development of scientific knowledge, while Popper, Kuhn and Lakatos emphasize the collective character of it. The difference between the personal knowledge of the scientist and scientific knowledge is noticed by other authors:

*Scientific practice may be regarded as a process with three distinct phases: creation, validation and incorporation into the body of knowledge. Scientific knowledge is the product of a complex social activity which precedes and follows the individual act of discovery or creation.*

(Hodson, 1985, p.36, my emphasis)

Despite these different emphases, the works of Popper, Kuhn, Lakatos and Feyerabend share the basic assumptions that observations are theory laden and that scientific knowledge is not truth. This perspective, compatible with the one adopted by Kelly, provides a common support to inform the development of a coherent science teaching practice, which should emphasize the importance of students' ideas prior to instruction, and would consider the content of science courses as the presently accepted way to explain reality and not as the absolute truth.

### 2.2 - CONSTRUCTIVISM USES IN SCIENCE TEACHING

Constructivist approaches share the assumption that people develop their ideas in interaction with the environment, instead of just being "impressed" by it. Therefore, they may construe different conceptions to explain the world.

In this section I intend to discuss the implications for science teaching, of the adoption of a constructivist perspective of learning. I shall concentrate initially on the relationship between scientific concepts and students' conceptions, the status given to students' ideas in relation to that given to scientific concepts, and the use made of these personal views. In the second part I shall analyse the "learning as conceptual change" approach, its links with constructivist ideas and its implications for science teaching.
2.2.1 - SCIENTIFIC CONCEPTS AND ALTERNATIVE CONCEPTIONS

Studies of children's ideas about scientific concepts and about science (Zylbersztajn, 1983; Swift, 1986) acknowledge their importance for science teaching. Reviews of the research in this field (Gilbert and Watts, 1983; Driver and Erickson, 1983) present a series of works conducted in order to identify common ideas held by children in relation to different concepts in the areas of physics, chemistry and biology.

These ideas were initially considered as misconceptions, misunderstandings or conceptual mistakes developed by students in the course of instruction. Driver and Easley (1978) describe a series of studies from 1963 where "misconceptions" in science have been identified among school pupils and university students. Although they have reported some studies which identify "misconceptions" held by students whether studying science or not, as well as "misconceptions" persistent despite instruction, they considered these studies as examples of incorrect assimilation after exposition to formal models or theories, and used Ausubel's theory to suggest that "pupils are relating new knowledge to existing knowledge and are making wrong connections" (Driver and Easley, 1978, p. 68). They differentiated these studies, which focussed on the learning of scientific concepts, from others where alternative frameworks arose from personal experience of natural events, prior to instruction.

This distinction between misconceptions and alternative frameworks reflects the different ways the processes of learning through instruction and learning through experience are perceived. In the first case, students are involved in a passive activity whose objective is the assimilation of scientific concepts. In the second, the ideas are constructed by the individual during his attempts to understand natural phenomena.

It is interesting to notice that although science education is involved with the teaching and learning of concepts, there is no unique way to define them. Different ideas about concept are discussed by Gilbert and Watts (1983), who acknowledge the ambiguity in the use of this term due to its different meaning to different research traditions. They present three views about concepts: classical, relational and actional. The first defines concepts in terms of necessary and sufficient properties. The second adds to this definition the relationships with other concepts. Both views may be included in the "erklären"
tradition which considers passive learners accumulating knowledge bit by bit. The actional view, adopted in the "verstehen" tradition, recognizes person's influence in the development of the concept, defined as active, constructive and intentional.

Although this last view implies that persons actively construe knowledge and that concepts are developed personally in alternative ways, the acknowledgement of science as "beyond a merely personal activity done by individuals in isolation... one which is very much connected to the social and cultural context in which it is embedded in which the work of scientists is seen as essentially communicative" (Pope and Novak, 1985, p. 1) leads to a search for shared meanings. It reinforces the idea that scientific concepts may be learned from their definitions, which would contain the shared meaning of them.

Therefore, it is not surprising that even researchers adopting an 'actional' view of concepts do not agree on the terms used to describe individuals' personal constructions of natural phenomena. Terms like alternative conceptions (Driver and Easley, 1978) and children's science (Gilbert, Osborne and Fensham, 1982) reflect more than a mere choice of words - they are connected to the status given to these constructions and to the use to be made of them. If scientific concepts are seen as entities with their meanings univocally specified by their definitions, the destiny of these alternative conceptions or children's science would be to conform to the accepted definition, or to develop accordingly.

To come to an agreement, it is necessary to identify the relationship between concepts and personal constructions. Kelly's Personal Construct Theory states that persons construe tentative models to anticipate events, using certain characteristics called CONSTRUCTS. Kelly stresses the difference between concepts and constructs. He sees concepts as defined by several characteristics and having universal applicability. Constructs, on the other hand, are bipolar entities, that is, have a dimension defined by two contrasting characteristics (as already discussed). For Kelly, thinking in terms of contrasts is inherent to human nature.

Despite this emphasis, an explicit account of the difference between constructs and concepts is not found in the works of researchers in science education who use Kelly's theory. On the contrary, although they start with different terms, they finish using them as synonyms. An example is given by Tomlinson (1981)
who, after suggesting that Kelly preferred to use \textit{construe} and \textit{construct} instead of \textit{conceive} and \textit{concept} to emphasize the active and individual ways in which people make sense of their situations, comes to the following conclusion:

\begin{quote}
The term \textit{concept} is sometimes taken to imply some fixed, externally defined practice, almost a 'thing out there'. However, the distinction can be over-drawn, for sooner or later even 'concept' implies \textit{someone} thinking, conceiving of events, which they may do in quite individual ways. I shall therefore use the terms \textit{construct} and \textit{concept} interchangeably from now on.
\end{quote}

(p.66, original emphasis)

According to Kelly's theory, persons construe meaning, that is, develop their constructions, using a system of constructs hierarchically organized. These constructions are related to a specific context. So, in order to give meaning to an abstract concept, persons need to develop a construct system which relates this entity to a specific context. It is similar to what Kuhn (1970) proposed when he emphasized that the empirical content of scientific knowledge would be centrally placed in shared examples, which would allow scientists to view the situations in the same gestalt as other members of their specialists' group.

The definitions or symbolic generalizations are not meaningful by themselves. They are useful to represent an idea, but this idea is linked to specific situations.

Thus, according to a constructivist perspective, the learning of scientific concepts and the development of "alternative conceptions" are similar processes - they correspond to the development of a construct system which allows the individual to give meaning to some ideas. Consequently, the use of the term \textit{scientific conception} is more appropriate to indicate the relative character of a concept and to identify the source of the status given to it.

If we consider that conceptions are internal representations for concepts, these assume the same status as what are called \textit{elements} in Kelly's theory, that is, "the things or events which are abstracted by a person's use of construct" (Kelly, 1955, p. 562). Putting forward this relation enables linking concepts to constructs and separating the different uses of both henceforth.
The difficulty recognized by Swift (1986) to construe a scientific theory starting with constructs does not exist any more if we adopt the relation proposed above. The suggestion of

...relinquishing Kelly's original strict adherence to universal bipolarity of constructs and embracing instead a less constrained notion of 'conception' in which a commitment to the notion of dimensionality would be preserved, but it would allow for it to be one of the relevant contrasts.

(Swift, 1986, p. 10-23)

is no more necessary and it only reflects the existing confusion between the ideas of concept and construct.

Results of studies about pupils' "alternative frameworks" presented by Driver and Easley (1978), identify some aspects which can be explained by Kelly's Personal Construct Theory:

1- Ideas developed in a hierarchical way with higher level ones subsuming and modifying lower level ideas (Guesne, 1976). It is in agreement with the Organization Corollary, which employs this type of structure as a way of providing the individual with some coherence, despite acknowledging the existence of inconsistencies between constructs at the same level.

2- The necessity of considering pupils' "alternative frameworks" to design teaching sequences. This argument was used in several ways, from giving pupils the opportunity to reject irrelevant factors (Cole and Raven, 1969), through demonstrating the limits of pupils' approach to them (Case, 1976), to refuting pupils' misconceptions (Rowell and Dawson, 1977). According to Kelly's Sociality Corollary, if the teacher wants to communicate with the pupils, and enhance the development of their ideas, he has to try to understand these ideas. The degree of communication, however, will depend on the investment teacher and pupils make in order to reconstruct the processes of each other.

3- The lack of reorganization of "intuitive ideas" (Fleshner, 1963), no change in pupils' thinking due to counter examples and conflicting evidence (Driver, 1973), and persistence of "misconceptions" despite instruction (Rowell and
Dawson, 1977). These examples corroborate Kelly's idea that what changes a person's construct system is not a simple encounter with an event but the active involvement of the person in anticipating the event, as well as the revisions of his constructs in the light of new evidence provided by the encounter.

4- Theories presented by the teacher or other pupils were not necessarily understood but accepted and learned at a verbal level (Driver, 1973). This idea of learning at a verbal level without understanding may be "translated" as a simple acquisition of information without implying any major change in the construct system. Learning, in Kelly's terms, involves trying to give meaning through the use of somebody's construct system. In this way, learning without understanding is meaningless. On the other hand, since meaning is given by the person, different types and degrees of "understanding" may be achieved, that is, people may come to different conclusions.

Hewson and Hewson (1988) reviewing studies about force and motion, identified several examples of inconsistencies across situations (Minstrell, 1982; Whitaker, 1983; McDermott, 1984; Champagne, Gunstone and Klopfer, 1985; Halloum and Hestenes, 1985) and situation-specific explanations (Minstrell, 1982; Champagne, Gunstone and Klopfer, 1985). These results are in complete agreement with my suggestion that concepts are constructed through the use of one or more sub-systems of constructs, each having its own range of convenience. Thus, each situation would be analysed using a different set of constructs. This lack of consistency is not recognized by the person because these constructs are at the same level and not linked in a hierarchical way. This phenomenon is acknowledged by the Fragmentation Corollary.

Logical thinking is not natural but something which people may develop in certain domains. "Human thought is essentially constructive in nature and ... even the thinking of logicians and mathematicians is no exception" (Kelly, 1969, p. 71). This statement addresses the problem of dimensionality in knowledge, that is, it refers to the use of directions, along which knowledge is constructed. Thus, knowledge is not developed in universal terms, but linked to context, and referred to dimensions of comparison and contrast.
In these terms, the differentiation between propositional knowledge and knowledge-in-action may be explained as a problem of development in different contexts. The existence of conceptual structures internally consistent but not necessarily related to actual phenomena (Driver and Erickson, 1983) may be seen as a result of instruction, which emphasizes the internal structure of the knowledge without making connections with real situations. These concepts, constructed with the aid of abstract situations, are not available when the person confronts real phenomena.

### 2.2.2 - LEARNING AS CONCEPTUAL CHANGE

Constructivist ideas about persons participating actively in their learning processes, studies about the importance of existing knowledge for learning, and research dedicated to identify alternative conceptions and to understand their persistence after instruction, lead to the view that learning involves changes in the conceptions held by persons, that is, learning is a process of conceptual change.

The consideration of this perspective, however, does not imply the adoption of a constructivist approach to learning. The idea of conceptual change can be constructed in different ways by people who use it in their work, according to their metaphysical and epistemological commitments.

One approach, adopted by Posner, Strike, Hewson and Gertzog (1982), is based on the assumption that learning is a rational activity that depends on motivational and affective variables:

> *Learning is fundamentally coming to comprehend and accept ideas because they are seen as intelligible and rational. Learning is thus a kind of inquiry. The student must make judgments on the basis of available evidence ... Learning is concerned with ideas, their structure and the evidence for them.*

(Posner et al., 1982, p.212)

In their work, Posner et al. draw a parallel between the development of science and students' learning of science. They use the contemporary views in philosophy of science held by Kuhn (1970) and Lakatos (1970) to propose two types of conceptual change: ASSIMILATION - in comparison with research done
during periods of "normal science" (Kuhn, 1970) or experiments conducted within a "research program" (Lakatos, 1970), when students apply their existing concepts to explain new phenomena; and ACCOMMODATION - in comparison with periods of "scientific revolution" (Kuhn, 1970) or "change of research programs" (Lakatos, 1970), when new phenomena cannot be explained by students' existing concepts, which must then be replaced or reorganized.

The objective of Posner et al.'s work is to study accommodation - the conditions for it and the kind of concepts which control it.

In order to analyse the conditions, they use the idea of competition between theories:

*Central concepts are likely to be rejected when they have generated a class of problems which they appear to lack the capacity to solve. A competing view will be accepted when it appears to have the potential to solve these problems and to generate a fruitful line of further research.*

(Posner et al., 1982, p. 213)

They propose four conditions to be met in order to effect accommodation: dissatisfaction with existing concept, intelligibility, plausibility and fruitfulness of new conception.

These conditions, despite the authors' claim about the importance of a person's "central concepts" as "the vehicle whereby a given range of phenomena become intelligible" (Posner et al., 1982, p. 213), are based on a view of conceptual change where "fundamental changes in a person's central, organizing concepts from one set of concepts to another set incompatible with the first" (Posner et al., 1982, p. 214) occur, that is, where a person exchanges his existing concepts for new ones.

Although this model is presented as having constructivist roots, it is possible to recognize the authors' "central concept" of learning as acquisition of knowledge "disturbed" by existing concepts - an assumption that persons "develop" their current ideas through acquisition of, or exchange for, new ones. One immediate corollary is that persons do not construe their views of the world but use the views they acquire.
The mixture between a constructivist approach and a passivist one may be identified from the beginning of the discussion about conditions of accommodation, when the authors expect that new concepts "appear to make sense" with the person experiencing no conceptual change, just after a statement that "central concepts" "...make competing concepts seem not just wrong but virtually unintelligible" (Posner et al., 1982, p. 214). Thus, they are relying on the internal organization of the content to talk about "making sense", instead of considering the person's construct system. This approach is compatible with the idea of acquisition, and not with construction.

In relation to the conditions of accommodation, it is possible to stress some aspects described below.

*If the dissatisfaction with the existing conception created by its inability to make sense of experience is followed by learning of an intelligible alternative which resolves or promises to resolve some of the anomalies of its predecessor, then the new conception may be plausible.*

(Posner et al., 1982, p. 221)

If a constructivist approach is adopted, the fact that an alternative is intelligible means that the person has understood it either through the use of his existing concepts or through a change in them. Therefore, intelligibility may be considered as a result of, instead of a condition for, a conceptual change. The nature of this change, however, varies among persons and does not necessarily involve the "central concepts".

*Initial plausibility can be thought of as the anticipated degree of fit of a new conception into an existing conceptual ecology.*

(Posner et al., 1982, p.218)

This definition, together with the ways by which a conception can become initially plausible, may be considered as a reflection of a passivist view that a conception may be acquired, as a whole, and "inserted" into an existing set.

From a constructivist point of view, a concept is constructed in a person's mind through the use of his existing knowledge. Since there are several ways to do it, and since logic is not the guiding principle in this construction, it is possible to
construct a concept that is inconsistent with others already present in a conceptual ecology. Plausibility, therefore, is not a condition for accommodation but for assimilation (as used by Posner et al.), that is, if a concept seems plausible it may be constructed with the construct system already existent in a person's mind.

In relation to fruitfulness, it is presented in the model as a characteristic of the concept or theory. This way of thinking is not consistent with a constructive point of view because any judgement, and fruitfulness does derive from a valuation process, must be considered in terms of a person's conceptual ecology. So, the type of investment necessary to change "central concepts" will depend on the fruitfulness the person puts on the concept, not the other way around.

The understanding of the contributions a theory makes to a variety of fields has no direct implications on change of "central concepts". It may favour more investment in terms of assimilation but it depends completely on the person whether the process will continue towards an accommodation.

The emphasis put by this model on the rational character of learning, is questioned by West and Pines (1983), who identify a series of nonrational components suggested in its theoretical analysis and empirical findings.

The model, as a whole, may be considered as an example of the type of inconsistencies a person may hold during a long process of conceptual change, due to lack of awareness of some "central concepts" and to the implications of their existence to the whole conceptual ecology.

Gil and Carrascosa (1985) suggest that alternative frameworks are originated by a methodology of superficiality, which leads persons to come to conclusions based on qualitative observation without control. For them, conceptual change may only occur if pupils are repeatedly put in the situation of "putting forward hypotheses, designing experiments, carrying them out, analysing carefully the results" (p.235), which they see as compatible with the nature of scientific methodology. Thus, to improve science learning they suggest that a conceptual and methodological change is necessary.
This emphasis on empirical aspects and on a specific methodology for science, may be linked to the belief that if persons follow the right processes, they will acquire the same knowledge. This kind of view may also be linked to the idea that conceptual change means displacement of alternative ideas by scientific ones.

On the other hand, analysis of the ideas presented in Gil and Martinez Torregrosa (1983) and also in Gil and Martínez Torregrosa (1987), suggests that what the authors intended to emphasize was the importance of the formulation and testing of hypotheses for knowledge production. This approach, compatible with the ideas of Kelly, is, however, mixed with the idea of organizing learning as an oriented inquiry, in domains well known by the teacher, where the results obtained by the students could be reinforced, mixed or challenged by the results obtained by the scientists (Gil and Martinez Torregrosa, 1987). It is interesting to notice that, although they reject the idea of transmission of knowledge already elaborated, they expect that through engagement in the activities proposed by the teacher, all students will construct the same knowledge. They give an indication in this direction when they say:

... it is well known that when somebody joins a group of researchers, he may quickly reach the level of the group. This happens not through a verbal transmission, but by approaching problems in which the group leaders are experts.

(Gil and Martinez Torregrosa, 1987, my translation)

I would like to suggest that this type of example is misleading because it does not distinguish the different levels at which the members of a research group conduct their work.

there is a tendency on the part of secondary workers in science to see only part of the intellectual picture in the subject with which they are concerned, and to restrict the choice of hypotheses by which they interpret their data, out of deference to the supposed example set them by a primary worker, whom they take as their master and whose magisterial authority they bow to.

(Toulmin, 1970, p. 40, original italics)
The engagement of students in the same activities does not guarantee that they will come to the same conclusions. Depending on students' previous ideas, the activities may be perceived in different ways. Furthermore, if students do not involve themselves, the activities may not cause any major restructuring of their construct systems. An important aspect of this work, however, is that it allows discussions between students. This may help them to recognize their viewpoints by comparison and contrast with others.

Group discussions within a "permissive and secure intellectual climate" were used by Abercrombie (1983) to help participants change their preconceptions. She emphasizes that preconceptions or assumptions are resistant to change because persons are unaware of them, and they are related to each other. Thus, change in one preconception generally involves changes in the construct system in unexpected ways.

The use of activities to promote conceptual change is also the strategy adopted by the Children's Learning in Science Project (Driver and Oldham, 1986). This project, whose aim was to develop revised teaching approaches based on results of research on children's thinking in science and on cognition, acknowledge the importance of the individual's active construction of meaning, and that these constructions are continually tested, and sometimes modified, against experience.

Their view of conceptual change is that of "the reorganisation and development of students' conceptions" (Driver and Oldham, 1986, p.108). They cite the works of Barnes (1974), Posner et al. (1982), Claxton (1984), and Pope and Gilbert (1985) as informing their view, but do not specify their theoretical position. Thus, the idea of conceptual change is stated in a very broad way.

As occurs in the work of Gil, there is an internal tension in the theoretical position adopted by this project, which is reflected in the following statement:

\[\text{Indeed, pupils need to be helped and guided to adopt the scientists' 'spectacles': and the challenge to curriculum developers is to do this in a way that neither undermines pupils' confidence in their own abilities to make sense of learning experiences, nor grossly misrepresents scientific ideas.}\]

\[(\text{Driver and Oldham, 1986, p.110})\]
Since the objective is the adoption of a chosen perspective, it is implicit that a higher status has been given to this perspective than to the ones constructed by the students. Thus, how is it possible not to undermine students' confidence when they may perceive that the objective of eliciting their views is to challenge them, unless they are compatible with the scientific one? If it is necessary to provide a learning environment where both students and teacher respect the views of others, how can it be compatible with the idea of a defined outcome?

Watts and Bentley (1987) approach the problem of conceptual change through the notion of "non-threatening learning environment" — a recognition that cognitive and affective aspects in learning are not distinct.

They call attention to classroom activities derived from current models of conceptual change (Strike and Posner, 1985; Swift, 1984), where learners have their own views about the subject being studied challenged by the teacher — the so called cognitive conflict. This type of activity, depending on the kind of classroom environment, may be very intimidating and sometimes counter-productive:

No one, at any stage in life, can consider their own beliefs and theories coldly and dispassionately — particularly at the point of change.

(Watts and Bentley, 1987, p. 123)

According to them, characteristics such as engaging, free thinking, free speaking, free of ridicule, supportive and empathetic of individuals' needs and emotions, are necessary in the school environment in order to help students in exposing their ideas and beliefs.

Instructional methods based on cognitive conflict may result in what Clark (1985) called a cognitive assault:

The teacher is asked to rush the students to readiness by posing a question ... that probably never occurred to the students, and then induce dissatisfaction with their own explanations by confrontation ... The result is a kind of 'cognitive assault' in
which students are forced to confront and abandon a part of self
that has been, and is, serving them reasonably well.
(In Watts and Bentley, 1987, p. 127)

In order to avoid such pressures, an instructional method based on exposure of
students' current ideas depends on the establishment of a supportive classroom
climate. To obtain it, teachers should be aware of the purpose of their actions,
especially their non-verbal behaviour. Considering the problems faced by
teachers in everyday school life, Watts and Bentley (1987) argue that a non-
threatening environment cannot be guaranteed and question the viability of this
kind of method in normal classroom situations.

2.3 - CONSTRUCTIVISM USES IN TEACHER TRAINING

Although a constructivist perspective has been adopted by educational
researchers for more than two decades (Magoon, 1977), its use in teacher
education and teacher training is more recent. In this section I shall present
some examples of the use of constructivism either as a research approach with
consequences for teaching practice, or as the basis for schemes adopted in pre-
service or in-service training.

In all these examples, emphasis was given to the personal perspectives of
participants, and a qualitative approach to collection of information was
adopted.

2.3.1 - THE USE OF RESEARCH TO CHANGE TEACHING PRACTICE

Considering that the ideas of student teachers about teaching are important for
their teaching behaviour and that they may benefit from reflecting on them,
Pope (1977) conducted research using repertory grid technique to elicit and
analyse changes in these ideas as a result of a teaching practice session.

Pope and Scott (1984) used semi-structured interviews and observations to
analyse the question of teachers' epistemologies. They studied the views about
knowledge and theories of learning of students involved in two courses for
initial teacher training and two for in-service teachers. They adopted the ideas
of Kelly as a framework for their research.
The students were followed throughout one academic year. The interviews were used to enable the students to reflect on their views of knowledge and pedagogic practice, from their perspective as teachers and learners simultaneously.

Participants commented that the interviews had helped them to focus and clarify their ideas about epistemology, teaching and learning. This process, according to the authors, should be an integral part of teacher education because it allows the transformation and assimilation of the formal concepts presented on college courses.

Ben-Peretz (1984) argues that Kelly's experience corollary provides "a frame of reference for viewing teacher development as a personal process of learning" (p.104). Thus, helping teachers to become aware of their personal theories enables them to change and, therefore, to learn. She considers participation in research as an educative process for teachers and suggests the inclusion of workshops and exercises for identifying personal constructs in staff development programmes. She used repertory grids to elicit teachers' views about curriculum and curriculum materials.

Day (1984) proposes a more interdependent role for researchers to help teacher learning and change, and more emphasis on observation of teachers' practice. For him, it is necessary for teachers to examine their theories of action in order to change them. This examination involves the problem of self-confrontation and the possibility to accommodate the consequences of it, in thought and action, without assistance.

He designed, collaboratively with the teachers involved in the research, an extended process of self-evaluation consisting of five stages:

- identification of inconsistencies within the teacher's prevailing theory of action, using self-confrontation and reflection;

- evaluation of this confrontation to generate information to support future decision taking;

- planning of new theories-in-use;
- Implementation of those new theories;
- Internalization of new theories of action and further confrontation or return to confrontation of initial theory of action.

As a result of this process, Day reports that the participants changed their practices and their attitudes towards themselves as teachers and towards their teaching. All of them recognized that, without the support given by the researcher, they would be unable to follow the process of self-evaluation.

Diamond (1985) studied student teachers during the year of their professional preparation. He suggests that student teachers, like other professionals in training, understand the specific domain of expertise in terms of their dimensions of appraisal.

He used repertory grids to explore their views of teaching and of people, over the course of the academic year. His intention was to focus participants' attention on the development of their constructions and to enable them to interpret their own perceptions. Through this process they could develop self-awareness, and also understand how self-awareness develops and the factors which may influence it.

Diamond argues that student teachers need to develop self-awareness in order to experiment with, and to change their views of teaching:

> It may be that change can take place, and then be accepted or rejected, only when individuals have a sharper picture of what their own ideal looks like. ...by knowing what they are, they can form an idea of what they would like to be, and by knowing that, they can work towards it.

(Diamond, 1985, p.34)

Oberg (1986) conducted a research project, the objective of which was to make personal grounds of teacher practice available for critical examination by the teacher. She organized teachers' thinking in five categories: teacher role, learner, learning, subject matter and schooling. In order to check the link between constructs and teachers' practice, she observed and discussed the classroom activities of one teacher every day for two weeks.
Hunt (1987) has used Kelly's repertory grids to elicit the theories of practitioners who participated in a learning styles course. The objective was for the teachers to use the results as they chose. He argues that by avoiding an outside-in perspective, which includes the use of this material for his own purposes, he can create a climate of openness, trust and goodwill which elicits much richer samples of teacher thinking than when teachers are subjects in an experiment. His suggestion is that persons start with an inside-out approach to provide a valuable base from which to consider outside-in information.

Another experience with self-reflection was conducted by Keiny and Dreyfus (1988) who acted as external consultants at a comprehensive school in Israel. After meeting regularly during one year with a group of twelve teachers in the school, and having supervised a process of deliberation and self-reflection, they were asked to help the teachers to conduct an experiment in mixed ability teaching.

They based their work on the following assumptions:

- Effective school change is an evolutionary, self-initiated process of teachers' personal professional development, and not an organizational change introduced by external agents;

- This development is better achieved by team-work;

- Teachers develop their theories-in-action by analysis of their practical problems and reflection-in-action;

- The external researcher assumes the role of collaborator, who articulates a process of group reflection on individual teachers' practice;

- Effective teachers behave according to their beliefs and basic assumptions.

Eight teachers of history and scriptures agreed to participate in the experience and were divided into three teams:

- subject teams, of history and scripture, supervised by their heads of department, responsible for the preparation of teaching materials;
- the general group, composed of all teachers and their heads of department, supervised by the researchers. This group provided the learning milieu where the reflection-on-action and reflection-in-action was practised in order to enhance the development of participants as mixed ability teachers;

- the steering team, composed of a deputy head, responsible for the whole project, and the two heads of department. This group was responsible for the organization of the activities of the other teams.

The group meetings were recorded and transcribed and this material, handed to participants, was used as data for analysis, since it also contained descriptive elements of actual teaching situations. Through the articulation and conceptualization of their practical knowledge within the group, the participants gained a better understanding of mixed ability teaching and other relevant concepts. The use of team-work helped teachers to perceive change and to develop learning materials. It also provided support.

All these studies acknowledge the importance of teachers' ideas, and especially reflection on them, as a way to improve teachers' practice. They emphasize the active role of persons in the construction of knowledge and the importance of personal involvement in changing processes.

Another aspect which should be stressed is the educative role of research when the persons involved are treated as participants and not as subjects. This kind of approach, which may be used as a process of staff development, was adopted in this work, where participation in a research project led to the development of teachers and student teachers.

2.3.2 – THE USE OF SCHEMES TO CHANGE TEACHING PRACTICE

Thomaz (1986) proposed a scheme to allow science student teachers to adopt a constructivist approach to teaching. This scheme, based on a five-stage model put forward by Rogers (1967) and on Kelly's epistemological position of constructive alternativism, was implemented over three consecutive years at the University of Aveiro, in Portugal. Its success depended on characteristics like good rapport between the student teachers and the teacher educator, time availability for change in student teachers' attitudes and development of appropriate teaching skills, as well as support and
a willingness by student teachers to persuade the pupils, in a manner somewhat paralleling their own experience, that the innovation is worthwhile.

(Thomaz, 1988, p. 269)

The scheme gave participants the opportunity to become aware of their own models of teaching and their aims in physics teaching, to have contact with constructivist models of teaching, as well as to develop and implement their own models.

Queiroz and Azevedo (1987) highlighted the problem of alternative conceptions held by primary teachers and their influence on reinforcement of the same views held by pupils. They used in-service courses, where they carried out a series of experiments, to make teachers aware of their views and to promote conflict between them and the scientific conceptions. The emphasis on experiments was aimed at enabling teachers to have contact with a teaching methodology different from the traditional expositive methods based on the content presented by the textbooks.

Hewson and Hewson (1987) used the workshop entitled "From Children's Science to Scientists' Science", or GO, designed by Gilbert and Osborne (1981) as a basis to develop another workshop entitled "The Diagnosis and Remediation of Alternative Conceptions", or DIRAC. This material has been used with pre-service and in-service student science teachers and science teachers educators in southern Africa.

The DIRAC workshop was used as instruction to student teachers, in order to encourage the incorporation of their ideas of learning as conceptual change into their conceptions of teaching. It's activities are based on the conceptual change model of learning (Posner et al., 1982; Hewson, 1981) and on the analogy between acquiring scientific conceptions and acquiring conceptions of teaching.

This workshop, which intends to provide an interpretation of the GO workshop in terms of conceptual change, was evaluated in two parts: in the first, through the opinion of student teachers about teaching activities which should be used in a hypothetical situation, and in the second, through their design of instruction for high school students previously interviewed by them.
The results in the first part showed a tendency among student teachers to prefer what the authors called conceptual change activities, although these activities were chosen initially on account of their discovery learning aspects. Thus, the choice made by the student teachers, although being coincident with the activities chosen by the authors, was not based on the same criterion adopted by them.

In the second part, although student teachers had used Osborne and Gilbert's (1980) "Interview about Instances" task to identify alternative conceptions about a specific topic, and were asked to plan their instruction considering these views, most of their suggested strategies addressed only the desired conceptions, or addressed alternative conceptions only implicitly. What is more relevant, is that although the majority of student teachers aimed to use conceptual change strategies, only a few actually designed activities using them.

It is interesting to analyse the discussion of the study. Although the workshop was designed to be based on the assumption that

science teachers need to acquire a conception of teaching as conceptual change, because then they will plan for and use teaching activities which are based on student conceptions

(Hewson and Hewson, 1987, p. 429, my emphasis)

the authors themselves acknowledged that

the workshop was incomplete with regard to the way in which ideas were presented. It used neither diagnosis nor exchange explicitly, i.e., it did not identify conceptions of teaching, nor did it attempt to reduce the plausibility of conflicting conceptions.

(Hewson and Hewson, 1987, p. 437)

In order to explain their results, the authors suggested that:

The fact that most student teachers aimed to use cc [conceptual change] strategies in theory, but did not use them in practice, seems to indicate that they found the CCM [conceptual change
method] Intelligible and possibly plausible, but certainly not fruitful.

(Hewson and Hewson, 1987, p. 438)

May we say the same about the authors when they did not use conceptual change strategies in their workshop?

I would like to suggest again (see section 2.2.2), that the conceptual change model of learning (Hewson, 1981; Posner et al., 1982) is internally inconsistent, inadequate to explain the processes of conceptual development, and can be used as a counter-example of itself. The inconsistency is due to the central idea of transmission, and therefore, the belief that persons acquire knowledge, existent in this model. This may be detected by the emphasis the authors put on the presentation of alternative models of teaching, without considering the views held by the participants.

The use of intelligibility, plausibility and fruitfulness as criteria to explain the process of conceptual change seems inadequate, as can be noticed in the case of the DIRAC workshop. On the other hand, the existence of inconsistencies in this model, which are not perceived by its authors, points towards the use of fragmentation to develop the model. Although the constructivist ideas were recognized by the authors of this model, as satisfying the conditions posed by their model in order to occur accommodation, there was no "replacement" of their old transmissionist views, as suggested by the model. Therefore, the model can be considered as a counter-example of itself.

Porlán et al. (1988) designed a course to prepare teacher trainers to implement a programme of updating and didactic improvement for science teachers. In this course, which took place from February to June 1988, the authors adopted a constructivist perspective in the design of the activities, emphasizing the previous views of participants as well as the development of new perspectives.

The course was composed of an intensive phase, lasting seven weeks, followed by a practical one, when the participants applied their ideas in their schools.

The introduction of the alternative conceptions theme during science teacher education was the object of study by Sequeira et al. (1989). They based their approach on the assumption that
...student teachers would be better prepared to deal with their future secondary school students' alternative conceptions if they could feel how conceptual change depends on the teaching strategy.

(Sequeira et al., 1989, p.2)

Therefore, student teachers were involved in a process where they could become aware of some of their own alternative conceptions, discuss the methodology applied to detect these conceptions as well as its value to promote change, analyse the importance of self-awareness for change and finally, try to develop their own teaching strategies to consider pupils' alternative conceptions.

The examples presented above acknowledge the fundamental role of teachers' ideas, and the change of them, in order to promote changes in their practice. In a process similar to that experienced by students, teachers are asked to change their conceptual systems in order to include new conceptions of teaching and learning. The methodologies adopted to enhance this process may be used as guiding lines for teachers who intend to consider students' ideas in their practice.

The specific situations faced by teachers during training processes and by students during their physics courses, are compared in the next section.

2.4 - DEVELOPMENT IN TEACHER TRAINING

The conception of in-service training as a learning activity with specific characteristics, enables the use of a training process as a moment to reflect not only on teachers' own practices, but also on their learning processes during the training. This may lead to a better comprehension of the processes students undergo during their courses, as well as to the use of a training approach to inform changes in teaching methods.

In this section I shall discuss briefly some characteristics of the learning processes occurring in science teacher education and in in-service teacher training, and I shall try to establish a parallel between them in terms of a constructivist perspective.
2.4.1 - LEARNING PROCESSES IN TEACHER EDUCATION

While in England and Wales the majority of teachers who will assume positions at primary and secondary schools are trained in PGCE (Postgraduate Certificate in Education) courses (Alexander, 1984), in Brazil the preparation of teachers is quite different.

The Brazilian educational system is formed by three cycles: primary or first cycle, secondary or second cycle, and superior or third cycle. The primary is eight years long, the secondary varies between three and four years, depending on the course being professionalizing or not, and the superior varies from four to six years, depending on the course.

Science is taught as an integrated discipline during the whole primary. In the first four years it is usually taught by the same teacher who teaches the other disciplines and who was prepared either by a department of education of an university or by a special course, given at secondary level, specific for primary school teaching. From the fifth to the eighth year, science is taught by a specific science teacher prepared either by a biology, chemistry or physics department of a university.

In the secondary level there are several courses which prepare students either for a profession or to go to university. All students who intend to continue their studies at university level, have to pass a selective exam, called vestibular, which is composed of tests about, among other disciplines, biology, chemistry and physics. Thus, these disciplines are taught separately in secondary courses, by teachers prepared by the respective departments of a university.

The university courses to prepare science teachers for primary and secondary schools give them a licentiate degree. They are four-year courses with disciplines divided into two groups: the specific, related to the scientific content which is considered necessary to form the basic knowledge of a physics, chemistry or biology teacher, and the pedagogic, related to the pedagogical activity, which is the same for all science teachers.

In the specific case of physics, student teachers follow a course where they have disciplines such as differential and numeric calculus, organic and inorganic chemistry, computing, mechanics, thermodynamics, electricity,
optics, structure of matter and special relativity, as specific disciplines, and history and philosophy of education, educational psychology and child development, teaching methods, evaluation and teaching practice, as pedagogic disciplines.

Teachers of the education department teach the pedagogic disciplines, while the specific disciplines are taught by teachers of their respective departments, for example, calculus is taught by teachers of the mathematics department and chemistry is taught by teachers of the chemistry department.

The pedagogic disciplines are introduced at the end of the course and do not have links with the specific disciplines. Thus, students have to establish the links by themselves after finishing their course. Even the discipline 'teaching practice' is not very useful for this purpose because the students spend most of the time observing other teachers, and scarcely have the opportunity to implement a teaching sequence.

In terms of learning, these two groups of disciplines present different characteristics. First, while in the specific disciplines the content is presented in a way which emphasizes the mathematical relations between variables, in the pedagogic disciplines the presentation of content is based on a lengthy description of the educational variables and their relationships. Therefore, the demands in terms of language are much heavier in the case of pedagogic disciplines.

Furthermore, the status given by the academic community to the specific disciplines is much higher than the one given to the pedagogic disciplines. There is a common idea between student teachers and teachers of specific disciplines that what is important for a good teacher is to know the specific content which he will teach. Teaching is seen as a craft which is developed through practice and thus the importance of the pedagogic disciplines is not recognized. This situation leads to a lack of analysis and development of student teachers' ideas concerning teaching and learning.

In general, student teachers undergo a process whereby they receive information about what to teach and how to teach, and are left alone to integrate these two complex pieces of information. In addition, while the body of knowledge about what to teach is presented as monolithic and highly
structured, the information about how to teach contains different perspectives and lacks an explicit structure linking its different parts.

2.4.2 - LEARNING PROCESSES IN STAFF DEVELOPMENT

The necessity of teachers in further education to engage in a process of professional development has been recognized for a long time, but agreement about the nature of this process has not yet been reached (Bradley et al., 1983). The conflict between the needs and interests of the individual and those of the institution appears as an important variable. As a result, two types of approaches have been implemented: one which emphasizes the institution's perspective and another based on teachers' views.

At present, staff development schemes try to harmonize these two perspectives and some examples of successful approaches are given by small-scale activities carried out by enthusiastic groups of individuals involved in the search of solutions for their own colleges (Bradley et al., 1983). This type of approach presents the advantage, in relation to more traditional staff development activities, including involvement in in-service courses or longer courses as MSc and PhD, of keeping the teachers at their positions, and of producing results directly linked to their practices.

It does not mean, however, that this type of approach is considered to be the most efficient or the most desirable, but that it must be seen as an alternative which may lead to positive results, especially when it is difficult to obtain permission to suspend or reduce teaching activities for some period of time.

In Brazil, the notion of staff development varies according to the level of the staff. In the case of university teachers, the emphasis is on further development of specific knowledge, which is commonly obtained through participation in academic post-graduation courses. They vary from 'specialization courses', with a minimum duration of 360 hours, to a 'master course', with a duration of two to three years, or even to a PhD, lasting four to five years. Secondary and primary teachers may engage in shorter in-service courses or, sometimes, in 'specialization courses'.

Even when these courses are about teaching, they generally concentrate on theoretical aspects and do not consider the actual contextual problems faced by
participants. The basic idea is to provide theoretical tools, materials or information about teaching methods, which the teachers may adopt in their practice.

In this work I adopted an approach to staff development which emphasized the needs and interests of the teachers and which considered the involvement of teachers in a research project as a way to promote their professional development (Ben-Peretz, 1984).

During this process, the participants basically learnt from reflection on their experience. It required that they became aware of their theories and the links between them and their practice. Although they were not asked to adopt any specific perspective concerning teaching and teaching methods, they were presented with different views which were considered as information about recent developments in this area and also as material to provoke comparison and contrast with their own views. Thus, the material used during the process, instead of being considered as the body of knowledge which I intended to transmit to the teachers, was used to focus their attention on some relevant aspects of teaching and learning and to help them to develop and integrate their own conceptions about these aspects.

In terms of learning, this process emphasized the active role of the individual on the development of his own knowledge, and the importance of personal relevance to acquisition of information.

2.4.3 - PARALLEL BETWEEN TEACHER TRAINING AND SCIENCE TEACHING

The reflection on the Kellyan point of view about learning:

*It is not something that happens to a person on occasions, it is what makes him a person in the first place.*

(Kelly, 1955, p.7)

enables me to enlarge my perspectives, or the range of convenience of the constructs I use to construe my concept of learning, in order to apply them to teacher training as well as to student learning.
If I construe my concept of learning as conceptual change, this means for me that a person changes his construct system when he learns something. It may happen in different ways, according to its association with aspects such as context, objectives, content and constraints.

From a constructive perspective, constructs are context-related. Since they are used to construe the representation of concepts (adopting my view of concept and its relation to constructs, section 2.2.1), these are ultimately context-related, too. If we compare the links between content and context in teacher training and student learning, it is possible to perceive that, while in student learning the content is generally taught and evaluated in the same context - for example, in the case of physics teaching, in some abstract world where physics laws can be easily observed - in teacher training the content is taught regarding an abstract context, the ideal classroom, and sometimes evaluated in terms of change in practice.

The use of a concept in a context different from the one in which it was constructed, requires the comparison and contrast of the contexts in order to find common constructs used to construe them and to construe the concept. If they are not found, and if the person wants to use the concept, a change is necessary either in the construct subsystem used to construe the concept, or in the construct subsystems used to construe the contexts. This type of process leads to the development of a person's construct system:

The normal course of development of a personal construct system involves the progressive differentiation of the system into relatively independent, internally organized, subsystems and increasing functional integration of subsystems within the overall system as an operational whole.

(Adams-Webber, 1970, p.36)

Although students during science lessons and teachers during training are taught in abstract contexts, the constructs they use to construe their new experiences may be the same they have developed in their contact with the real world. In this situation, what will happen to their construct systems will depend on the objective of the instruction they receive.
If the objective is to prepare students to obtain correct answers to questions on tests and examinations, especially in the case of pre and post-tests, or to prepare teachers to apply a specific teaching technique, it may be better obtained through the development of a construct subsystem whose range of convenience is limited to the situations analysed during instruction.

... the more unidimensional the structure of an individual's system, the fewer the alternatives which are available to him in interpreting events since, the more closely related all constructs constituting the system, the more his successive constructions will fit the logical constraints of a single set of construct relationships.  

(Adams-Webber, 1970, p. 35-36)

In this case the change in the whole construct system is minimal and the development of this subsystem depends only on the permeability of some existing constructs. This type of change can be achieved in relatively small time intervals and does not involve person’s core constructs.

If, on the other hand, the objective is the development of the capacity of formal reasoning in relation to some specific content, in the case of student learning, or, in teacher training, the teacher’s own practice, it may be translated into constructive language as the development of person’s capacity to construe the concepts involved as well as the relationships between them.

This type of process requires, as a starting point, that the person becomes aware of his own ideas about what is being treated.

... statistics on intellectual development indicate very strongly that the majority of students do not attain formal operations through being "told" about concepts, modes of thought, and lines of reasoning. The promising channel appears to reside in that being offered children in the new inquiry-oriented elementary curricula: direct personal experience with phenomena, evidence, inference, concept formation, and quantitative reasoning, as well as experience in verbalizing one's own growing insights and perceptions of relationship.  

(Arons, 1976, p. 834)
It is not enough to talk to the teacher about teaching, we must also observe him in the behavioural world of the classroom. He may be unwilling or unable to think or behave differently until both thinking and practice have been made explicit.

(Day, 1984, p. 75)

Since, in this case, the objective is concept construction as well as integration of new and existing knowledge, the changes in the construct system may involve core constructs. To change them, however, it requires a much longer time interval and explicit support for the person. In addition, due to construct systems' organization, it is possible for a person to construe concepts inconsistent with some of his core constructs.

Another aspect that influences the type of conceptual change in student learning or teacher training is the content.

*It may in fact be true that in certain semantically rich domains, a student's initial state dominates the perturbations we can apply as teachers.*

(DiSessa, 1982)

This statement acknowledges that it is much more difficult to teach a content that contains concepts already familiar to the learner but structured and/or defined in a different way.

From a conceptual change perspective, this may be explained in terms of necessary change in the learner's construct system in order to solve the inconsistencies faced by him. Depending on the range of convenience of the constructs involved, this change may involve the central or core constructs and is, therefore, very difficult to be obtained since change in these constructs is very threatening to the person.

This situation becomes especially difficult when the ideas present in the content are not well articulated - which seems to be the case in teacher education.

Concepts like teaching, learning, significance and use of curriculum materials, teacher's role, student's role, etc, are not yet well defined and structured and
there is no consensus around a specific view. Moreover, teachers and students develop personal conceptions about teaching and learning through their own long experience in schools. These conceptions, however, are not well articulated and do not seem to share the same characteristics.

In analysing the concept of teaching, Hewson and Hewson (1988) stressed that, discussion about teaching necessarily raises questions about learning, and that this relation, which is seen by them as the distinction between teaching and similar activities like performing, is sometimes forgotten. Pope et al. (1987) studying teachers' views about their profession in different countries, could observe different relations between this and other professions as well as different perceptions about demands on it.

The influence of boundary conditions on the type of conceptual change may be analysed in terms of social and time constraints.

In the case of teachers, attempts to innovate generally find opposite pressure from colleagues and students. Although they recognize that they are not satisfied with the current situation, there is a tendency to avoid changes in the system. A frequent reason for this is lack of interest, created by the belief that the educational system is intrinsically inefficient in terms of preparation of students. Furthermore, any change requires more involvement with a system which is perceived as worthless, and which does not recognize, in terms of institutional and economical rewards, the importance of teachers.

Another aspect is the isolation of teachers' practice. Teachers have scarce opportunities to meet to discuss their classroom experiences. Evaluation procedures, which could be used to enhance a debate around innovations and teachers' ideas concerning the teaching-learning process, are usually perceived by teachers as a threat to their position and, therefore, something to be avoided.

All these factors tend to maintain possible inconsistencies in teachers' construct systems, either due to lack of development of a construct sub-system compatible with core constructs, or to lack of change in the core constructs due to a new construct sub-system. In both cases, opposite pressure may force teachers to conform with old ideas and prevent them from testing and elaborating new ones.
In the case of students, however, the pressure from the teacher as well as from colleagues tends to be towards the adoption of new ideas, which may help in the process of conceptual change. Despite this, if students do not have the opportunity to reflect about their core constructs and possible inconsistencies between them and the new ones, the changes may be limited to the development of structures with very narrow ranges of convenience.

Time constraints seem to limit the extent of conceptual change in relation to teachers and students, because they do not allow for enough experimentation with new ideas or reflection about old ones. It is necessary to recognize that changes in persons' ideas require time, especially when central ideas are involved. If students spend years to develop their views about nature, it is naive to expect that they change their views in short periods of time, just because they were told to do so by their teachers, or because they saw an experiment during a laboratory class.

Similarly, if teachers developed their views about how to teach during years of practice, and even before starting, they will require time in order to reflect about them and analyse their usefulness, before changing this practice by the introduction of new perspectives.

2.5 - SUMMARY

In this chapter I have identified the research field in which my work is embedded and its current theoretical framework. I have shown that Personal Construct Theory (Kelly, 1955) may be used as a basis for a model of learning because it provides consistent epistemological and psychological approaches, is compatible with the ideas of recent philosophers of science, and may explain the main problems identified during recent years in the research in science education.

Some implications of the adoption of a perspective of learning based on Personal Construct Theory have been discussed. They are:

- Alternative, as well as scientific, conceptions derive from similar processes, that is, they are internal representations of concepts, which are abstracted by a person's use of a sub-system of constructs. They are not the
result or right or wrong connections, but the result of the use of different parts of his construct system. Therefore, for the person, they have the same status.

- In order to change their conceptions, persons must involve themselves actively in anticipating an event and using the new evidences to revise their constructs (experience corollary). It means that readiness to learn depends only on the learner.

- Changes in a person's construct system are limited by the permeability of his constructs (modulation corollary). Therefore, new ideas must be linked to existent ones.

- A person's construct system is able to maintain non-logical relations through the use of different ranges of convenience (fragmentation corollary). Thus, inconsistencies depend on the relations in a person's construct system.

- A person plays a role in the development of another by reconstruing his construction processes (sociality corollary). It means that communication leads to development of ideas.

- Meaning depends on context, that is, an idea is linked to specific situations. Thus, concepts are constructed through the use of one or more sub-systems of constructs, each having its own range of convenience.

- Conceptual changes take time and are influenced by a person's awareness of his own conceptions. Thus, it is not enough to engage in activities to change these conceptions, but also necessary to try to anticipate the outcomes of these activities.

- An instructional method based on exposure of learner's current ideas is problematic and difficult to achieve.

- Reflective processes enhance learning, that is, enhance the reorganization and change of ideas.

Therefore, in order to further the analysis of these implications, as well as the influence of aspects such as context, objectives, content and constraints, to
learning, I developed the idea of engaging teachers in a training process, organized according to a constructivist perspective, where they could experience the possibilities and limitations derived from the adoption of such perspective. The reflection on their practice, as well as on their learning experiences during the training, would enable the participants to develop their conceptions about teaching and learning, and to change their teaching methods.

Furthermore, the analysis of the learning processes occurring during this training would clarify the conditions for the implementation of a constructivist methodology of physics teaching.

The methodology adopted in this study is presented in the next chapter, together with the justification for its adoption.
3.0 - INTRODUCTION

The choice of a methodological approach to research should be based on three aspects: a theoretical framework, the objectives of the research, and the specific conditions of the situation under study.

In this chapter I shall discuss the relationships between these three aspects and the definition of the methodology. More specifically, the following points will be considered: philosophical basis, type of approach (reductionist/holistic), problems of validation and authentication, relation theory/practice, and quantitative/qualitative methods.

I shall also present the research and the instructional techniques used in this study.

3.1 - PHILOSOPHICAL COMMITMENTS

Educational studies conducted within the traditional research paradigm, or quantitative model of research, are based on the philosophical assumption that reality can be perceived through its parts, and on a mechanicist 'model of man'. The objective of this kind of research has been, in general, the search for universal laws relating variables identified as relevant for the teaching-learning process. It also aims at prescribing what teachers should do in the classroom. The research methods adopted in these studies, therefore, are quantitative and designed to enable the establishment of relationships between variables. The ideas associated with such a model of research are shown in figure 3-1.
Although this methodological approach is consistent with its theoretical basis as well as with the objective of this type of research, the results obtained so far have had little impact on teachers' practice. The reason for such a failure has been associated with the inadequacy of research methods, based on a reductionist approach to the analysis of reality, to cope with the complex situations existent in the educational environment (Elton and Laurillard, 1979).

In the same way teachers have to consider several aspects in order to plan their practice, a methodological approach, characterized as holistic, was adopted by researchers to obtain their results. This approach would consider the influence of variables relevant to the student (intellectual and affective aspects), to the teacher (intellectual and affective aspects) and to the relationship between them (group characteristics, social relations and pressures inside the classroom).

This change from a methodology which reduces the analysis of reality to the analysis of relations between some variables, to another which considers the situations as a whole, was followed by the adoption of qualitative research methods.
This change from a reductionist to a holistic approach in educational research, was also associated to a rejection of the positivist ideas which constituted the theoretical basis for the first type of approach. The ideas associated with the known as qualitative approach, which are based on a different 'model of man', are shown in figure 3-2.

![Figure 3-2](image-url)  

Figure 3-2 Ideas associated with the qualitative model of research (Pope and Denicolo, 1986, p.164)

Due to this shift of paradigms, educational researchers working within the qualitative model concentrated their efforts on the description and understanding of how teaching and learning occur. The analysis and communication of their results, however, are still generally considered in terms of concepts such as validity and reliability, developed for and within the quantitative model.

The choice facing a researcher using a qualitative approach appears to be between taking the philosophical basis seriously and being unable to communicate their findings, or accepting the criticism and the values of the existing channels of communication and hence moving significantly away from that philosophical basis.

(Lafferty, 1984, p.4)
In order to avoid this problem, Lafferty stresses the necessity of constructing a methodological rationale which is consistent with the philosophical basis of qualitative approach, and which can redefine scientific credibility in a non-positivist manner. Thus, besides the development of a philosophical basis which could provide an answer for issues such as the nature of the relationship between individuals and the world, and how knowledge is constructed, it is necessary to consider the objective of the research.

Also considering the difficulties met by qualitative research, Pope and Denicolo (1986) identified a paradox in the situation faced by researchers:

...if one is concerned with a wide dissemination of one's results and that these are perceived as having practical utility one might feel that full portrayal of the complexity of events is inappropriate. Often the pressurised practitioner looks to tidy tabulation in traditional form for immediate application to own context.

(p.161)

In the way this paradox is described, the more general the results were, the more practical applications they would have. It also reveals an idea held by some researchers working within the qualitative model, i.e., that descriptive knowledge may be transformed into prescriptive knowledge (Lowyck, 1988).

As mentioned earlier, the choice of the research techniques and the way data are analysed and presented, are directly linked to the objectives of the research. These, in turn, are informed by the researcher's view about the complex relationships between theory and practice and, more specifically, between researcher and practitioner.

Although educational research has borrowed its traditional approach from the physical sciences (Evans, 1968), it has not adopted the same type of relationship between theory and practice used in that field. The 'scientific method', as derived from positivist philosophy, has been used mainly to develop fundamental theory, that is, theory used to explain the relationships between a small number of independent variables, which are considered as defining a physical situation. Applied science, on the other hand, has been developed in specific contexts, using the fundamental theory as basic information about specific relations present in their complex situations. There was no direct
transference from theory to practice - which is indeed acknowledged by the emphasis given to the difference between the words *science* and *technology*.

The belief in the possibility of direct transference of results from theory to practice, whether it is held by physicists or educators, reflects a philosophical commitment to a mechanist view of reality, that is, reveals the existence of profound links with a positivist perspective. It is interesting to notice, however, that despite the strong influence of positivism in the physical sciences, the split between pure and applied science denotes an acknowledgement of the limitations of positivism in dealing with everyday life situations.

When educational researchers believe that their results may be immediately applied to several contexts, or, in other words, when they see the objective of educational research as producing solutions for educational practice in general, they are inherently committed to a philosophical position which acknowledges practitioners as passive receivers of information. This commitment may exist even in the case of researchers using qualitative methods to obtain their data and full portrayals to describe the complexity of events under study.

Viewing practitioners as active agents, together with the acknowledgement of the complex situations they face during their practice, leads to the conclusion that the results produced by educational research are always restricted, in terms of immediate application, to a specific context. These results, however, may be used as a source of inspiration for practitioners who can come to see parallels between the situation they experience and the one under study.

Clark (1988) suggested an approach where researchers would behave as consultants to practitioners. They would not solve practitioners' problems, but would provide examples of concepts, methods and generally, "food for thought". This kind of relationship is consistent with the philosophical basis of qualitative research and justifies the use of both quantitative and qualitative methods within a paradigm which not only takes into account individuals' ideas but actually respects and values them.

This perspective - where collaboration is sought between researchers and practitioners - leads to a situation opposite to the one presented in the paradox mentioned by Pope and Denicolo (1986). Since the results provided by
educational research are context-related, the analysis and presentation of them should identify as well as possible the context where they were collected, so they would have practical utility. Especially when very complex situations, involving several variables, are under study, the generalizations in a context-free format conducts to an inevitable loss of meaning. The identification of the context, on the other hand, gives potential users the opportunity to judge the relevance, or not, of these results for their own context.

Within this perspective, the use of quantitative methods is not seen as a possibility to obtain results which may be directly transferred to other situations. Since it is acknowledged that the results are valid for a specific context, any transference will indeed require adjustments to new situations, and information obtained from quantitative as well as from qualitative methods will be considered as a starting point and not as the final answer to practitioner's problems.

An attempt to use both quantitative and qualitative methods together, with different objectives, is found in the work of Zubir (1983), where a questionnaire survey method was used to make conjectures and inferences, which were subsequently used as the basis for a series of in-depth interviews. These, in turn, revealed aspects uncovered by the survey. This type of result points towards a complementarity in the use of these different types of methods.

3.1.1 - METHODOLOGICAL RATIONALE

The theoretical framework adopted in this work is based on the Personal Construct Theory, developed by George Kelly. According to his epistemological position, individuals construct conceptual frameworks in order to anticipate events. These structures are constantly revised and adjusted, in accordance with the results of individuals' experiences.

The basic objective of this research was to understand the ways physics teachers change their ideas about teaching and learning during a teacher training process. It was also expected that the results of this work could be used by the physics teachers themselves, to inform possible changes in their practice, especially in relation to planning learning activities which would help
students to change their conceptual frameworks involving concepts present in physics courses.

Another objective was to test a process of staff development based on the participation of practitioners in a research project. This process aimed at developing basic skills necessary to conduct research, in order to establish a research group in the Physics Department of Universidade Católica de Pernambuco.

These objectives can be summarised in the research questions I am raising in this work:

1 - How does teacher's awareness of his/her own implicit theories of teaching and learning enable him/her to evaluate/change his/her teaching practice?

2 - How does teacher's construct system in relation to curriculum materials interfere in his/her adoption of new teaching methods?

3 - What aspects of PCT could be used in respect to what aspects of a Physics course?

In agreement with these objectives, and considering the assumptions presented in the previous section, the type of relationship considered in this project between practitioners and the researcher, was that of a consultant who helped teachers to become aware of and criticize their own ideas. Furthermore, since the researcher was supposed to become a member of this research group, and was also a practitioner, the whole process also constituted an opportunity for my development in both roles.

This means that there was indeed no attempt to tell teachers what to do, but rather to give them an opportunity to reflect about their practice, to come to know other experiences, and to support them while trying out new ideas. There was also the intention of stressing the importance, for teachers, of monitoring and changing their practice in order to attain the objectives they have established.

The research strategy, therefore, consisted in eliciting participants' ideas about teaching and learning, through methods which would allow them to reflect
upon these same ideas and, at the same time, could be used to conduct research in their classrooms. This situation would be somehow the opposite of that considered as ideal by Clark (1988), that is, instead of researchers on teacher thinking becoming practitioners who would learn how to apply their research findings to their own teaching, practitioners would become researchers on teacher thinking, thus learning how to investigate their practice to find solutions for their problems.

Considering the theoretical basis, the objectives, and the specific conditions of this study, it was conducted as case studies. Some reasons justify this choice. First of all, case studies enable the researcher to analyse situations in depth, and offer a holistic view of the situation under study:

*It is attention to context that the case study handles best. As a research method its strength is not so much its capacity for analysis, but its ability to synthesize. The case study reassembles ideas, information, insights and understandings into a human and institutional whole.*

(Walker, 1982, p.69)

These two characteristics were very important for this study, since its objective was to analyse the influence of a set of variables (personal, intellectual and affective) on changes occurring in teachers' ideas and practice.

The number of teachers who could participate in this study was reduced to two, due to organizational and institutional constraints. Two student teachers were also involved, as well as three small groups of students (during the pilot lessons), and two classes of around fifty students (during the mechanics course). On the other hand, the study was conducted during one year. So, the situation was one where I could analyse deeply the relationships between the variables involved and where I was dealing with small groups.

Another aspect is that case studies provoke intervention in the lives of the persons involved in the research (Walker, 1986). In this case, what could constitute a problem was, indeed, a desired characteristic, because my intention was to use this study to promote change. I did not consider subjects in my research, but participants who would find the process relevant enough to provoke changes in their ideas and practice.
Using interviews and concentrating on people, two common features of case studies, inevitably leads to results highly connected to their perspectives (Walker, 1986). This characteristic was also wanted in this study, since I was interested in the views of participants, how they felt during the process and how they changed these views.

The influence of case studies on the researcher was another characteristic relevant for their choice:

*One of the incidental qualities of case studies is that they usually reveal that the person writing them is, to an extent, changed by doing the research.*

(Walker, 1986, p.104)

During the whole process I was also interested in analysing the changes in my ideas and practice. Since one of the basic assumptions was that reflection leads to learning, I was all the time analysing the activities from my own perspective, as a teacher, in order to detect possible sources of problems and discuss them with the group. By doing this I learnt a lot, especially in relation to the different meanings given to teaching, learning, and to the physics concepts.

Although case studies do not provide general principles, they may be used as a basis for developing models. In this way, they can be used not only to describe but also to explain the situations under study. It does not mean that they can be used to prescribe, but that a deep analysis may reveal a set of relationships which can be structured and this structure may lead to the development of knowledge in that area.

They also present other important characteristics for teaching practice (Stenhouse, 1985), such as:

- They provide evidence, which may be used as a common basis for discussion between teachers;

- They can be used as a source for comparing and contrasting with one's own case, thus helping the development of one's own theories;
- They help in establishing a systematic body of critical standards which may be used to criticize educational practice, and to improve quality in education;

- They contextualize this critique by identifying the situation under study.

All these case studies characteristics were in agreement with the theoretical framework adopted, the objectives of this study and its specific conditions.

Finally, since one of the objectives of this study (see Chapter 1) was to introduce teachers to action research, it adopted some principles suggested by Elliott (1985), such as: to help teachers to clarify their pedagogical aim by focussing attention on their practice, to provide opportunities for teachers to discuss their reflections with each other and to become aware of common understandings.

These principles were considered by emphasizing participants' reflection about their present situation and different situations presented to the group. The main activities were workshops and group discussions, thus participants could discuss their points of view. There was not a preferable outcome from the discussions, which highlighted the importance of participants' ideas. Observations in teachers' classrooms provided direct information about their practice.

A description of the whole study will be made in Chapter 4. The specific techniques adopted during the study will be presented in the next section.

3.2 - RESEARCH TECHNIQUES

The gathering of information for this study was conducted with techniques which would allow the inclusion of several aspects present in the situations being studied, as well as the relationships between them. These techniques were: repertory grids, audiotape recordings, observations, questionnaire and interviews.

Although there was no intention of generalizing the results, parallels between some aspects discussed in this study, such as the influence of teachers' personal values for their teaching practice, and those found in the literature,
During this work, instead of considering the results in terms of reliability and validity, which were not perceived by myself and other researchers as appropriate for a study conducted within the qualitative model, the idea of 'authenticity' (Guba and Lincoln, 1989) was applied. The teachers selected to participate in this study shared similar constraints faced by the majority of physics teachers working at secondary schools and at university courses which prepare future teachers in Brazil. Thus, the data and its interpretation checked by them contributes to its authentication to context.
were stressed in order to try to improve the understanding of these relationships.

The presentation of the information collected must be sufficient to enable the reader to check how the conclusions were reached and also to develop his own alternative interpretations. The problem of personal bias in the analysis of data may be overcome by an explicit disclosure of them (Nisbet and Watt, 1978), as well as by the use of different techniques of data collection—what is called *triangulation* (Denzin, 1978).

Different techniques were used not only to enable the construction of a better picture of the situations under study, but also to give participants an opportunity to experience the possibilities and limitations of them. Since one of my objectives was to introduce these techniques to participants, the use of them would provide participants with a direct contact, thus they would learn from their experience.

One of the ways to approach the issue of validation has been suggested by McCormick and James (1983). It is carried out through the recognition of the authenticity of the analysis of the results by the subjects of the research themselves. This is known as *respondent validation*. In this study, this particular type of validation was attempted. However, in practice it was not always possible to realize it, due to lack of feedback from participants. In these cases, the results were compared with those obtained by other researchers or with those available in the literature.

### 3.2.1 - REPERTORY GRIDS

*... man begins to cope with events by devising reference axes called *constructs*. A system of such referents permits him to put the events he encounters in some kind of perspective.*

(Kelly, 1969, p.32, original emphasis)

According to Kelly, when persons analyse situations, they make double entity instead of single entity choices. Therefore, personal constructs abstract similarity and difference simultaneously. They come to existence when at least three objects or events are compared. If two of them are perceived as similar, it means that they are perceived as different from the third one. If two of them
are perceived as different, one must be similar to the third one. It does not mean that a construct applies to just three events, but that three is the minimum number of events necessary to define a construct.

In order to elicit constructs and the relationships between them, Kelly (1969) suggested the use of repertory grids. These are matrices formed by elements, as columns, and constructs, as rows. Kelly used persons as elements but he acknowledged the use of occupations, toys or signals, for example, as elements, depending on the objective of the grid. Some choices of elements relevant for teacher development are described below. Other examples may be found in Pope and Keen (1981) and Keen (1977).

Olson and Reid (1982) used repertory grids to study curriculum innovation in science teaching. Twenty short statements of instructional events were provided to teachers as elements. Some constructs were elicited and others were supplied, in order to form a common basic set against which the elicited constructs could be compared. The objective of this study was to investigate how the success or failure of interventions relate to teachers' views about their work.

Oberg (1986) used repertory grids to identify a comprehensive set of constructs underlying the classroom practice of teachers. She provided the categories: teacher role, learner, learning, subject matter and schooling, as elements.

Denicolo and Pope (1986) used grids to illuminate teachers' views of their professional roles and activities. Two grids were used with each individual. In the first, elements were provided, consisting of a set of professions, and constructs were elicited. The objective of this grid was to encourage teachers to contemplate their own profession in relation to others. In the second grid, a list of activities which were considered as part of their professional practice was used as elements. The constructs were again elicited. Both lists of elements were obtained through the common choice of a wide spectrum of teachers.

Ben-Peretz and Katz (1982) provided twenty curriculum items as elements, to elicit teachers' constructs about them. The objective of the study was to investigate the criteria (teachers' constructs) involved in making decisions about curriculum implementation.
The participants were introduced to the universe of discourse to be addressed in the repertory grids, e.g. the different roles taken by teachers as practising teachers. The elements chosen needed to be representative of that range of roles.

During the elicitation of the elements, some examples were given to participants in order to help them in identifying the entities which could be used as elements. It was necessary, especially in relation to teacher's roles, because the participants were not used to thinking about roles other than the one of transmitting knowledge to the students. The elements elicited were written on cards, which were used later to elicit the constructs.
The technique

The first step to obtain a grid is to choose the elements. After defining them, the name of each one is written on one card. Three elements are considered at a time and a construct is elicited by asking the respondent to think in what way two of these elements are similar and different from the third. The common characteristic between two elements is known as the emergent pole, while the characteristic which applies to the third element is called implicit or contrast pole.

After eliciting a construct, the other elements are located in relation to the two poles of the construct. The process is repeated with different combinations of elements until the relevant constructs relative to that set of elements are elicited.

This type of elicitation is known as triadic method. Other types of elicitation have been used in educational research by Olson and Reid (1982), who used the full context form – all elements were presented to the respondents to be grouped according to some common characteristic, and by Oberg (1986), who presented respondents with predetermined sets of items and asked them to identify characteristics which applied positively to some items and negatively to others.

In this study I have used four repertory grids to elicit each participant’s ideas about four topics: teaching-learning process and nature of knowledge, curriculum materials, teacher’s roles, and students’ roles in a specific course. In each grid, the elements were elicited from the participants and not provided, because my intention was to collect information which could be used by the participants, as well as by me, to understand the various aspects involved in their practices.

The constructs were obtained using the triadic method, with the choice of the three elements made at random. Sometimes, however, this choice was made by the respondent, who selected them from the full set of elements. It happened especially with Student 1, who expressed his preference for this method. According to him, it was easier to think about the construct and then identify the elements which it would apply to. Since I had no intention of using the results of the grids to compare different participants, but to understand the
relationships between their ideas, the adoption of a different procedure to elicit the constructs was not relevant.

During the elicitation of the constructs, it was emphasized that there was no correct answer and that the objective of the grid was to obtain a personal view of each participant about the topic. The grids were repeated after the development process to analyse the changes in participants' views. Here again, the elements and constructs were elicited and not provided. My intention was not only to detect changes in the ideas involving the same elements, but to go further, analysing even the new choice of elements.

According to Kelly's suggestion, elements should be grouped around either pole of the construct. He did not mean, with this, that events should be described by either one pole or another, or that it was not possible to organize an array of events ranged between them. What he wanted to emphasize was the dichotomous nature of the construct itself:

\[
\text{We may then apply it sequentially to the different objects we want to place in the array. But the array of objects we have thus set in order is not the construct; it is only one kind of concrete explication of the construct.}
\]

(Kelly, 1969, p.104)

Olson and Reid (1982) used a four-point scale to locate the elements between the two poles of the constructs. García (1986) asked the respondent to locate the elements in a seven-point scale and analysed the results with a computer program package which applied the factor analysis technique. Pope and Denicolo (1986) used a five-point scale to locate the elements and analysed the resulting matrix with the program FOCUS developed at the Centre for the Study of Human Learning, at Brunel University.

In this study, I adopted a five-point scale, and asked the participants to locate all elements in relation to it, after eliciting each construct. The results were analysed using the FOCUS program.

This program produces a linear re-ordering of elements and constructs in order to highlight similarities between them (Pope and Keen, 1981). The grid is re-
organized and the elements and constructs are grouped in "trees" at different matching levels.

Figure 3-3 shows the grid elicited from Teacher 1 about teacher’s roles in the Physics I course. This grid has twelve elements, corresponding to the twelve columns, and nine constructs, corresponding to the nine rows. The elements correspond to teacher’s roles, and the constructs are the ideas used to represent these roles. The emergent poles of the constructs are associated to the number 1, while the contrast poles are associated to the number 5. The number 3 is used either to locate elements equally distant from both poles, or to indicate that the element is out of the range of convenience of that construct.

The focused grid obtained after the analysis made by the FOCUS program enables the drawing of the construct and element “trees” (figure 3-4). Thus, the relationships between the constituents of the grid can be visualized.

![Grid elicited from Teacher 1 about teacher’s role](image)

**Figure 3-3 Grid elicited from Teacher 1 about teacher’s role**
The tables presented in figures 3-3 and 3-4 will be analysed in Chapter 7.
My conclusions about the participants' views, derived from the construct and element trees, as well as from their statements during the interview in which they filled the grids. They were discussed with the participants in order to enhance their reflections and to corroborate my data. These results will be presented in Chapters 5, 7 and 8.

This instrument was considered by all of us as very useful to enable concentration and reflection upon specific aspects of teaching practice. The only disadvantages were the complex mathematical analysis of the grid, which demanded the use of special computer programs not available in Brazil, and the time required to elicit the constructs.

3.2.2 - AUDIOTAPE RECORDINGS

During the several workshops and group discussions, as well as during observations in teachers' classrooms, audiotape recordings were used to register participants' utterances and to facilitate a closer look at the development of their ideas. They were particularly important because they enabled the registration of participants' own words together with their interactions during the activities.

Although the workshops and group discussions were considered by me as staff development activities (see section 3.3), the audiotape recordings of them are full of information about participants' ideas and their reactions to the whole process. From a researcher's perspective, the workshops are very useful because they enable participants to express their views and share their knowledge.

Another important aspect is the establishment of an informal environment in which all members of the group are expected to engage in some type of activity. This fact together with the lack of a final assessment e.g. a test, give participants the opportunity to relax and enjoy the activities more fully than in a traditional course. Therefore, it enhances the quality as well as the quantity of the information available during the activities. Thus, the transcription of these activities were considered to support my discussion in Chapters 7 and 8. The description of these activities and the presentation of their results will be made in Chapters 4 and 6.
For the teachers involved in this work, the audiotape recordings of their lessons were especially interesting as a source of information "unspoiled" by an observer's point of view or note taking. They had never recorded their lessons before and they saw this technique of data collection as extremely valuable for improvement of their practice. The presence of a tape recorder in the classroom also influenced the students, who participated more actively in the lesson.

Audiotape recordings were also used to register participants' impressions about the whole process of teacher training. In this case, the use of a more informal way of communication, which is more coherent with Brazilian culture, would enhance the presentation of ideas held by the participants.

Each participant was given a blank audio cassette tape and was asked to register his impressions, suggestions, critiques, etc, during the whole process of teacher training. The recordings were used during an evaluation session conducted with participants, and also provided data to analyse various aspects involved in this study.

The meetings held during the practical phase of this project were also tape recorded. It enabled the reconstruction of several situations, as well as the preservation of information whose value was not initially recognized.

For all participants in this research project, including me, the use of the tape recorder as an auxiliary memory revealed itself as extremely useful in the detection of relationships which were not perceived during the development of the activities. Its capacity to register several details at the same time was very important for the process of reflection, and enhanced the analysis of the situations.

3.2.3 - OBSERVATIONS

Within a perspective of qualitative research, the use of observations is fundamental to provide data which give a holistic view of the situations faced by participants. It also has the advantage of registering participants' behaviour during their occurrence (Selltiz and others, 1975). Therefore, observations were carried out at different occasions in this study, such as structured activities (workshops, group discussions, lessons) and informal conversations. Among these, observations of classroom activities were considered particularly
Important to attain the main objective of action research, that is, to link theory and practice.

The observation of teachers during their practice was conducted with the following objectives:

- To compare what teachers do with what they say, that is, to assess possible mismatches between theory and practice;

- To detect forms of behaviour which are so intrinsic to teachers' practice, that are not perceived by them;

- To give support to the implementation of innovations in the teaching style.

In relation to the first aspect, Oberg (1986) noticed that:

_The link between any given list of constructs and actual classroom practice remained problematic. As we know that teachers sometimes claim beliefs which are contradicted in their practice, it is imprudent to presume that the constructs as stated would be borne out in actual daily practice._

(p.59)

The same problem was detected by Benson (1989) who observed a discrepancy between how teachers conceptualize curriculum and what they provide to students as the curriculum.

In my case, I used observations together with repertory grids to detect inconsistencies between teachers' ideas and practice. These types of mismatch, once acknowledged, may lead to the identification of factors whose influence would otherwise never be investigated.

Although in this study teachers were considered as active agents who can work on their own practices and change them, reflection on action and in action are fundamental for this change (Keiny, 1988). In order to reflect on their action, teachers must be aware of their behaviour. It is especially difficult when procedures have been turned into routines. In these cases, feedback from an external observer may help to overcome this problem.
Another aspect stressed by Day (1984), is the difficulty, for teachers, of accommodating the consequences of self-reflection into their action without assistance. Pressure from students, colleagues and administration tends to keep teachers working within some boundaries which seem adequate to the whole system. Even when teachers feel that their practices are not leading to the results they wanted to reach, the tendency to keep things going is so strong that they do not change it.

It is especially significant in the case of teaching methods. In the Brazilian educational system, lecturing is accepted as the 'natural' way of teaching, whereas any other type of student-centred teaching is regarded as a trick teachers use to avoid the effort involved in 'transmitting knowledge'. The presence of an external observer during the implementation of an innovation gives support to the teacher by acknowledging publicly the importance and seriousness of his attempt. At the same time, the feedback received by the teacher helps him in correcting possible mistakes and in keeping and improving positive aspects of the innovation.

With these objectives in mind, I conducted a series of unstructured observations in the classrooms of the two teachers involved in this study. The choice of unstructured observations was made because I had no previous hypotheses to test, and was interested in the inclusion of other variables besides the ones identified by the teachers. The use of this type of observation for considering the context in which the data are obtained, to permit a better follow-up of the development of the content and the inclusion of other variables, is suggested by Tamir (1983).

The four basic questions concerning observations (Selltiz and others, 1975), were treated in the following way:

1- What should be observed? Not only the behaviour of the teacher, regarding the teaching techniques, but also the treatment given to the content, and his conceptual structure in relation to this content. His interaction with the students and their reactions were also considered.

2- How to keep the records? Through note taking during the lessons, and transcription of audiotape recordings.
3- What processes should be used to try to guarantee the precision of the observations? Besides the comparison between the notes and the transcriptions of the recordings, I also discussed my conclusions with the teachers after the lessons.

4- What relationship should exist between the observer and the observed? The presence of the observer to give feedback to the teacher was negotiated during the first phase of this study.

Although the observation of teachers' practice was considered as an important source of information for the teacher and for the researcher, it presented some limitations. One of these was the perturbation it provoked in the classroom environment. The teachers, despite being familiar with the researcher, were not completely at ease with my presence in their classrooms. It led to a change in their natural behaviour and may have been an extra preoccupation during the implementation of new teaching strategies. The students were also affected by the presence of the observer. In one occasion, for example, they did not express some doubts about fundamental aspects of the content of one lesson, in order to make a good impression, and it resulted on the waste of a whole teaching sequence.

In general, however, the observations were considered by the teachers as an useful feedback about their practice and an opportunity to discuss different perspectives about the teaching methods. The role of the observer as a listener (Goode and Hatt, 1979) was welcomed by teachers and students, and helped in raising their self-esteem.

3.2.4 - INTERVIEWS

During this study, interviews were used in two occasions: together with the repertory grids, in order to clarify the meaning of elements and constructs elicited from participants, and with a qualitative problem, in order to understand students' conceptions.

The repertory grids were used to give information about the participants' views concerning some topics, as well as to permit reflection about these views. This reflection was enhanced by the use of unstructured interviews during the completion of the grids. The participants were asked to make comments about
their choices of elements and constructs, and to try to identify the relationships between them.

The interviews also had the objective of helping the elicitation of ideas through the use of questions about aspects related to the topic of the grid. They lasted around one hour and a half, and sometimes were divided in two sessions.

This technique required a lot of concentration from the participants and was considered by all of them as a very tiring activity. Nevertheless, it was also considered as a very powerful technique for organizing their ideas.

During the repetition of the interviews at the end of the study, the participants declared that after having gone through a series of those interviews, they found it much easier to reflect about their ideas. It affected the duration of the interviews, which were reduced to one hour or even less.

The use of semi-structured interviews to elicit students' understandings about science concepts was developed as a technique - the Interview-about-Instances (IAI), by Osborne and Gilbert (1980). This technique uses a series of cards with line drawings which represent various situations. These cards are presented to students who have to decide if the situations are examples or not of a specific concept, and to give a reason for that. The interviews are tape-recorded and transcribed verbatim. They last for about forty minutes and concentrate on the study of one concept.

In this study I was interested in eliciting students' conceptions about a set of concepts, which were the focus of the new teaching sequences implemented by teachers, and the relationships between them. Since the IAI technique concentrates on one concept a time and is very time consuming, I decided to adapt the idea of using examples of a concept to another technique which would also permit a qualitative analysis of a situation, but which could treat several concepts at the same time.

Instead of using several cards, I presented either one or in some cases two situations, described orally to the student, and asked him or her about the development of the situation, in time, and about the presence or not of some concepts. I also asked the student to analyse the situation from a different perspective, changing the concepts involved, and to explain the relationship...
between these two points of view. During the interview the student was encouraged to use drawings to represent what was happening.

The oral descriptions used during these interviews are presented in Chapter 5, together with the explanations given by the students.

The situations used in this technique were chosen in order to have the following characteristics:

- They could be found in everyday life as well as in exercises used by textbooks;
- They were completely described in a qualitative way;
- They could be analysed in different ways depending on the concepts chosen.

The first characteristic was selected because it would permit the detection of possible conflicts between students' ideas developed in school and the ideas developed in their everyday lives. This could be obtained by the use of the same range of convenience for both types of ideas.

The use of a qualitative description of the situation was adopted because it could refer to more general ideas, instead of to the more specific ones developed to deal with the situations described quantitatively in the classrooms or textbooks.

Since one objective was to identify the relationships between conceptions developed to represent different concepts, the situations should be such that they could be considered from different perspectives and could involve the use of several concepts, for example, they could be analysed using the description of motion, the forces involved or the energy.

This technique permitted the assessment of student's understanding of a set of concepts in a period of about forty minutes. During the interview it was also possible to discuss the quantitative approaches which would be useful to determine the value of some variables (if we decided to transform the situation in a quantitative problem).
This type of technique, which is not directed to a deep understanding of students' conceptual frameworks, may, however, be useful to science teachers who do not have enough time to look for the several ways students construe a scientific concept, but have to know students' main constructions in relation to course's content and, especially, the way they are articulated in the range of convenience which will be explored during the course.

*Besides the advantage of saving time through concentration on a specific range of convenience, this technique may also be adapted for group discussion, enabling the teacher to have an overview of the main difficulties felt by a whole class.*

It is important to note that it is not my intention to suggest a substitution of other techniques to elicit students' conceptions by this one. The objectives of them are different, and those techniques which lead to a deeper understanding of students' conceptions are important to give the teacher a starting point through the information of the variety of students' constructions.

### 3.2.5 - QUESTIONNAIRE

Traditional evaluation strategies are criticized because concentration on pupils' achievements as a measure of the success of an innovation does not provide valuable information about the reasons for this success or failure (Olson, 1982).

Although the use of questionnaires has been associated to research conducted within the traditional paradigm, in this study a questionnaire was used to explore some reasons for the results obtained with an innovation. It concentrated on the ways teachers and students perceived their roles during a physics course, on some aspects of the course itself, and on possible differences detected by students due to the implementation of the innovation.

The objective of this questionnaire was not to provide information which could be used to make generalizations, but to enhance the understanding of the problems faced by the two teachers involved in this study. It was responded by the two teachers and by their classes, at the end of the course.

The questionnaire and its results are presented in Appendix II and Chapter 6, respectively.
Closed and open questions were used in this instrument. The alternatives presented in closed questions were selected from data collected during repertory grids conducted with teachers and students. The questions concentrated on the aspects investigated with other instruments, so the results could be used for triangulation.

Before being applied to the groups involved in this study, the questionnaire was discussed with several teachers in the Physics Department of UNICAP and was applied to a different group of students who were asked to make comments about its clarity and relevance. Despite these precautions, some problems in its format were only detected at the time of the actual application of the instrument. Therefore, to avoid possible mistakes from the respondents, I stressed the possible sources of misunderstandings, to the whole group as well as individually, and checked their responses during the application.

The use of the research techniques described above constituted a personal process of development for myself, as researcher and teacher, as well as for the teachers, student teachers and students involved in this study. It happened especially due to their novelty in terms of research instruments and of learning situations. The lack of more experience with the use of these techniques, however, was responsible for some mistakes committed during their application, and for the non-utilization of their full resources. Nevertheless, I consider that even the mistakes were important for my personal learning process.

3.3 - INSTRUCTIONAL TECHNIQUES

In addition to the techniques to collect data, I used two techniques to instruct participants: workshops and group discussions. Both were group activities but their organization and objectives were quite different.

Workshops were used to introduce themes which were analysed later during the group discussions. They concentrated on participants' knowledge, whereas group discussions usually concentrated on different views presented on papers.

The uses of both activities during this study will be discussed below.
3.3.1 - WORKSHOPS

Staff development materials may be considered in two categories: direct support materials and indirect support materials (Cryer, 1981). In the first category are materials such as simulations, games and workshops, which provide detailed, timetabled programmes for staff developers to use in their courses. Indirect support materials are usually reference works about staff development or aspects of education.

Although workshops have been used as staff development activities for some time, the production and dissemination of materials to support this type of activity started in 1982 with the publication of a series of workshops on teaching and learning (Cryer, 1982). This material consisted of detailed instructions on how to run the workshops, together with master copies for the transparencies and other resources which would be used during them.

The design of workshops may be analysed from different theoretical perspectives. Cryer (1986) presents an analysis made from a change theory perspective. In another publication (Cryer, 1988) she identifies three types of workshop, classified according to their purposes: 1- To impart factual information and the understanding and mental abilities to handle that information; 2- To impart professional attitudes and behaviours; 3- To impart skills.

Despite this differentiation, she acknowledges that a workshop will inevitably contain elements of all of these three types.

The learning experiences within a workshop with the first purpose are inserted in a framework based on the categorization due to Bloom (1972). They follow a line compatible with traditional ideas of learning as acquisition of information. Workshops to impart skills are based on the idea of stimulus-response, with feedback being considered as an important part.

Workshops to impart professional attitudes and behaviours are based on the idea of 'experiential learning'. According to Kolb and Wolfe (1971), it is formed by a cycle comprising the following steps: experience, internalization, generalization and application. It starts with the occasion when the person experiences the concept through an activity - the experience phase. Then the
person reflects upon the experience and analyses the causes of it - what Kolb and Wolfe called internalization. During this phase the person shares impressions with others. Next, due to this interchange of information, the person extends the range of convenience of the concept - what they called generalization. Finally, behaviour is affected by the understanding of the situation - the application phase. This phase, according to Kolb and Wolfe, can only be addressed during participants' everyday lives.

Although in this model the idea of experiential learning is linked to professional attitudes and behaviours, it is compatible with constructivist ideas about learning in general. Therefore, the use of workshops, designed according to this model, to promote participants' learning, is consistent with the theoretical framework adopted in this study.

The workshops, presented in Chapters 4 and 6, were conducted during the first phase of this study, from August to October. Their main objective was to make participants aware of their ideas, through the drawing of analogies between the activities and problems they face in the classroom. The activities were designed to involve all participants and establish a relaxed environment where their comments were received without judgement. This enhanced the reflective process before the introduction of different perspectives.

3.3.2 - GROUP DISCUSSIONS

The second type of instructional technique adopted in this study was the group discussion. The objective of this technique was to introduce new perspectives of the themes discussed during the workshops.

These discussions were organized around some written materials distributed among the participants before the meetings. Some details of this structure were changed along the meetings, due to specific constraints or to discuss the influence of them on the results of the discussion. Thus, before some meetings I distributed the written material in Portuguese, with a list of questions to be responded in writing, while in other occasions the written material was in English, with no annexed list. At the end of the meetings I asked the participants to give their opinions about the structure and possible influences on the level of the discussion.
Another objective of the group discussions was the use of a more traditional approach, where the focus of interest was the written material and not the ideas of participants. This provided a parameter for comparison with the workshops, in terms of personal involvement and development of knowledge. These different experiences were designed to enhance reflection about the types of learning activities, and their effects on participants.

The description of the group discussions conducted during this study as well as their results will be presented in Chapters 4 and 6.

3.4 - SUMMARY

In this chapter I presented the reasons for the definition of the methodology, the type of relationship adopted between the researcher and the participants, and the arguments in favour of the research method (case studies).

I emphasized the necessity of coherence between the theoretical bases, objectives of the research and specific conditions of the situation under study.

I also presented the research and instructional techniques used during the study, and the reasons for their choice.

In the next chapter I shall describe the whole process, pointing out its structure and the roles of the different techniques.
4.0 - INTRODUCTION

In this chapter I shall present the steps followed during this study. I shall start identifying the context in which the data were collected, and pointing out the main constraints.

In section 4.2 I shall present the results of the pilot study conducted to detect the main problems perceived by teachers and students involved in a specific course. These results were considered in the formulation of the research strategy.

In section 4.3 I shall describe the main study, its phases, and the techniques applied in the development process.

4.1 - THE CONTEXT AND CONSTRAINTS

This study was conducted at the Physics Department of Universidade Católica de Pernambuco (UNICAP), Recife, Brazil. UNICAP is a private, catholic institution, community-oriented, with around fourteen thousand students and six hundred teachers. Its undergraduate courses are organized in a credit system, with some courses being prerequisites or co-requisites for others. Courses' contents are determined by the Federal Council of Education, on a national basis.

The Physics Department of UNICAP is concerned with the preparation of physics teachers for primary and secondary schools, and with physics teaching for Engineering, Chemistry, Mathematics, Statistics, Biology and Phonoaudiology undergraduate courses.

Student teachers attend a four-year undergraduate course. Each year is divided in two semesters (February to June and August to December) and disciplines are taught by teachers from different departments in the University, depending on
their content. Thus, teachers from Physics Department are responsible only for disciplines with physics content, while the pedagogical disciplines are taught by teachers from Education Department. Therefore, the integration between the disciplines is made by the students themselves.

Although designated as a Physics undergraduate course, during the first year, referred to as the first cycle, the students also have courses of general interest, and physics is only introduced at the second semester, through the Physics 1 course. Therefore, the experiences they have during this course are basic for their perception of the whole undergraduate course. Furthermore, the content of this course is fundamental for the understanding of several disciplines taught during the following years.

The majority of students in the University have jobs during the whole day to pay their fees. The others either receive loans from the Government, or pay by themselves. The courses, therefore, must take place mainly during the evenings, so the students may adjust their timetables to work. It represents an important constraint to students’ time to study.

The classes generally comprise about sixty students during the first year, in all undergraduate courses, but they reduce to around fifteen at the end of the Physics undergraduate course. The students either transfer to other undergraduate courses or leave the University. The majority of transferences occur after the Physics 1 course.

Physics and Engineering students have four courses with physics content in common: Physics 1, 2, 3 and 4. These are basic courses they have to attend during the first two years of their undergraduate courses, and correspond to introductory courses in mechanics, heat, electricity and optics. Students’ poor performance in these courses has attracted teachers’ interest in Physics Department. Special concerns involve Physics 1 course where up to 50% of students fail.

The academic career for teachers in the University is very limited. The rules for promotion through the four existing levels emphasize the time dedicated to teaching, and the difference in salary is not significant. The majority of teachers are paid just for the time they spend giving lessons. Thus, besides not
being stimulated to pursue postgraduate studies, they generally have to work in other institutions to maintain a reasonable income.

Some teachers, however, are appointed as coordinators, and have special periods of time (five or ten hours a week) to dedicate to preparation of experiences in the laboratories or to organize the activities of teachers in the theoretical courses. These teachers spend more time in the University, and tend to be more involved in the implementation of innovations.

4.2 - PILOT STUDY

The high rate of failure in Physics 1 course, as well as the importance of its content either for other disciplines in the Physics undergraduate course or for physics teaching in primary and secondary school, were important reasons to choose it as the focus for my research. Another important aspect was the potential close relationship between the course's content and everyday life situations.

This course is given in ninety hours, during fifteen weeks, with four hours a week for theoretical and practical (exercises) lessons, and two hours for laboratory. The classes are generally composed by sixty students. During laboratory lessons there are two teachers and one monitor responsible for the class, which is divided in ten groups.

The evaluation is based on two tests applied after one third and at the end of the course, respectively. The grades are given in a zero to ten scale, against check with the correct answers. They are calculated with the results from theory and laboratory, with weights eight and two, respectively. If students get grade five or more they are approved, otherwise they have to do a final test.

In the period from 9 to 17/12/86, I conducted a pilot study to identify the main problems in this course. Information was obtained through interviews conducted with three students, one of whom repeated the course four times, and four teachers. I have, in addition, taught this course two times already, and could experience the difficulties involved in this course.

The main problems detected by the students were:
In relation to the lessons:

- The teachers do not discuss the theoretical part of the program deeply;

- The teachers do not solve the more complicated problems, that is, problems involving more theoretical concepts or more advanced calculus;

- The full program is not studied;

- Several teachers do not show interest in what they are doing;

- There are too many people in the laboratory;

- The teachers, during laboratory lessons, are not well prepared to explain the experiments to the students;

- Theory and laboratory are disconnected;

- The majority of students do not ask questions during lessons;

- Students do not know each other.

In relation to study:

- Students have only a few hours per week to study because they generally work in their employment four to eight hours a day;

- Several students only use the textbook to study;

- They do not relate what they are studying to the real world;

The students like to study alone and then discuss their concerns in groups. They see the teacher as a transmitter of knowledge and principal conductor of the teaching-learning process.

The main problems detected by the teachers were:

- Program too extensive;
- There is a lack of student participation during problem solving lessons;
- Students do not have a good basis in mathematics;
- Laboratory teachers and monitors need better training;
- Difficulties in understanding the use of vectors;
- It is necessary to articulate theory and laboratory;
- In evening classes students and teachers are tired and make less progress than during the day.

Teachers in general base their teaching on the use of formulae. The tests applied are a collection of problems.

One teacher saw the necessity of exploring the qualitative and theoretical aspects and to apply qualitative instead of numerical problems in tests. He also suggested the use of some qualitative experiments during theoretical classes.

During one interview the necessity of defining the objectives of the laboratory became clear.

One teacher suggested the use of exercise lists as an orientation for the tests.

The problems identified by the students are primarily linked to the fact that the course is taught under severe time restrictions - the programme is too extensive and the students do not have enough time to study. In addition, teachers and students are not actively involved with the course, and there is neither internal (relationship between theory and laboratory) nor external (relationship between course's content and problems in everyday life) integration.

The teachers acknowledged the points highlighted by students, and also identified lack of mathematical basis and physical constraints (students and teachers too tired during evening lessons) as problems.
It is interesting to notice that, although students and teachers agreed in pointing out the content, or lack of it, as the main problem, they did not stop to reflect about the objectives in studying this content nor about the ways to do so. Some students mentioned lack of relationship with reality as a problem, but they were not aware of the implications of this situation to their failure in the course.

Teachers and students accept lecturing as a 'natural' way of teaching and see the transmission of information, mainly through teacher's verbal communication, as the main objective in the course. On the other hand, lack of clear objectives for what they are doing in the classroom, has led to a situation where teachers and students find themselves lost in the middle of a system, in which the main objective is to deliver credentials which may be used to obtain a better job (Schwartzman, 1988).

Considering the problems detected by teachers and students, it is possible to identify several aspects which need to be changed. These changes, however, are limited by institutional and material constraints, and cannot be accomplished in a short period of time.

Since some problems detected in this course are also perceived in other basic courses given at UNICAP, and since teachers involved in this course are also involved in those others, I decided to initiate this process of change working with the teachers. My initial idea was to review the teaching methods, in order to promote student participation in classroom discussions, to give students a chance to ask questions, and to have more contact with each other.

This idea of training the teachers to behave in a specific manner evolved towards the idea of giving them the opportunity to analyse their practice, review the current problems in Physics I course, and try solutions which would be consistent with their points of view. Thus, my final idea was to engage the teachers in a learning process, organized according to a constructivist perspective, whose objectives were the understanding and development of their practice, and to give participants the opportunity to experience the possibilities and limitations derived from the adoption of a constructivist perspective of learning.
The results obtained during this study would help me in answering my research questions:

1 - How does teacher's awareness of his/her own implicit theories of teaching and learning enable him/her to evaluate/change his/her teaching practice?

2 - How does teacher's construct system in relation to curriculum materials interfere in his/her adoption of new teaching methods?

3 - What aspects of PCT could be used in respect to what aspects of a Physics course?

Another reason for choosing to work with teachers instead of students, was linked to the role of the Physics Department in the formation and support of science teachers in primary and secondary schools. If this department intends to assume the responsibility for giving support to the science teachers already in service, besides its current involvement in the preparation of science teachers, it needs to develop the competency necessary to carry out its duties. Part of this development consists in forming a group with a solid theoretical background, and a critical vision of what constitutes a coherent teaching practice.

With the formation of this group in mind, I started to plan my work, acknowledging the present situation faced by teachers in our university, as well as my limitations in terms of time and competence to promote the changes which I considered necessary.

Although several teachers intended to participate in my study, only two of them had enough time available to do it. Since the teachers usually work in other institutions, it was very difficult for them to find a common period of time when we could meet. The two teachers had the advantage of being coordinators, and thus, being able to use part of their coordination time to attend our meetings. They kept, however, their normal obligations and this research project represented an extra workload for them.

Besides the teachers, two student teachers, who were in their final year, were contacted and agreed to participate. I decided to involve students because I
would like to have a perspective closer to that of Physics 1 students in our meetings. They were allocated as monitors in the Physics Department, so they would receive some financial support for the time dedicated to our research. They had, however, to work besides following their studies.

For all participants, however, the involvement with this research project represented an important aspect of their professional development. This was the main reason for their willingness to make the extra effort necessary to participate. No financial or academic rewards were involved.

Although this situation limited our objectives and possible results, it represented a reality which cannot be ignored if we want to conduct any work in Education in Brazil. On the other hand, the existence of research projects in such situations may provide results which can be used as arguments to change this reality.

4.3 - MAIN STUDY

To review teaching methods with the objective of promoting student participation means to look for different ways of teaching which consider students’ ideas as an important part in the teaching-learning process. This new approach can be found in the constructivist epistemology although it is not yet completely developed into teaching methods. Some experiences have been conducted in special situations, and we have access to them through the literature, but there is no organized teaching material available.

On the other hand, since the idea is to emphasize student participation, a training process which is based on the transmission of new ways of thinking and acting without considering teachers’ own ideas would be at least inadequate. Specially in the case of experienced teachers, with specific procedures corroborated by years of practice, to adopt such approach would be the same as to ask teachers to abandon what they have construed for years in order to use something completely new for them.

A strategy more coherent, therefore, would be to give teachers the opportunity to devise new teaching methods which would include constructivist ideas, besides using some techniques adopted by them during their practice. This
would require a reflection on teachers' own ideas as well as contact with constructivist ones, in order to detect and resolve possible conflicts between them.

Since this process is open-ended (the teachers may not accept the constructivist ideas as the answer to their problems) and has the solution of problems in teachers' practices as the main objective, it has some connections with the theoretical background of action research. It is also a process of staff development that focuses on some aspects of teaching and research.

Considering these arguments and my research questions, it is hoped that the study would result in some guidelines which would help to:

- make teachers aware of their theories about nature of knowledge, teaching, learning and use of curriculum materials;
- help them in analysing their practices considering their theories;
- enable them to change, if they found it necessary, their theories and/or practices;
- put them in contact with theoretical and practical uses of action research;
- help them in developing, implementing and evaluating a teaching module.

The study was divided in two phases. During the first, from July 87 to January 88, theoretical and practical aspects concerning teaching and learning processes were approached during workshops and group discussions. The intention was to provide participants with an opportunity to become aware of their current ideas and to make contact with new ones.

The second phase, from February to June 88, consisted in the preparation for and implementation of small teaching sequences designed by the teachers. The intention was to give them an opportunity to try their possible new hypotheses concerning teaching methods.

Before starting the workshops and group discussions, I conducted a series of interviews with participants to explore their construct systems about teaching
and learning. Each one was interviewed four times to complete repertory grids about: nature of knowledge and teaching/learning process, curriculum materials, teacher's roles and students' roles in the specific course analysed. These last two grids were included to complete the main aspects involved in teaching and learning as well as to provide a specific context within which the teachers could construe. This would avoid the problem suggested by Yorke (1987) connected to looseness in specifying the context - "the outcome is always inevitably a construct of such generality - or vagueness - as to be of minimal value to the researcher".

The objective of eliciting participants' ideas at the beginning of this process, was to give them an opportunity to start reflecting about these ideas, and thus, preparing them to participate more effectively in the workshops and group discussions.

An overview of the whole process is given next page in figure 4-1. The structure of the workshops used in this study will be presented in the next section.
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<td>Workshops and group discussions</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Jan.88</td>
<td>Revision of course's schedule</td>
<td>Attempt to solve the conflict</td>
</tr>
<tr>
<td>Feb.88</td>
<td>Interviews with students</td>
<td>Detection of students' alternative conceptions</td>
</tr>
<tr>
<td>Mar.88</td>
<td>Preparation of teaching materials</td>
<td>Creation of new hypotheses</td>
</tr>
<tr>
<td>Apr.88/</td>
<td>Implementation of teaching sequences</td>
<td>Testing of new hypotheses</td>
</tr>
<tr>
<td>Jun.88</td>
<td>Observations in teachers' classrooms</td>
<td>Detection of changes in teachers' practice</td>
</tr>
<tr>
<td></td>
<td>Interviews with students</td>
<td>Detection of changes in students' frameworks</td>
</tr>
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<td></td>
<td>Repertory grids</td>
<td>Detection of changes in teachers' ideas</td>
</tr>
<tr>
<td></td>
<td>Questionnaire</td>
<td>Elicitation of teachers' and students' views about the innovation</td>
</tr>
</tbody>
</table>

Figure 4-1 Teacher Development Process
4.3.1 - DETAILMENT OF WORKSHOPS

Workshops based on the idea of experiential learning were used during the first phase of the main study, to introduce the main study itself as well as the following themes:
- Nature of scientific knowledge
- Alternative conceptions
- Teaching methods
- Evaluation
- Curriculum change
- Instructional process

In these workshops, participants' views about the theme were elicited through different activities (described below) and discussed afterwards as a way to make them aware of their current ideas.

The objectives, development and evaluation of the workshops are presented below. The results obtained with the workshops are presented in Chapter 6.

I- Describe and explain activity (2 hs)

Objectives:
- To discuss the difficulties inherent to teaching-learning process;
- To introduce the main study, its relevance and organization.

Development:
- Explain to participants the objectives and development of the workshop (15 min);
- Divide the group in pairs and sit them back to back so that one of the pair (A) faces a screen where a diagram is projected and the other (B) can not see it (10 min);
- Person (A) is to whisper over his shoulder to person (B), giving instructions or a description so that person (B) can draw the diagram on the screen (10 min);
- Person (B) can not ask questions and must not let (A) see what he is drawing;
- Change places and repeat the exercise with a different diagram so that person (B) becomes the explainer and (A) the explainee (5 min);
- When the exercise is finished, ask participants to make individual notes of difficulties which they experienced as an explainer and as an explainee (15 min);
g- Ask them to share these first with their partner and then with the group (20 min);
h- Compare the different forms that explanations took (15 min);
i- Compare the results obtained with the objectives of the main study, highlighting its relevance. Explain the organization of the study and reasons to include student-teachers in the group (30 min).

**Evaluation:**
Commentaries of participants after the session.

2- **Person’s object activity (1.5 hs)**

**Objectives:**
- To give to participants the opportunity to know each other;
- To discuss the nature of knowledge.

**Development:**
a- With chairs in a circle, explain to participants the objectives and development of the workshop (10 min);
b- Each element provides an object (they are asked beforehand) which tells a lot about himself. While explaining his choice he gives information about himself (25 min);
c- While each element is talking, the others stay silent, paying attention and taking notes;
d- After everybody in the group has talked, ask each person to give his views about a member and to give the reasons for his conclusions (40 min);
e- The different conclusions are compared considering the following aspects:
  - each person observes part of reality
  - the same information is apprehended differently by different persons (influence of prior experiences)
  - different ways to transmit knowledge (verbally, body language, etc) and its influence on the conclusions
  - bases for the hypotheses (feelings, facts, etc)

**Evaluation:**
Commentaries of participants after the session.
Each participant records his commentaries about the workshop in a cassette.
3- Hidden assumption activity (1,5 hs)

Objectives:
- To discuss the problem of alternative conceptions;
- To consider the interaction between different conceptual frameworks which occur during the teaching-learning process.

Development:
  a- With chairs in a circle, explain the objectives and development of the workshop (10 min);
  b- Provide a transparence with the following story:
Paul went for a walk in the environments and met a small animal, which he called Charlie, apparently lost. Since he did not see anything that could help him in determining Charlie’s origin, he decided to take it to his home. There, he gave some food to Charlie, provided a comfortable place to put it to sleep and went to bed. Next day when the cleaner came to Paul’s home she found him dead, the place in a mess and no sign of Charlie. What happened?
The story is read and participants are asked to write down (individually) a possible answer to this question (20 min);
  c- Each participant reads his own answer while the others pay attention and take notes (20 min);
  d- Each participant makes comments about the possibility of the answers given by the others (20 min);
  e- The different conclusions are compared considering the following aspects:
   - Influence of alternative conceptions on the solutions;
   - Answers obtained cannot be seen as true or false;
   - Necessity to know the alternative conceptions in order to anticipate possible answers (15 min);

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the workshop in a cassette.

4- Listening activity (1,5 hs)

Objectives:
- To introduce the problem of verbal transmission of information;
- To discuss the efficiency of a teaching method based on verbal transmission of knowledge.
Development:
a- With chairs in a circle, explain the objectives and development of the workshop (10 min);
b- One participant spends 10 minutes talking to another about a specific topic. During the explanation the other listens without asking questions;
c- The participant who was listening has to give the same information to the other members of the group (10 min);
d- The first participant criticizes the information given by the second, specially in relation to what he intended to say and to the points he considered as the most important (10 min);
e- The activity is repeated by another pair of participants (30 min);
f- The group discusses the problems found in verbal transmission and the relations with the problems they have in their lessons (20 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the workshop in a cassette.

5- Brainstorming (1,5 hs)
Objectives:
- To elicit participants' ideas about evaluation;
- To discuss the difficulties in carrying out an evaluation process;
- To suggest instruments of evaluation which could be used in a physics course.

Development:

a- With chairs in a circle, explain the objectives and development of the workshop (10 min);
b- Use the question "What is evaluation useful for?" to elicit participants' ideas about the objectives of evaluation and register their answers on the blackboard (15 min);
c- Use the answers as a base for other questions about what to evaluate. Use the blackboard to register their answers (15 min);

d- Open the discussion about how to evaluate each aspect chosen by participants, in the case of a physics course (50 min).
Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the workshop in a cassette.

6- Conceptual maps (1,5 hs)
**Objectives:**
- To discuss the problem of curriculum change;
- To introduce an instrument to elicit students' ideas.

**Development:**
a- With chairs in a circle, explain the objectives and development of the workshop (10 min);
b- Each participant draws a conceptual map about curriculum change in Physics 1 (20 min);
c- Each map is discussed by the group, considering its elements and structure (30 min);
d- A different perspective about curriculum change (Driver and Oldham, 1986) is presented and compared with the perspectives of participants (30 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the workshop in a cassette.

7- Square game (1,5 hs)
**Objectives:**
- To discuss the instructional process;
- To discuss the teacher's and student's roles in this process.

**Development:**
a- With chairs in a circle, explain the objectives and development of the workshop (10 min);
b- Choose a pair, put them in the middle of the circle, and give them a puzzle so that one of the pair (A) sees the puzzle assembled and the other (B) does not (10 min);
c- Person (A) is to help person (B) to assemble the puzzle, each one moving one piece each time, without talking to each other (20 min);
d- Choose another pair and repeat the exercise with a different puzzle, giving more time to person (A) to observe it assembled (20 min);
When the exercise is finished, open the discussion about the difficulties and the roles of persons (A) and (B) in the process (20 min);

Compare the results obtained with the constructivist ideas about teaching and learning (10 min).

**Evaluation:**
Commentaries of participants after the session.
Each participant records his commentaries about the workshop in a cassette.

### 4.3.2 DETAILMENT OF GROUP DISCUSSIONS

During the first phase of the main study, the themes for discussion were approached in two sessions a week. In the first, participants' views about the theme were elicited through different activities, generally during workshops. In the second session, generally organized as a group discussion, someone else's view was presented by me and participants were encouraged to discuss as well as to point out advantages and disadvantages between this view and their own. These sessions were planned to create a conflict between the different views.

A group discussion was also used to introduce the theme "Objectives in a course".

The structure of these group discussions is presented below. The results obtained in these sessions are presented in chapter 6.

### 1. Nature of scientific knowledge (1.5hs)

**Objectives:**
- To appreciate some theories of knowledge;
- To compare the two research paradigms.

**Development:**

a- With chairs in a circle, explain the objectives and development of the meeting (10 min);

b- Each group member talks about his answers to the following questions related to a paper (Zylbersztajn, 1985) distributed at the end of the workshop "Person's object activity":

- What are the main aspects (positive and negative) you see in the different theories?
- Do you see any relation between these theories and the results we found during last session?
- Do you see any relation between these theories and the learning process students undergo in a classroom?

After everybody has talked, open the discussion (50 min);

c- Present the characteristics of paradigms 1 and 2 and the reasons to work with paradigm 2 (30 min).

**Evaluation:**
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.

2- Alternative conceptions (1.5hs)

**Objectives:**
- To discuss the relation between alternative conceptions and teaching methods;
- To appreciate some research findings concerning alternative conceptions.

**Development:**

a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- Each participant talks about his answers to the following questions related to a paper (Zylbersztajn, 1985a) distributed at the end of the workshop "Hidden assumption activity":
  - What are the main aspects (positive and negative) you see in this article?
  - Do you see any consequence of these aspects to the teaching-learning process?
  - Can you make any comparisons between these ideas and your own about the teaching-learning process? (30 min);
c- After everybody has talked, open the discussion, introducing some views detected in the repertory grids about teaching methods (30 min);
d- Present an overview of the research findings in the field of alternative conceptions (20 min).

**Evaluation:**
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.
3- Teaching methods I (1,5hs)

Objectives:
- To present an alternative teaching method;
- To discuss the possibility to adopt it, considering our reality;
- To present different uses of a traditional teaching method.

Development:
a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- Present the teaching method described in the article distributed some days before the meeting (Nussbaum and Novick, 1981) (30 min);
c- Open the discussion about the difficulties to adopt such method (30 min);
d- Present the article about lecture (Beard, 1978) and compare its findings with participants' uses of this teaching method (20 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.

4- Teaching methods II (1,5hs)

Objectives:
- To present some teaching methods;
- To reflect about the possibility to adopt these ideas;
- To emphasize the theoretical bases of these methods.

Development:
 a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- Present the teaching method described in the article distributed at the beginning of the meeting (Cañal, 1986), stressing its theoretical basis (15 min);
c- Open the discussion about the possible uses of this method (10 min);
d- Do the same with the other two articles ((Northedge, 1977) and (Zylbersztajn, 1985b)) (55 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.
5- Evaluation (1,5hs)
Objectives:
- To elicit participants' ideas about evaluation;
- To present some ideas about evaluation.

Development:
  a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
  b- Review the information obtained during the workshop "brainstorming" (10 min);
  c- Invite participants to suggest ways to evaluate several aspects of a physics course (30 min);
  d- Present the article given previously to participants (Elton, 1982) (15 min);
  e- Open the discussion (15 min);
  f- Introduce the idea of lecturers evaluating their peers (Mathias and Rutherford, 1982) (10 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.

6- Curriculum change (1,5hs)
Objectives:
- To present a scheme for curriculum change (Driver and Oldham, 1986);
- To reflect about the parallels between these ideas and the ones presented by participants in their conceptual maps.

Development:
  a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
  b- Present the scheme suggested by Driver and Oldham (1986), making comparisons between this scheme and the conceptual maps drawn by participants in the workshop "conceptual maps" (40 min);
  c- Open the discussion, emphasizing the conditions at the university to implement these changes (40 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.

7- Objectives In a course (1,5hs)
Objectives:
- To introduce the problem of defining objectives;
- To reflect about objectives in the affective domain.

Development:
a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- Ask participants if they have ever defined objectives in their courses (20 min);
c- Open the discussion about the importance to work in the affective domain and the difficulty to define objectives in it (40 min);
d- Open the discussion about general and specific objectives and the relationship between them and a constructivist approach to learning (20 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.

8- Instructional process I (1,5hs)
Objectives:
- To present an example of instruction involving conceptual change (Gunstone, Champagne and Klopfer, 1981);
- To compare this example with participants' practice;
- To discuss the problem of conceptual change.

Development:
a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- The discussion is centred on the article, with participants making comparisons with their practice (80 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.
9- Instructional process II (1,5hs)

Objectives:
- To present another example of instruction involving conceptual change (Champagne, Klopfer and Gunstone, 1982);
- To compare this example with participants' practice;
- To discuss the problem of conceptual change.

Development:
a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- The discussion is centred on the article, with participants making comparisons with their practice (80 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.

10- Choosing the topics (1,5hs)

Objectives:
- To choose the topics to be prepared for the Physics 1 course;
- To discuss the strategy to test this material.

Development:
a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- Present the schedule of the study, explaining the components of the next phase (10 min);
c- Open the discussion about the topics to be chosen and the procedure to test them (70 min).

11- Instructional process III (1,5hs)

Objectives:
- To discuss the problem of the organization of information;
- To present another example of instruction using constructivist ideas (Driver and Oldham, 1986),
- To compare this example with participants' practice;
Development:
a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- The discussion is centred on the article, with participants making comparisons with their practice (60 min).

Evaluation:
Commentaries of participants after the session.
Each participant records his commentaries about the meeting in a cassette.

12- Preparing the instructional material I (1.5hs)
Objectives:
- To discuss the Ideas concerning the instructional material.

Development:
a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- One teacher presents his Ideas about how he intends to work with the students. The other participants ask questions and suggest alternatives (20 min);
c- The other teacher and I do the same with our ideas (60 min).

Evaluation:
Commentaries of participants after the session.

13- Preparing the instructional material II (1.5hs)
Objectives:
- To discuss the use of the instructional material.

Development:
a- With chairs in a circle, explain the objectives and development of the meeting (10 min);
b- Part of the instructional material is presented to the group and the discussion about its use is open (20 min);
c- The uses of the instructional material devised by the teachers are discussed (60 min).
4.3.3 - PILOTING THE TEACHING SEQUENCES

After discussing these themes we started a more practical phase when the teachers and myself prepared each one a teaching sequence involving different topics of Physics 1 course. This material was tested with students (three different groups, one with each teacher) in the presence of the other participants.

The topics under study were: 1- work of a force (myself); 2- conservation of energy (Teacher 1); 3- projectiles (Teacher 2).

Topic 1 was developed during three sessions of one hour and forty minutes each, with a group of ten secondary school students, who had studied this topic one year before. At the first session, the group was divided in small groups, which received different pictures together with two questions: 1- Is there any work being done in this situation?; 2- By what or by whom?

The small groups had ten minutes to discuss and write down the answers for the questions. Then I wrote the main characteristics of the answers on the blackboard, stressing the alternative conceptions of work, the attributes of the scientific conception and the relations between work and energy. This stage lasted for twenty minutes.

The last forty minutes were used to present the scientific conception of work, based on the definitions given by the students, and to ask the students to prepare a problem about work (in group) to be brought and solved at the beginning of the next session.

At the second session the problems were interchanged, solved, and their results were discussed in the big group. Then each student received an exercise to solve individually. The results were discussed in groups of two students, and then in the big group. The small groups of two students received another exercise, and its result was discussed in two groups of five students each (including one member of each small group).

After a pause, this last procedure was repeated with another exercise.
At the third and last session, an exercise was given to the small groups to be solved. Its result was used to introduce the relation between work and energy and the definitions of conservative and non-conservative forces. After a pause, other pictures, together with questions about the aspects discussed during the sessions, were used to evaluate learning. The students had to answer the questions individually in writing.

Topic 2 was developed during two sessions of one hour and thirty minutes each, with a group of four physics student teachers, who had studied this topic previously, at a Physics I course. At the first session, the topic was introduced by Teacher 1 in a conversational mode. Teacher 1 gave some information about History of Science, using a table with events and dates, and asked questions to participants. The answers were summarized and used to introduce more information. An example was used at the second part of the session to discuss the concepts of Kinetic and Potential Energy. It also provoked a discussion about force, acceleration and velocity.

At the second session, Teacher 1 wrote the expressions for Kinetic and Potential Energy on the chalkboard and asked the students to determine the Mechanic Energy in a situation described in a picture he gave to them. The students discussed the situation between them and with Teacher 1, who used the dialogue to present different ways to calculate the Mechanic Energy.

Topic 3 was partially developed in one session of one and a half hours, with a group of fourteen secondary school students, who had already studied this topic. Teacher 2 decided to change his approach due to observations he made during the sessions conducted by Teacher 1 and me. Therefore, instead of working directly with projectiles, he started exploring the concept of acceleration through the use of graphs. Then he analysed the upward and downward movement of a piece of chalk. His methodology was based on questions he used to present the content and on examples used to solve the doubts presented by the students.

The tests with teaching materials conducted to a change in the topics chosen by teachers. It was necessary to make several adjustments on the materials and, due to lack of time, it was not possible to test them again.
4.3.4 - IMPLEMENTING THE TEACHING SEQUENCES

The second phase of the main study consisted of a series of observations conducted by me in teachers' classrooms. Physics 1 course is normally given in 90 hours, distributed among theoretical lessons (60 hours) and laboratory lessons (30 hours). My intention was to introduce some changes in the laboratory, and therefore I had allocated some time to observe these lessons in my fieldwork project. These changes, however, were not carried out due to lack of materials in the laboratories, and so I cancelled these observations.

I also cancelled the observations which I intended to carry out during the assessment, to avoid disturbance during this critical period. Therefore, my observations were reduced to the theoretical lessons, when the teachers used old and new materials. Teacher 1 was observed during 20 hours and Teacher 2 during 14 hours. Among these, 26 hours were recorded.

Due to a change in University's calendar I had to suppress the part of the training process where the teaching materials developed by the teachers and me would be presented to the group, evaluated and used by the two teachers.

In addition to these observations, the group had a meeting each week to discuss the development of the innovation.

4.3.5 - INTERVIEWS WITH STUDENTS

During this phase I also conducted interviews with four students from Teacher 1's group and two students from Teacher 2's group, to find out the alternative conceptions concerning some topics to be worked during the course, such as the use of a system of reference and the concepts of velocity, acceleration, force, weight, work of a force and conservation of energy.

These interviews were conducted before and after instruction to detect possible changes in students' views. They were centred on a specific situation which could be analysed using these concepts. The idea, therefore, was to explore not only the concepts themselves but also their relationships.
4.3.6 - QUESTIONNAIRE

At the end of the whole process I repeated the repertory grids with participants and applied a questionnaire, to students and teachers, to find out their views about roles of teacher and students, the innovation and results obtained in the course. The questionnaire and its results are presented in Appendix II and Chapter 6.

4.4 - SUMMARY

In this chapter I presented the context in which this study was conducted and the aspects which influenced on its definition. The problems faced by teachers and students in relation to a specific course, Physics 1, were explored in the pilot study, which was described. The importance of this course's content for other disciplines in the Physics undergraduate course as well as for the teaching of physics in primary and secondary schools, were among the reasons to choose it as the focus of my research.

The objectives of the main study, devised to answer my research questions, were presented as well as an overview of the whole process adopted to attain them. The structure of workshops and group discussions was detailed to allow their use by the readers.

Finally, the activities applied at the second phase of the main study were described.
CHAPTER 5
GENERAL RESULTS 1

5.0 - INTRODUCTION

In this chapter I shall present the results obtained with the repertory grids, which were completed by the participants at the beginning and at the end of this study. The other general results obtained during the main study will be presented in the next chapter.

Other results, more specific for each teacher, will be presented in Chapters 7 and 8.

5.1 - REPERTORY GRIDS

The two teachers and two student teachers who participated in this study, completed four repertory grids each at the beginning and the end of the main study. The elements and constructs of these grids are presented in Appendix I together with the element and construct trees. The clusters obtained in these trees are presented below and analysed.

To explain how the data were collected and analysed I shall present the complete data related to Teacher 1’s first grid about the teaching-learning process.

5.1.1 - REPERTORY GRIDS ABOUT TEACHING-LEARNING PROCESS AND NATURE OF KNOWLEDGE (TLP)

TEACHER 1/1ST-GRID (TLP1)

The elements considered by Teacher 1 were:

1- Dialogue; 2- Student’s interest; 3- Teacher’s Interest; 4- Teacher’s time to prepare lessons; 5- Compatible salary; 6- Extra-class orientation; 7- Knowledge of students’ conceptions; 8- Classroom infrastructure; 9- Historical
context of content; 10- Planning of content; 11- Teaching method; 12- Student's time to study.

The constructs elicited after two sessions of one and a half hours each, were:

01- Related to material question/Related to ideological question
02- Open to reconstruction/Finished
03- Influences learning/Irrelevant to learning
04- Organizes work/Does not facilitate organization
05- Dependent on teacher/Independent of teacher
06- Dependent on student/Independent of student
07- Develops critical sense/Irrelevant to critical sense
08- Develops creativity/Has no Influence on creativity
09- Respects student's individuality/Does not respect
10- Stimulates student passivity/Stimulates student participation
11- Encourages production of knowledge/Does not encourage
12- Structures ideas/Just Identifies ideas

Figure 5-1 shows the matrix relating elements and constructs. In this figure, the elements used to define the emergent and the contrast poles are identified. The element and construct trees are shown in figure 5-2. Considering these trees, it is possible to group the elements and constructs in clusters, which highlight similarities between them.

To analyse these data, two categorizations were made. The first categorization considered the categories: prerequisites (PR), conditions (C), curriculum (CU), teaching methods (TM), affective factors (AF) and evaluation (E). These categories were applied to the elements and constructs. They were chosen because I was interested in identifying the presence of these aspects in participants' views, since the study concentrated on aspects related to curriculum, teaching methods and evaluation.

The second categorization was applied to the members of the category "teaching methods". They were grouped in the categories: common (c), constructivist (con) and transmissionist (t). The first category included basic aspects which could be associated either to a constructivist or to a transmissionist teaching method.
These categories were chosen to identify the influence of the constructivists ideas discussed during our study on the participants' views.

![Figure 5-1 First grid elicited from Teacher 1 about teaching-learning process (TLP1)](image-url)

<table>
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<th>related to material question</th>
<th>dialogue</th>
<th>student's interest</th>
<th>teacher's time to prepare lessons</th>
<th>compatible salary</th>
<th>extra-class orientation</th>
<th>knowledge of students</th>
<th>classroom infrastructure conceptions</th>
<th>planning of content</th>
<th>classroom context of content</th>
<th>teaching method</th>
<th>student's time to study</th>
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<td>3</td>
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<td>1</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>stimulates student passivity</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>encourages production of knowledge</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>structures ideas</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

○ - element used to define the construct

Figure 5-1 First grid elicited from Teacher 1 about teaching-learning process (TLP1)
<table>
<thead>
<tr>
<th>Dialogue</th>
<th>Teaching Method</th>
<th>Historical Context of Content</th>
<th>Teacher's Interest</th>
<th>Knowledge of Students' Conceptions</th>
<th>Planning of Content</th>
<th>Teacher's Time to Prepare Lessons</th>
<th>Student's Time to Study</th>
<th>Student's Interest</th>
<th>Extra-Class Orientation</th>
<th>Compatible Salary</th>
<th>Classroom Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>6</td>
<td>9</td>
<td>11</td>
<td>5</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5-2 Construct and element trees (TLP1)
The clusters involving elements and constructs, with the respective categorizations, are shown below.

CLUSTERS OF ELEMENTS:

Dialogue (1) (TM) (con)
Teaching method (1) (TM) (c)
Historical context of content (1) (CU)
Teacher's interest (1) (AF)
Knowledge of students' conceptions (2) (PR)
Planning of content (2) (CU)
Teacher's time to prepare lessons (3) (C)
Student's time to study (3) (C)
Student's interest (3) (AF)
Extra-class orientation (3) (TM) (c)
Compatible salary (4) (C)
Classroom infrastructure (4) (C)

It is interesting to observe that there were no elements related to evaluation. Emphasis was given to the conditions (4 elements) followed by teaching methods (3 elements).

CLUSTERS OF CONSTRUCTS:

Develops creativity/Has no influence on creativity (1) (TM) (c)
Encourages production of knowledge/Does not encourage (1) (TM) (con)**
Stimulates student participation/Stimulates student passivity* (1) (TM) (con)
Open to reconstruction/Finished (1) (TM) (con)
Respects student's individuality/Does not respect (1) (TM) (con)
Influences learning/Irrelevant to learning (1) (TM) (c)
Related to ideological question/Related to material question* (1) (AF)
Dependent on teacher/Independent of teacher (1) (TM) (c)
Organizes work/Does not facilitate organization (2) (CU)
Structures ideas/Just identifies ideas (2) (TM) (con)

Develops critical sense/Irrelevant to critical sense (3) (TM) (con)
Dependent on student/Independent of student (3) (TM) (con)

(*) Construct with reversed poles due to statistical analysis.
(**) The categorization considered the first pole of the construct.

Emphasis was given to teaching methods (10 constructs), which were related to affective factors and curriculum.

TEACHER 1/2ND GRID (TLP2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Teacher-student relationship (1) (AF)
Teacher's conduct (1) (AF)
Dialogue (1) (TM) (con)
Student's interest (1) (AF)
Students' alternative conceptions (1) (PR)
Student's time to reflect (1) (C)
Student's working conditions (1) (C)
Course and students evaluation (2) (E)
Content-everyday life relationship (3) (CU)
Teacher's working conditions (3) (C)
Teacher's time to prepare didactic materials (4) (C)
Course planning (4) (CU)

An element related to evaluation appeared in this second grid. The emphasis on conditions (4 elements) was then followed by affective factors (3 elements). The number of elements related to teaching methods was reduced to one. The
view about the teaching-learning process was thus more complete, due to the inclusion of evaluation and more global, due to more elements of different types put together.

CLUSTERS OF CONSTRUCTS:

Inside classroom/Outside classroom (1) (C)
Connected to affective question/Connected to material question (1) (AF)
Student preparation as person/Student preparation in content (1) (AF)

Depends on teaching method/Independent of teaching method (2) (TM) (c)
Does not help content preparation/Does* (3) (CU)
Student leading the process/Teacher leading the process* (3) (TM) (con)
Fundamental to learning/Not fundamental.. (4) (TM) (c)

(*) Construct with reversed poles due to statistical analysis.

The view was enlarged with the inclusion of a construct related to conditions, which was linked to other constructs related to affective factors. The emphasis on teaching methods was reduced, in relation to the first grid, and they appeared linked only to curriculum. The clusters were smaller and included more ideas related to affective factors.

In relation to the ideas associated with teaching methods, there was a mixture of constructivist and common ideas amongst the elements and constructs.

TEACHER 2/1ST GRID (TLP1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Uses of content in everyday life (1) (CU)
Teacher's dedication (1) (AF)
Emphasis was given to conditions (5 elements) followed by affective factors (3 elements). All types of elements were present. The element related to teaching methods was linked to curriculum, affective factors and evaluation.

**CLUSTERS OF CONSTRUCTS:**

- Leads to questioning/Does not lead (1) (TM) (con)
- Connected to innovations in the process/Not connected (1) (TM) (c)
- Improves learning/Does not influence learning (1) (TM) (c)
- Connected to student's interest/Not connected (1) (AF)
- Connected to valuation of process/Connected to mechanical reproduction of process (1) (AF)
- Does not depend on economic factors/does* (1) (C)

- Knowledge transmission/Knowledge acquisition (2) (TM) (t)
- Connected to results of teaching-learning process/ (E)
- Connected to prerequisites to teach. learn. process* (2) (TM) (t)
- Depends on teacher/Depends on student (2) (TM) (t)

- Connected to teacher's formation/Not connected (3) (PR)

(*) Construct with reversed poles due to statistical analysis.
Ideas related to teaching methods (5 constructs) and affective factors (2 constructs) were the most frequent. A large cluster showed a link between teaching methods, affective factors and conditions.

**TEACHER 2/2ND GRID (TLP2)**

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

**CLUSTERS OF ELEMENTS:**

- Time availability to prepare lessons (1) (C)
- Teacher's knowledge about content (1) (PR)
- Teacher's theoretical knowledge about teaching methods (1) (PR)
- Incentive to utilize books (1) (TM) (c)
- School's infrastructure (1) (C)
- Time to discuss students' doubts (1) (C)
- Student assiduity (2) (C)
- Periodical verification of learning (2) (E)
- Uses of content in everyday life (2) (CU)
- Students' knowledge of course importance (2) (AF)
- Assessment of students' knowledge level (2) (E)

Elements of all types were present. The element related to teaching methods was linked to prerequisites and conditions instead of curriculum, affective factors and evaluation as in the first grid. These types of elements were grouped together with conditions in another cluster. Emphasis was given to conditions.

**CLUSTERS OF CONSTRUCTS:**

- Involves the institution/Does not involve (1) (C)
- Classroom activity/Extra-class activity* (1) (C)
- Activity involving teacher and students/Teacher activity (1) (TM) (c)
- Related to knowledge application/Not related (2) (TM) (c)
Related to teacher/Related to student (2)  
Requires usual remuneration/Requires specific remuneration (3)  
Is made during the process/Is made at the beginning of the process* (4)(CU)

(*) Construct with reversed poles due to statistical analysis.

The constructs were only related to teaching methods, curriculum and conditions. The element related to teaching methods was grouped with conditions. This reinforced the importance given to conditions for teaching-learning process.

In relation specifically to teaching methods, the elements in the first and second grids were associated with common ideas while the constructs presented a mixture of the three types in the first grid and just common ideas in the second.

STUDENT 1/1ST GRID (TLP1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Affective relation between student and teacher (1)  
Teacher-student communication (1)  
Teaching method (1)  
Didactic resources (1)  
Preparation of lectures' content (1)

Student's life aspirations (2)  
Student's effort (2)  
Student's social environment (3)  
Student's previous knowledge (3)
All types of elements were present. Emphasis was given to affective factors (4 elements) followed by conditions (3 elements). The teaching methods (common and constructivist ideas) were linked to all types of elements except prerequisites.

**CLUSTERS OF CONSTRUCTS:**

May vary during the process/Does not vary (1)  
Open to questioning/Closed to questioning (1)  
Develops student's knowledge/Does not develop (1)  
Depends on teacher-student dialogue/Does not depend (1)

Systematic/Not systematic (2)  
Depends on the teacher/Does not depend (2)  
Does not depend/Depends on the student* (2)

Not product of social environment/Product of social environment* (3)(C)  
Does not depend/Depends on the affective factor* (3)  

Does not facilitate/Facilitates teaching (4)

(*) Construct with reversed poles due to statistical analysis.

Emphasis was given to teaching methods (7 constructs), which appeared in two clusters, involving common, constructivist and transmissionist ideas. Affective factors and conditions were grouped together in another cluster.

**STUDENT 1/2ND GRID (TLP2)**

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.
CLUSTERS OF ELEMENTS:

Didactic materials (1) (C)
Student’s organization (1) (C)
Student’s interest (1) (AF)
Teacher’s knowledge (1) (PR)
Teacher’s organization (1) (C)

School’s physical infrastructure (2) (C)
Number of students in the classroom (2) (C)

Critical reading (3) (TM) (con)
Student’s mathematical background (3) (PR)

Language (4) (TM) (c)

Evaluation (5) (E)

Teacher-student affective relation (6) (AF)

There was a change in the view of the teaching-learning process, with emphasis transferred from affective factors (in the first grid) to conditions. Constructivist and common ideas about the teaching methods appeared quite isolated, grouped just with prerequisites.

CLUSTERS OF CONSTRUCTS:

Regards student’s idea/Does not regard (1) (TM) (con)
Facilitates content organization/Does not facilitate (1) (CU)
Unchanging presentation of content/Varied presentation of content (1) (TM) (C)

Influences on the conditions for attentiveness to occur/Does not influence (2) (C)

Facilitates concept formation/Does not facilitate (3) (TM) (con)
Utilizes reason/Utilizes emotions* (3) (AF)

Influences directly on the teaching method adopted/Does not
The view was enlarged, in relation to the first grid, with the inclusion of curriculum. The teaching methods (constructivist and common ideas) appeared linked to affective factors and curriculum.

STUDENT 2/1ST GRID (TLP1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix 1. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

- Teacher's didactic (1)  (TM) (c)
- Teacher's Interest (1)  (AF)
- Teacher's language (1)  (TM) (c)
- Student's Interest (1)  (AF)
- Objectives (1)  (CU)
- Content's utility for the student (1)  (CU)
- Content (1)  (CU)
- Didactic materials (1)  (C)
- Student's prerequisites (2)  (PR)
- School's infrastructure (2)  (C)
- Teacher's salary (2)  (C)
- Evaluation (3)  (E)

All types of elements were present. Emphasis was given to conditions and curriculum (3 elements each) followed by teaching methods (common ideas) and affective factors (2 elements each). These elements were grouped in a large cluster.
CLUSTERS OF CONSTRUCTS:

Prepares the student for life/Does not prepare (1) (AF)
Necessary for learning to occur/Not necessary (1) (TM) (c)
Depends on teacher's interest/Independent of teacher's interest (1) (AF)
May facilitate student's learning/May hinder student's learning (1) (TM) (con)
Necessary for a good teaching/Not necessary (1) (TM) (c)
Necessary for planning/Not necessary (1) (CU)

Depends on teacher's character/Independent of teacher's character (2) (AF)
May influence on the student's moral formation/Does not influence (2) (AF)
Carried out by the teacher/Not carried out (2) (TM) (c)
Depends on teacher's ability to present the content/Does not depend (2) (TM) (t)

Depends on economic factors/Independent of economic factors (3) (C)

Emphasis was given to teaching methods (5 constructs) followed by affective factors (4 constructs). The teaching methods (mixture of the three types of ideas) were linked to affective factors and curriculum.

STUDENT 2/2ND GRID (TLP2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix 1. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Audio-visual resources (1) (C)
Student's prerequisites (1) (PR)
Teacher's general knowledge (1) (PR)
Planning (1) (CU)
Teacher's time availability (1) (C)
Extra-class work (1) (TM) (c)
Course's program (1) (CU)
Questions and exercises (1) (TM) (c)
Student's time availability (2)   (C)
Teacher's working conditions (3) (C)
Student's Interest (4)           (AF)

Emphasis was given to conditions (4 elements) followed by teaching methods, curriculum and prerequisites (2 elements of each). In relation to the first grid there was a change in the links involving the teaching methods, including prerequisites and isolating affective factors. The ideas related to teaching methods were common as in the first grid.

CLUSTERS OF CONSTRUCTS:

- Facilitates reinforcement/Does not facilitate (1)   (TM) (c)
- Gives conditions to innovate the process/Does not give conditions (1)(C)
- Raises the level of knowledge/Does not raise (1)   (TM) (c)
- Is gratifying for the teacher/Is not gratifying* (1) (AF)
- Is not fundamental for evaluation/Is fundamental* (1) (E)
- Influences teaching positively/Influences learning positively (1) (TM) (c)

- Facilitates teacher's work in the classroom/Hinders teach's work (2)(C)
- Develops student's interest/Develops student's uninterest (2) (AF)

(*) Construct with reversed poles due to statistical analysis.

The evaluation substituted curriculum. Emphasis continued to be given to teaching methods (only common ideas), followed by affective factors. The view was more global, including in the same cluster constructs of four types.

Considering the eight grids about the teaching-learning process, it is interesting to notice the emphasis given to elements related to conditions and affective factors, especially in comparison with teaching methods. In the first grids there was a tendency to link the teaching methods to affective factors. In the second grids there was a reduction in the emphasis given to affective factors and the teaching methods appeared linked more frequently to conditions and prerequisites.
In relation to the constructs of these grids, there was a predominance of ideas related to teaching methods. This emphasis was reduced in the second grids. The ideas related to affective factors and conditions were present in almost all grids. Very little attention was given to prerequisites and evaluation. There was a considerable change in the links between the ideas, comparing the first and second grids.

Concentrating on teaching methods, there were elements related to common and constructivist ideas in the first and second grids. The constructs in the first grids were more related to common and constructivist ideas, with the presence of some related to transmissionist ideas. In the second grids there was a tendency to common ideas, with the presence of some constructivist and only one transmissionist idea.

5.1.2- REPERTORY GRIDS ABOUT CURRICULUM MATERIALS (CM)

TEACHER 1/1ST GRID (CM1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

<table>
<thead>
<tr>
<th>Slides (1)</th>
<th>(C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparencies (1)</td>
<td>(C)</td>
</tr>
<tr>
<td>Blackboard (1)</td>
<td>(C)</td>
</tr>
<tr>
<td>Lesson plan (1)</td>
<td>(CU)</td>
</tr>
<tr>
<td>Auxiliary bibliography (1)</td>
<td>(C)</td>
</tr>
<tr>
<td>List of exercises (1)</td>
<td>(E)</td>
</tr>
<tr>
<td>Textbook (1)</td>
<td>(C)</td>
</tr>
<tr>
<td>Written test (2)</td>
<td>(E)</td>
</tr>
<tr>
<td>Oral test (2)</td>
<td>(E)</td>
</tr>
<tr>
<td>Report of activities (3)</td>
<td>(E)</td>
</tr>
<tr>
<td>Laboratory (3)</td>
<td>(C)</td>
</tr>
<tr>
<td>Probe test (3)</td>
<td>(E)</td>
</tr>
</tbody>
</table>
Emphasis was given to conditions (6 elements) followed by evaluation (5 elements). Elements related to teaching methods were not present.

CLUSTERS OF CONSTRUCTS:

Useless/Useful to evaluate the process as a whole* (1) (E)
Not used to evaluate/Used to evaluate the student* (1) (E)
Unrelated to skills/Develops skills* (1) (TM) (c)
Useful to lesson preparation/Useful to lesson evaluation (1) (CU)
Facilitates content presentation/Not useful (1) (TM) (c)

Unrelated to methodology/Determines methodology* (2) (TM) (c)
Not useful/Useful to identify student's initial conditions* (2) (E)
Concrete/Abstract (2)

Useful to concept learning/Useful to concept demonstration (3) (TM) (c)

Teacher's support material/Student's support material (4) (C)
Essential to process/Complementary to process (4) (C)

(*) Construct with reversed poles due to statistical analysis.

Emphasis was given to teaching methods (5 constructs) followed by evaluation (3 constructs). There were links between teaching methods (common ideas), evaluation and curriculum. The constructs related to conditions were isolated from the others, grouped in one cluster.

TEACHER 1/2ND GRID (CM2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Text reading and interpretation (1) (TM) (con)
Laboratory (1) (C)
Seminars (1) (TM) (c)
List of exercises (1) (E)
Textbook (1) (C)

Oral test (2) (E)
Written test (2) (E)

Lesson plan (3) (CU)
Activities timetable (3) (CU)
Tape recorder (3) (C)

Blackboard (4) (C)
Overhead projector (4) (C)

Emphasis was given to conditions (5 elements) followed by evaluation (3 elements), as in the first grid. Two elements related to teaching methods (common and constructivist ideas) were included. These elements were linked to conditions and evaluation.

CLUSTERS OF CONSTRUCTS:

Develops skills/Unrelated to skills (1) (TM) (c)
Facilitates communication in the classroom/Does not facilitate (1) (C)
Develops creativity/Does not develop (1) (TM) (c)
Uses student’s reasoning/Uses teacher’s reasoning (1) (TM) (con)

Student active/Student passive (2) (TM) (con)
Organizes content internally/Organizes content externally* (2) (TM) (con)
Develops student's oral communication/Does not develop (2) (TM) (c)

Evaluates work in the classroom/Organizes work in the classroom* (3)(E)

Content presentation/Content development* (4) (TM) (t)

(*) Construct with reversed poles due to statistical analysis.
The view was reduced, in relation to the first grid, due to the exclusion of curriculum. The teaching methods (common and constructivist ideas) were linked only to conditions. An isolated construct appeared, related to a transmissionist idea.

TEACHER 2/1ST GRID (CM1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Audio-visual resources (1) (C)
Laboratory (1) (C)
Blackboard (2) (C)
Voice (2) (C)
Reports from communication media (2) (C)
Scientific publications (2) (C)
Evaluation materials (2) (E)
Discussions with colleagues (2) (E)
Student's notes during lesson (2) (C)
Everyday life objects (3) (C)
Nature's phenomena (3) (C)
Textbook (4) (C)

Emphasis was given to conditions (10 elements), which were linked to evaluation.

CLUSTERS OF CONSTRUCTS:

Useful to evaluate the process/Useful to encourage the process*(1) (E)
Connected to application/Connected to information*(1) (TM) (c)
Useful to test the acquired knowledge/Useful to acquire knowledge*(1) (E)
(1) Product of person's work/Not a product (2) (TM) (con)
(2) Varies during the process/Does not vary (2) (TM) (c)
(3) Connected to school's precinct/Not connected (3) (C)
(4) Depends on teacher/Does not depend (3) (TM) (t)
(5) Part of research elaboration/Contains the research results (4) (TM) (c)
(6) Involves the student in an active way/Involves in a passive way (5) (TM) (con)
(7) Direct result from teacher's work/Is not a result (6) (TM) (c)

(*) Construct with reversed poles due to statistical analysis.

Emphasis was given to teaching methods (7 constructs) followed by evaluation (2 constructs). The constructs appeared loosely connected, with teaching methods linked to evaluation and conditions. Constructivist, transmissionist and common ideas were present.

**TEACHER 2/2ND GRID (CM2)**

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

**CLUSTERS OF ELEMENTS:**

Laboratory (1) (C)
Blackboard (1) (C)
Regular University tests (1) (E)
Textbook (1) (C)
Books (1) (C)
Magazines and reports (1) (C)
Evaluation after each chapter (2) (E)
Extra-class activities (2) (TM) (c)
Course plan (3) (CU)

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Initial evaluation (3) (E)

The emphasis on conditions was reduced, in relation to the first grid, and the number of elements related to evaluation was increased. The view was enlarged with the inclusion of curriculum. The element related to teaching methods (common idea) was linked only to evaluation.

CLUSTERS OF CONSTRUCTS:

Does not force student to follow the course/Forces* (1) (TM) (T)
Controlled by student/Controlled by teachers* (1) (TM) (CON)
Gives support to student to improve his conditions/Indicates student’s conditions* (1) (C)
Establishes a connection with everyday life/Does not (2) (TM) (CON)
Changes during the course/Does not change (3) (TM) (C)
Activity during the course/Activity at course’s beginning (4) (CU)
Takes part in learning process/Checks learning (5) (E)
Can only be used at university/Can be used outside university (6) (C)

(*) Construct with reversed poles due to statistical analysis.

Emphasis was given to teaching methods (4 constructs) followed by conditions (2 constructs). The view was enlarged with the inclusion of curriculum. The ideas were very loosely connected. The teaching methods were linked to conditions. Constructivist, transmissionist and common ideas were present.

STUDENT 1/1ST GRID (CM1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.
CLUSTERS OF ELEMENTS:

Blackboard (1)  
Didactic books (1)  
Drawing materials for use on the blackboard (1)  
Demonstrations conducted by the teacher (1)  
Classnotes (1)  
Existing materials in the classroom (1)  
Demonstrations conducted together (1)  
Demonstrations conducted by the students (1)  
Reports (2)  
Problem solving in the classroom (2)  
Oral tests (2)  
Written tests (2)

CLUSTERS OF CONSTRUCTS:

Requires an adequate environment/Does not require (1)  
Retains more Information/Retains less Information (1)  
Concrete/Abstract* (1)  
Practical teaching/Theoretical teaching (1)  
Depends on student’s skills/Depends on teacher’s skills (2)  
Students’ exclusive work/Teacher’s exclusive work (2)  
Tests learning/Introduces a new concept* (2)  
Develops student’s critical sense/Does not develop (3)  
Develops student’s creativity/Does not develop (3)  
Develops cognitive skills/Develops motor skills* (4)  

(*) Construct with reversed poles due to statistical analysis.

Emphasis was given to conditions (5 elements) followed by teaching methods (4 elements). The constructs were grouped in two clusters where teaching methods (common, constructivist and transmissionist ideas) were linked to conditions and evaluation.
Teaching methods (common and constructivist ideas) appeared linked to conditions and evaluation, with emphasis given to the former.

STUDENT 1/2ND GRID (CM2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

- Demonstrations conducted by the students (1) (TM) (con)
- Laboratory (1) (C)
- Audio-visual resources (1) (C)
- Drawing materials for use on the blackboard (1) (C)
- Blackboard (1) (C)
- Classroom (1) (C)
- Blackboard Pointer (1) (C)
- Lesson plan (1) (CU)
- Demonstrations (1) (TM) (c)
- Stationery (1) (C)

- Evaluation checklist (2) (E)
- School register (2) (CU)
- Course plan (2) (CU)

- Reports (3) (E)
- Written and oral tests (3) (E)
- Didactic books (3) (C)

Emphasis was given to conditions (8 elements) followed by curriculum and evaluation (3 elements each). The view was enlarged with the inclusion of curriculum. The teaching methods (common and constructivist ideas) appeared in a cluster, linked to conditions and curriculum, instead of to conditions and evaluation as in the first grid.
CLUSTERS OF CONSTRUCTS:

Facilitates the organization of students' ideas/Does not facilitate (TM) (con)
Improves student's speech/Does not improve (TM) (c)
Stimulates student participation/Does not stimulate (TM) (con)
Develops student's psychomotor skills/Does not develop (TM) (c)

Puts the student under stress/Does not put (AF)

Collects data/Uses data (TM) (c)

Helps in visualizing the real world/Does not help (TM) (con)

Only one large cluster with constructs related to teaching methods (common and constructivist ideas) was present. The view was reduced with the exclusion of conditions and evaluation and the inclusion of one isolated construct related to affective factors.

STUDENT 2/1ST GRID (CM1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Laboratory (1) (C)
Audio-visual resources (1) (C)
Visits (1) (TM) (c)
Demonstrations prepared by the students (1) (TM) (con)

Classnotes (2) (C)
List of exercises (2) (E)
Apostilles (2) (C)
Books (2) (C)
Blackboard (2) (C)
Emphasis was given to conditions (6 elements) followed by teaching methods (common and constructivist ideas) and evaluation (2 elements each). The teaching methods were only linked to conditions.

CLUSTERS OF CONSTRUCTS:

- Increases student's interest/Does not increase (1) (AF)
- Facilitates student's learning/Does not facilitate (1) (TM) (con)
- Enhances practical lessons/Enhances theoretical lessons (1) (TM) (c)
- Facilitates teaching/Does not facilitate (1) (TM) (c)
- Used by the teacher during the planning phase/Not used (1) (CU)
- Stimulates teacher to show his knowledge/Does not stimulate (1) (TM) (t)
- Does not require more student participation/Requires* (2) (TM) (t)
- Used in a lecture/Not used (2) (TM) (c)
- Gives knowledge to student/Does not give (2) (TM) (t)
- Not useful for student evaluation/Useful* (3) (E)
- Materials under teacher responsibility/Materials under school responsibility (4) (C)

(*) Construct with reversed poles due to statistical analysis.

Constructs related to teaching methods (7 constructs) predominated. No constructs related to prerequisites. Common, constructivist and transmissionist ideas were present. The teaching methods were linked to affective factors and curriculum.

STUDENT 2/2ND GRID (CM2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.
CLUSTERS OF ELEMENTS:

Monitors (1) (C)
Blackboard (1) (C)
Books (1) (C)
Apostles (1) (C)
Homework (1) (E)
Tests (1) (E)

Laboratory experiments (2) (TM) (c)
Posters (2) (C)

School trips (3) (TM) (c)
Demonstrations prepared by the students (3) (TM) (con)

The view was similar to the one shown in the first grid, with emphasis given to conditions (5 elements) followed by teaching methods (3 elements). Common and constructivist ideas were present.

CLUSTERS OF CONSTRUCTS:

More important in the classroom/Not important in the classroom (1)(C)
Essential to the process/Not essential (1) (C)
Useful to reinforce content/Useful to widen student's knowledge (1)(TM) (c)

Better to work alone/Better for group work* (2) (TM) (c)
Based on the planning/Not based (2) (CU)
Does not stimulate student's reasoning/Stimulates* (2) (TM) (t)
Requires more knowledge from the teacher/Does not require (2) (TM) (c)

(*) Construct with reversed poles due to statistical analysis.

The view was reduced with the exclusion of affective factors and evaluation. Emphasis was given to teaching methods (common and transmissionist ideas), which were linked to conditions and curriculum.

In general, in these eight grids about curriculum materials, it is interesting to observe the lack of elements related to prerequisites and affective factors.
Emphasis was given to conditions. Comparing the first and second grids of each participant, there are changes in the links between teaching methods and the other types of elements.

In relation to constructs, there is a predominance of ideas related to teaching methods in all grids. Teaching methods, conditions and evaluation are present in all first grids, whereas there is no presence of prerequisites. In the second grids the teaching methods appear linked predominantly to conditions or isolated. Common, constructivist and transmissionist ideas are present.

5.1.3- REPERTORY GRIDS ABOUT TEACHER'S ROLES (TR)

TEACHER 1/1ST GRID (TR 1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

- The one who rationalizes science (1) (TM) (con)
- The one who modifies attitudes (1) (AF)
- The one who keeps the dialogue (1) (TM) (con)
- The one who respects students' individual characteristics (1) (TM) (con)
- Guide (1) (TM) (t)
- The one who organizes activities (1) (CU)
- The one who produces knowledge (1) (TM) (con)
- The one who transmits knowledge (1) (TM) (t)
- The one who receives knowledge (1) (TM) (t)
- The one who links Physics and Basic Departments (2) (C)
- The one who gives encouragement (2) (AF)
- The one who shows exemplary attitudes (2) (AF)

The emphasis was on teaching methods (7 elements) followed by affective factors (3 elements). There were no elements related to prerequisites and evaluation. The teaching methods (constructivist and transmissionist ideas) were linked to affective factors and curriculum.
CLUSTERS OF CONSTRUCTS:

Contributes to content learning/Adds to student's moral formation (1) (TM) (c)
Creates ideas/Reproduces ideas (1) (TM) (con)
Integrates the student in this course/Integrates the student in the undergraduate course (1) (C)
Transforms a model/Constructs a model* (1) (TM) (con)
Suggests possible solutions//Collects information about students*(1) (E)

Related to process development/Related to process results (2) (E)
Gives/Receives (2) (TM) (t)

Unilateral relationship/Bilateral relationship* (3) (TM) (t)

Works with students' ideology/Works with students' techniques (4) (TM) (c)

(*) Construct with reversed poles due to statistical analysis.

The emphasis was on teaching methods (6 constructs) followed by evaluation (2 constructs). The teaching methods (common, constructivist and transmissionist ideas) were linked to evaluation and conditions.

TEACHER 1/2ND GRID (TR2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Course planner (1) (CU)
The one who produces didactic materials (1) (CU)
The one who influences on content selection (1) (CU)
The one who links university to the profession (2) (C)
The one who influences attitudes (2) (AF)
The one who links the Physics Dept. to the students (2) (C)
The emphasis was transferred from teaching methods to curriculum (3 elements) and evaluation was included. The element related to teaching methods (transmissionist idea) was linked to evaluation.

CLUSTERS OF CONSTRUCTS:

Work developed with students/Work devel. by the teacher alone (1) (TM) (con)
Applies the activities/Plans the activities* (1) (CU)

Does not influence students Ideologically/influences* (2) (AF)
Develops student's critical sense/Does not develop (2) (TM) (con)

Depends on course's content/Does not depend (3) (CU)
Organizes the content/Does not organize (3) (TM) (c)

Does not give student opportunity to produce knowledge/Gives* (4) (TM) (t)

(*) Construct with reversed poles due to statistical analysis.

Emphasis was given to teaching methods (4 constructs) followed by curriculum (2 constructs). There was a change in the types of constructs, from conditions and evaluation to curriculum and affective factors. Common, constructivist and transmissionist ideas continued to be present.

TEACHER 2/1ST GRID (TR1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

The one who encourages student participation (1) (TM) (c)
The one who encourages student participation in the laboratory (1) (TM) (c)
The one who relates course's content with everyday life (1) (TM) (con)
The one who evaluates learning at each stage (1) (E)
The one who provides texts and exercises (1) (E)

The one who provides the objectives and the course planning (2) (CU)
The one who probes students' level of knowledge (2) (E)
The one who knows the course followed by the student (2) (PR)
The one who discusses and communicates the evaluation process (2) (CU)

Emphasis was given to teaching methods and evaluation (3 elements of each) followed by curriculum (2 elements). The teaching methods (common and constructivist ideas) were linked to evaluation.

CLUSTERS OF CONSTRUCTS:

During the whole course/Limited to the beginning* (1) (CU)
Gives student opportunity to think/Discovers information possessed by the student* (1) (E)
Connected to evaluation process/Not connected (1) (E)

Constructed/Already prepared* (2) (TM) (con)
Gives feedback about teacher efficiency/Does not give (2) (E)

Related to practice/Related to concepts (3) (TM) (c)
Guides methodology/Gives attention to the uses (4) (TM) (c)

(*) Construct with reversed poles due to statistical analysis.

Emphasis was given to teaching methods and evaluation (3 constructs each). The element related to teaching methods (constructivist idea) was linked to evaluation. Two isolated constructs related to teaching methods (common ideas) were present.

TEACHER 2/2ND GRID (TR2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.
CLUSTERS OF ELEMENTS:

The one who evaluates students regularly (1) (E)
The one who is flexible (1) (AF)
The one who is available outside classroom to discuss students' doubts (1) (C)
The one who is confident on his knowledge of course's content (1) (AF)

The one who leads students towards consulting books (2) (TM) (c)
The one who gives students works to be done outside classroom (2) (TM) (c)

The one who gives classes frequently (3) (C)
The one who has a natural way with students (3) (AF)
The one who knows students' level of knowledge (3) (E)

Emphasis was placed upon affective aspects (3 elements) followed by teaching methods, evaluation and conditions (2 elements each). There was a qualitative change on the view of teacher's role with the exclusion of prerequisites and curriculum, and the inclusion of affective aspects and conditions. The teaching methods (common ideas) which were linked to evaluation in the first grid, appeared isolated.

CLUSTERS OF CONSTRUCTS:

Influences on quantity of information/Influences on quality* (1) (CU)
Linked to affective aspect/Linked to cognitive aspect (2) (AF)
 Leads to non-directed learning/Leads to directed learning* (3) (TM) (con)
Evaluates learning after the course/Evaluates learning before (4) (E)

(*) Construct with reversed poles due to statistical analysis.

Affective factors were included. Equal emphasis was given to all types of constructs. The constructs appeared very loosely connected.
STUDENT 1/1ST GRID (TR1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these tree are shown below.

CLUSTERS OF ELEMENTS:

The one who transmits knowledge (1) (TM) (t)
The one who organizes students' ideas (1) (TM) (con)
Inquirer (1) (TM) (con)
The one who gives encouragement (1) (AF)

Affective guide (2) (AF)
The one who creates analogies (2) (TM) (con)
The one who keeps students quiet (2) (C)
Judge (2) (AF)
The one who talks with the students (2) (TM) (c)

The one who prepares didactic materials (3) (CU)
Technician (3) (PR)
Instructor (3) (PR)

The emphasis was placed upon teaching methods (5 elements) followed by affective factors (3 elements). No element was related to evaluation. The teaching methods (common, constructivist and transmissionist ideas) were linked to affective aspects and conditions.

CLUSTERS OF CONSTRUCTS:

Stimulates stud. towards scientific research/Does not stimulate (1) (TM) (c)
Depends on teacher-student communication/Does not depend (1) (TM) (con)
Holds student's attention/Does not hold (1) (TM) (c)

Does not depend on a previous organization/Depends* (2) (TM) (t)
Requires emotional control/Does not require (2) (AF)

Does not stimulate student's interest/Stimulates* (3) (AF)
(*) Construct with reversed poles due to statistical analysis.

The emphasis was on teaching methods (4 constructs) followed by affective factors (2 constructs). No element of any other type was present. The teaching methods appeared isolated (common and constructivist ideas) and linked to affective factors (transmissionist idea).

STUDENT 1/2ND GRID (TR2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Judge (1) (AF)
The one who keeps students quiet (1) (C)
Organizer (1) (PR)
Interpreter (1) (TM) (con)
Guide (1) (TM) (t)
The one who gives encouragement (1) (AF)
Friend (1) (AF)

Technician (2) (PR)
The one who prepares didactic materials (2) (CU)

Leader (3) (AF)

The one who transmits knowledge (4) (TM) (t)

The emphasis was transferred from teaching methods to affective factors (4 elements) followed by teaching methods (3 elements). The teaching methods (constructivist and transmissionist ideas) were linked to affective factors, conditions and prerequisites.

CLUSTERS OF CONSTRUCTS:

Requires a formal treatment with the student/Does not require (1) (TM) (c)
Leads to a more consistent learning/Does not lead (1) (TM) (con)
Requires method/Does not require (1) (TM) (c)
Helps student to think fast/Does not help (1) (TM) (c)
Detects student's and process deficiencies/Does not detect (1) (E)

Arouses student's pride/Does not arouse (2) (AF)
Facilitates verbal communication/Does not facilitate (3) (C)

The view was enlarged with the inclusion of conditions and evaluation. The emphasis stayed on teaching methods (common and constructivist ideas), which were linked to evaluation instead of to affective factors as in the first grid.

STUDENT 2/1ST GRID (TR1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

The one who gives examples related to everyday life (1) (TM) (con)
The one who gives a conceptual perspective about the content (1) (TM) (c)
The one who gives encouragement (1) (AF)
Adviser (1) (TM) (c)
The one who evaluates learning (1) (E)
The one who is available outside classroom to discuss students' doubts (1) (C)

The one who makes innovations (2) (CU)
Instructor of studying methods (3) (PR)

The one who transmits course's content (4) (TM) (t)
The one who gives grades (4) (E)
The one who tries to put all students at the same level of knowledge (4) (TM) (t)
The emphasis was placed upon teaching methods (5 elements) followed by evaluation (2 elements). All types of elements were present (1 of each). The teaching methods (common, constructivist and transmissionist ideas) were linked to evaluation, affective aspects and conditions. Elements related to curriculum and prerequisites appeared quite isolated.

CLUSTERS OF CONSTRUCTS:

Leads students to transform what was given/Leads students to reproduce what was given* (1) (TM) (con)
The student reaches higher levels of learning/The student learns more superficially (1) (TM) (con)
Causes student to care about learning/Causes student to care about evaluation (1) (TM) (con)
Induces changes on student's method of studying/Does not induce (1) (TM) (c)
Demonstrates more preoccupation with learning/Demonstrates more preoccupation with teaching* (1) (TM) (con)

Enables stud. development/Leads stud. to the same proficiency* (2) (TM) (c)
Provokes student's Interest/Does not provoke (3) (AF)

Enables the teacher to know better students' difficulties/Hinders the teacher in discovering students' difficulties (4) (E)

(*) Construct with reversed poles due to statistical analysis.

The emphasis was on teaching methods (6 constructs) followed by affective factors and evaluation (1 construct of each). The constructs related to teaching methods (common and constructivist ideas) were grouped together in a large cluster.

STUDENT 2/2ND GRID (TR2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.
CLUSTERS OF ELEMENTS:

Friend (1) (AF)
The one who shows patience (1) (AF)
The one who is fair in giving grades (1) (AF)
Guide (1) (TM) (t)
The one who follows a method (2) (TM) (c)
Well-informed (2) (PR)
The one who knows the content (2) (PR)
Expert in teaching (3) (PR)
The one who works together with the institution to improve the course (3) (C)
Fighter (4) (AF)

The emphasis was transferred from teaching methods to affective factors (4 elements). The teaching methods were linked to affective factors (transmissionist idea) and to prerequisites (common idea). The view was reduced with the exclusion of evaluation and curriculum.

CLUSTERS OF CONSTRUCTS:

Creates better teaching conditions/Does not create (1) (C)
Improves student's performance/Does not improve (1) (TM) (c)
Facilitates student's work/Facilitates teacher's work (1) (C)
Influences evaluation/Does not influence (1) (E)
Gratifies the student/Does not gratify (1) (AF)

Emphasizes content learning/Emphasizes content presentation (2) (TM) (con)
Fundamental to learning/Not fundamental (2) (TM) (c)

Influences on system's changes/Influences on student's behaviour* (3) (AF)

(*) Construct with reversed poles due to statistical analysis.
The emphasis stayed on teaching methods (3 constructs) followed by affective factors (2 constructs). The view was enlarged with the inclusion of conditions. Links between teaching methods (common idea), evaluation, affective factors and conditions were present. A small cluster included two constructs related to teaching methods (common and constructivist ideas).

Considering the eight grids, it may be noticed that the initial emphasis on elements related to teaching methods was transferred in the second grids to an emphasis on affective factors with a significant reduction of elements related to teaching methods. No importance was given to prerequisites.

In relation to constructs, the emphasis was given to teaching methods in all grids. There was an equal presence of common and constructivist ideas in the first grids. Common ideas predominated in the second grids, followed by constructivist ideas.

5.1.4- REPERTORY GRIDS ABOUT STUDENT'S ROLES (SR)

TEACHER 1/1ST GRID (SR1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

The one who contributes to teaching methodology (1) (TM) (con)
The one who participates in dialogue (1) (TM) (con)
The one who seeks solutions to his problems (1) (TM) (con)
The one who seeks integration with classmates (1) (AF)
The one who produces knowledge (2) (TM) (con)
The one who develops study habits (2) (PR)
The one who is considerate to classmates (3) (AF)
The one who is considerate to teacher (3) (AF)
The one who observes his duties (4) (PR)
The one who receives information (4) (TM) (t)

The emphasis was given to teaching methods (5 elements) followed by affective factors (3 elements). The teaching methods were linked to affective factors (constructivist ideas) and to prerequisites (constructivist and transmissionist ideas).

CLUSTERS OF CONSTRUCTS:

Requires expression of thoughts/Does not require (1) (TM) (con)
Develops in group/Develops alone* (1) (TM) (c)

Makes the lesson more dynamic/Does not influence lesson's dynamics (2) (TM) (c)
Stimulates analysis of altern. conceptions/Does not stimulate (2) (TM) (con)
Provokes changes on teach. process/Does not change the process (2) (TM) (con)
Increases interest/Does not increase (2) (AF)

Develops the critical sense/Does not develop (3) (TM) (con)

Leads to organization of thoughts/Leads to organiz. of attitudes (4) (TM) (con)

(*) Construct with reversed poles due to statistical analysis.

The constructs concentrated on teaching methods (common and constructivist ideas), which appeared isolated and linked to affective factors.

TEACHER 1/2ND GRID (SR2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Reader (1) (PR)
The one who does his homework (1) (TM) (c)
Inquirer (1) (TM) (con)
The one who does classroom exercises (1) \( (TM) \) \( (C) \)
The one who is obstinate (1) \( (AF) \)
The one who asks the teacher to solve his doubts (1) \( (TM) \) \( (t) \)
The one who plans his studies (1) \( (PR) \)

The one who is interested in course's content (2) \( (AF) \)
The one who seeks integration in the course (2) \( (AF) \)

The one who is disciplined (3) \( (PR) \)

The same types of elements were present as in the first grid. The emphasis stayed on teaching methods (common, constructivist and transmissionist ideas) and was linked to affective factors and prerequisites in the same cluster.

**CLUSTERS OF CONSTRUCTS:**

Develops reasoning/Does not develop (1) \( (TM) \) \( (con) \)

Works with the content/Does not work (1) \( (CU) \)
Develops a critical sense/Unrelated to critical sense (1) \( (TM) \) \( (con) \)

Organizes the work/Executes the work (2) \( (CU) \)
Work devised by the student/Work suggested by the teacher* (2) \( (TM) \) \( (con) \)
Facilitates student's emancipation/Does not facilitate (2) \( (TM) \) \( (c) \)

Student's attitude independent of classroom/Student's attitude linked to classroom (3) \( (AF) \)

(*) Construct with reversed poles due to statistical analysis.

The view was enlarged with the inclusion of curriculum. Emphasis stayed on teaching methods (constructivist and common ideas) which appeared linked to curriculum. The affective factor appeared isolated.

**TEACHER 2/1ST GRID (SR1)**

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these
trees are shown below.

CLUSTERS OF ELEMENTS:

The one who observes attentively the laboratory's objectives (1) (C)
The one who tries to make laboratory's measurements precisely (1) (C)
The one who attends the classes (1) (C)

The one who knows of course's content (2) (CU)
The one who knows the importance of this course in relation to his academic course (2) (CU)

The one who relates the course's content to everyday life (3) (TM) (con)
The one who discusses his doubts with teachers and colleagues (3) (E)
The one who gives emphasis to concepts before solving problems (3) (TM) (con)
The one who has the textbook and consults other books (3) (C)
The one who adopts a study scheme (3) (PR)

The emphasis was placed upon conditions (4 elements) followed by teaching methods (constructivist ideas) which were linked to conditions, prerequisites and evaluation.

CLUSTERS OF CONSTRUCTS:

Related to the use of information/Related to the access to information (1) (TM) (c)
Activity developed outside classroom/Activity developed inside* (1) (C)
Not related to the laboratory/Related* (1) (C)
Related to course planning/Related to course execution (1) (CU)

Activities developed at course's beginning/Activities developed during the course (2) (CU)
Not related to student's way of studying/Related* (2) (C)

Activity developed with the teacher/Activity developed without the teacher (3) (TM) (c)

(*) Construct with reversed poles due to statistical analysis.
The emphasis was placed upon conditions (3 constructs) followed by teaching methods (common ideas) and curriculum (2 constructs of each). The element related to teaching methods was linked to conditions and curriculum.

**TEACHER 2/2ND GRID (SR2)**

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

**CLUSTERS OF ELEMENTS:**

- The one who attends the classes (1) (C)
- The one who uses didactic books (1) (C)
- The one who reserves some time to study (1) (C)
- The one who is critical (1) (E)
- The one who uses the special schedule to discuss his doubts (1) (C)
- The one who discusses with colleagues (1) (TM) (con)
- The one who makes an auto-evaluation (2) (E)
- The one who relates the content with his previous knowledge (2) (TM) (con)
- The one who applies content to everyday life (3) (TM) (con)
- The one who knows of course's content (4) (CU)

The emphasis stayed on conditions (4 elements) followed by teaching methods (3 elements). More links were made between teaching methods (constructivist ideas) and conditions. Evaluation (linked to teaching methods) was included, whereas prerequisites was excluded.

**CLUSTERS OF CONSTRUCTS:**

- Related to course planning/Related to course execution (1) (CU)
- Activity developed at the beginning of the course/Activity developed during the course (1) (CU)
- Related to knowledge assimilation/Related to knowledge application (2)(TM) (c)
Permits to discuss the teaching method/Does not permit (2) (E)
Group evaluation/Individual evaluation* (2) (E)
Permits learning/Permits knowledge if you have learned (2) (E)

Activity Imposed to the student/Activity not imposed (3) (TM) (c)

(*) Construct with reversed poles due to statistical analysis.

The emphasis was transferred from conditions to evaluation (3 constructs) followed by teaching methods and curriculum (2 constructs each). The teaching methods (common ideas) appeared isolated and linked to evaluation. There were no constructs related to conditions.

STUDENT 1/1ST GRID (SR1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix 1. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

The one who follows the rules of good behaviour (1) (PR)
The one who fulfils his duties (1) (PR)
Dissertator (1) (PR)
Reader (1) (PR)
Listener (1) (PR)
The one who is careful (1) (AF)
Researcher (1) (TM) (con)
The one who prepares materials (1) (TM) (con)

The one who makes general criticism (2) (E)
The one who participates in the teacher–student dialogue (2) (TM) (con)
The one who transforms ideas (2) (TM) (con)

The one who takes notes (3) (TM) (c)

The emphasis was placed upon teaching methods and prerequisites (5 elements each). The teaching methods (constructivist ideas) were linked to prerequisites
and affective factors in a large cluster, and to evaluation in a small cluster. An isolated element related to teaching methods (common idea).

CLUSTERS OF CONSTRUCTS:

Develops emotional self-control/Does not develop (1) (AF)
Not based on previous learnings/Based* (1) (TM) (t)
Does not depend on student's organization/Depends* (1) (C)
Does not depend on the environment/Depends* (1) (C)

Developed by group work/Not developed (2) (TM) (c)
Develops creativity/Develops discipline (2) (TM) (con)
Develops the ability to memorize the content/Does not develop (2) (TM) (t)
Uses reasoning/Does not use* (2) (TM) (c)

Develops motor skills/Develops cognitive skills (3) (TM) (c)

(*) Construct with reversed poles due to statistical analysis.

The emphasis was placed upon teaching methods (6 constructs) followed by conditions (2 constructs). In one cluster the teaching methods (transmissionist idea) appeared linked to affective factors and conditions. Another cluster included only the teaching methods (common, constructivist and transmissionist ideas).

STUDENT 1/2ND GRID (SR2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Organizer (1) (PR)
Collector (1) (PR)
The one who solves problems (1) (TM) (c)
The one who interprets what he reads (1) (PR)
The one who creates new ideas (2) (TM) (con)
The one who is guided by idealism (2) (AF)
The one who prepares experiments (2) (TM) (con)
Inquirer (2) (TM) (con)

Dissertator (3) (PR)
Researcher (3) (TM) (con)
Friend (4) (AF)

The view was reduced with the exclusion of evaluation. The emphasis stayed on teaching methods (5 elements) followed by prerequisites (4 elements). The teaching methods (constructivist ideas) were linked to affective factors and to prerequisites (common and constructivist ideas).

CLUSTERS OF CONSTRUCTS:

Facilitates understanding of scientific jargon/Does not facilitate (1) (TM) (con)
Organizes the activities/Does not organize (1) (CU)

Does not stimulate creativity/Stimulates* (2) (TM) (t)
Does not stimulate comprehension/Stimulates* (2) (TM) (t)
Does not allow student participation in the classroom/Allows* (2) (TM) (t)
Organizes the ideas in writing/Organizes the ideas mentally (2) (TM) (con)

Helps icebreaking/Increases the resistance due to stress (3) (AF)

(*) Construct with reversed poles due to statistical analysis.

The emphasis was on teaching methods (5 constructs), which were linked to curriculum in one cluster and appeared isolated in another. Both constructivist and transmissionist ideas were present. The affective factor appeared quite isolated.

STUDENT 2/1ST GRID (SR1)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these
trees are shown below.

CLUSTERS OF ELEMENTS:

The one who transforms knowledge (1)  (TM) (con)
Researcher (1)  (TM) (con)
The one who questions course's content (1)  (CU)
The one who applies knowledge (1)  (TM) (c)
The one who participates in the choice of course's content (1)  (CU)
The one who has learning as the main objective (1)  (AF)

Member of a working group (2)  (C)
Collaborator in keeping the discipline (2)  (AF)

Listener (3)  (PR)
The one who studies (3)  (C)

Core element in the teaching-learning process (4)  (TM) (con)

The emphasis was given to teaching methods (4 elements) followed by affective factors, curriculum and conditions (2 elements of each). The teaching methods appeared isolated (constructivist idea) and linked to curriculum and affective factors.

CLUSTERS OF CONSTRUCTS:

Develops more responsibility in the student/Does not develop (1)  (AF)
Causes changes in the teaching methodology/Does not cause (1)  (TM) (con)
Causes changes in the teaching-learning process/Does not cause (1)  (TM) (con)
Leads teacher to prepare himself better for the course/Does not lead (1)  (PR)

Increases student's self-confidence/Does not increase (2)  (AF)
Gives teacher the opportunity to evaluate learning/Does not give (2)  (E)

Leads to a more solid learning/Leads to a superficial learning* (3)  (TM) (con)
Uses new didactic resources/Uses only the blackboard (3)  (TM) (c)
Raises course's level/Does not raise (3)  (TM) (c)
Causes a better teacher performance/Does not cause (3) (TM) (c)
Provokes more interest on social integration/Does not provoke (3) (AF)

(*) Construct with reversed poles due to statistical analysis.

The emphasis was placed upon teaching methods (6 constructs) followed by affective factors (3 constructs). The teaching methods (constructivist ideas) were linked to affective factors and prerequisites, in one cluster, and to affective factors in another (common and constructivist ideas).

STUDENT 2/2ND GRID (SR2)

The matrix relating elements and constructs, as well as the element and construct trees are shown in Appendix I. The clusters which appear in these trees are shown below.

CLUSTERS OF ELEMENTS:

Researcher (1) (TM) (con)
The one who seeks the truth (1) (TM) (c)
The one who participates (1) (TM) (c)
The one who shows interest (1) (AF)
The one who shows enthusiasm (1) (AF)
The one who follows a method (2) (PR)
The one who studies (2) (C)
The one who knows his rights and obligations (3) (PR)
Friend (3) (AF)
Self-evaluator (3) (E)
The one who demands (4) (TM) (con)

The emphasis was given to teaching methods (4 elements) followed by affective factors (3 elements). The view changed with the inclusion of evaluation and the exclusion of curriculum. The teaching methods (common and constructivist ideas) appeared linked to affective factors.
CLUSTERS OF CONSTRUCTS:

Essential to good teaching/Not essential (1) (TM)(c)
Influences on teacher evaluation/Does not influence (1) (E)
Influences on classroom work/influences on univer. as a whole (1) (C)
Provokes a more active teacher participation/Provokes a more active student participation* (1) (TM)(t)

Essential to learning/Not essential (2) (TM)(c)
Facilitates teacher-student communication/Facilitates student-student communication (2) (TM)(con)
May change the teaching method/May change the study method* (2) (TM)(con)

Better for individual activity /Better for group activity* (3) (TM)(c)

(*) Construct with reversed poles due to statistical analysis.

The view was reduced with the exclusion of prerequisites and affective factors and the inclusion of evaluation. The emphasis continued to be placed upon teaching methods, which appeared isolated in one cluster (constructivist and common ideas) and linked to evaluation and conditions in another cluster (common and transmissionist ideas).

In relation to the eight grids about student's roles, it is interesting to notice the emphasis given to teaching methods and the preoccupation with prerequisites. Very few elements related to evaluation. There was a constant link between teaching methods and affective factors. The emphasis was placed upon constructivist ideas.

The constructs emphasized the teaching methods, with the presence of common, constructivist and transmissionist ideas.

5.2 - SUMMARY

In this chapter I presented the results of the repertory grids. It is interesting to notice that the majority of the elements elicited in these grids were related to conditions. Elements related to affective factors were also very frequent.
CHAPTER 6
GENERAL RESULTS 6

6.0 - INTRODUCTION

In this chapter I shall present the results obtained in the workshops and group discussions. I shall also present the results of the questionnaire answered by the two teachers and their students, as well as the alternative conceptions elicited during interviews conducted with the students.

Specific results for each teacher will be presented in Chapters 7 and 8.

6.1 - WORKSHOPS AND GROUP DISCUSSIONS

The main results obtained in workshops and group discussions are presented below in chronological order as they occurred.

ACTIVITY No.1
WORKSHOP "DESCRIBE AND EXPLAIN" (29/6/87)

Objectives:
- To discuss the difficulties inherent in the teaching-learning process;
- To introduce the main study, its relevance and organization.

Development:
This workshop was held in a classroom in Physics Department. Physics students and teachers attended it.

I started the session by introducing myself and explaining the activity they would do, as well as the objectives for them. I did not record the beginning of the workshop because there were around forty participants and it would be impossible to record and transcribe what they were saying in any meaningful way.
The activity developed was suggested by Dr Pam Denicolo. Its aim was to illuminate to the participants the difficulties involved in explaining concepts. It consisted in trying to transmit orally a picture projected on the wall (see figures 6-1 and 6-2). The participants worked in pairs, sat side by side in such a way that one of them could see the picture and the other could not. The person who was looking at the picture described it to the other, who tried to draw it based on the received information. During this process the receiver was not allowed to ask questions and the giver was not allowed to look at the receiver's drawing. The information was flowing only one way and was transmitted orally. A second picture was projected afterwards when the participants changed roles.

While six pairs were developing the activity, the other participants observed them and shared comments. Some concentrated their attention on one pair, while others preferred to circulate and observe several pairs at the same time.

Results/Discussion:
After the activity I asked the participants what they found most difficult in receiving as well as in giving information. I tried to use their observations to highlight some aspects I intended to discuss during my work.

I present below a transcription of comments made by the teachers and students who, after this session, agreed to work with me (I will call them Teacher 1, Teacher 2, Student 1 and Student 2).

Teacher 1: During explanation the major difficulty was the impossibility of dialogue ... and lack of visual aid to show it, as well as oral language. When receiving information, the language itself and dialogue too.

Teacher 1 highlighted lack of dialogue - his usual way to teach is talking about the content and asking questions of students. He also stressed lack of visual aids although he does not use them frequently during his classes. Finally he stressed problems with the language. It is important to observe that he was sensitive to the role of two aspects involved in his way of teaching: (a) the importance of visual aids in helping understanding and (b) implicit problems in oral communication.
Figure 6-1 First figure projected
Figure 6-2 Second figure projected
Student 2: When understanding the picture, when he was passing it to me, I felt it was difficult because I was trying to memorize, that is, follow his thinking regarding that picture and then I got lost... I've used two ways, his way, the position he is seeing, and mine. Then it is very difficult... but when passing... to him, I didn't feel any difficulty because the picture was somewhat easy. It was possible to show making an analogy with a clock... I started to give ways to explain to him.

Student 2, when understanding, felt the problem of interference between his picture and the picture of the other person. He tried to accumulate the information he was receiving without relating to the one existing in his mind but he could not succeed and got lost. In order to explain the picture he was seeing he used a model. He felt the picture easy because he could draw an analogy and he used it as common information between himself and the receiver.

Student 1: I think that the difficulty for him in listening was exactly the precision of directions in the picture, of vertices that were upwards or downwards, and dialogue. For me the fact of having a picture like that, to make an image like that, it should have a dialogue, at least a survey. Who is that person, to know how his language is.

Student 1 highlighted the lack of dialogue with the receiver and lack of a survey to know the receiver's language, the way he expresses himself, in order to know his ideas. In this situation, involving transmission of precise information, he considered it important to take the receiver's ideas into account.

Teacher 2: I also consider that the second picture was easier than the first. The idea of putting something already known, for example, when I had to talk about the triangle, the first information I gave was a person seated... but drawn in a more geometric way, and tried to tell that a triangle corresponded to the legs and so on. As a result, the idea remained.

Researcher: So, did you see a seated person?

Teacher 2: ... I highlighted that the circle was up there. When he talked to me he used far fewer words. Information from him was fast and it was really good... I think he explained much better than I did. Now I defend myself due to the difficulty of the picture...
Teacher 2 recognized that using something familiar helped in the transmission of information. He used models, but concentrated on his vision of the content. When explaining the other person's success, he highlighted the use of few words - he always uses a lot when he is teaching - and the speed.

In general, the teachers acknowledged that certain aspects of teaching are necessary, although in practice they do not always pay attention to them.

During my comments I tried to highlight some aspects that I intended to discuss during my work, such as: planning, time, feedback (evaluation). I also talked about the research fields involved (teachers' thinking, alternative conceptions) and tried to explain the role of students in the process.

**ACTIVITY No.2**
**WORKSHOP “PERSON’S OBJECT” (30/7/87)**

**Objectives:**
- To give participants the opportunity to get to know each other;
- To discuss the nature of knowledge.

**Development:**
This workshop was held in a classroom in Physics Department. The participants were Teacher 1, Teacher 2, Student 1, Student 2 and myself. This activity was suggested by Dr. Pam Denicolo.

I started the session explaining the objectives and development of the workshop. Then I talked about myself, presenting the object I had brought. I was followed by Student 1, Teacher 1, Teacher 2 and Student 2, who talked about themselves while presenting their objects.

After everybody had spoken I asked each one to give his opinion about one group member. The others paid attention in order to compare what they had perceived with the perception of the one who was talking. I also asked them to justify their impressions and to relate the knowledge they had acquired with the way they had done it.

At the end of the workshop I presented some comments about the way they expressed their opinions.
Results/Discussion:
After I presented my object, Student 1 presented his own.

Student 1: My object is the Bible. I'm very related to the Bible. One thing, I started to read then I saw that everything in me, all my questions that I would care about in my mind, everything was in here. In my lifestyle, in my moral instruction, in punctuality too, then I chose a Bible, an object that is constantly connected to me, in all aspects, in everything that I can imagine, it is related. Before I have attached myself to this object, I lived in a way different from the one I live today. These differences are: to look at the persons with different eyes, to look at the persons with more benevolence. I cared a lot about myself, I was more interested in solve my problems and didn't care about other persons. Then after this, since six years ago, I have started to participate more with other persons, to share more. This was really a radical change for me ... to invest more, to study more. To search for several things in the Bible, several passages, that make persons study more, develop themselves more.

Student 1 showed a lot of self-confidence. He looks for his answers in the Bible and not in people. His relationship with persons is more to give, to direct, to develop them. He seems to be a leader.

Teacher 1 presented the object he brought.

Teacher 1: This is a capoeira* graduation cord. What does it have in relation to me? Since 1971 I have had contact with capoeira ... a sport and a culture, basically national, basically Brazilian, and I started to identify myself a lot with it. First, because I always had a very timid temperament. In the period of my adolescence, in the classroom, I was scared of writing on the blackboard ... capoeira helped me to overcome these things. For example, you come to a circle, you are there ... there are lots of people looking at you. You play an instrument, there is a music, there is a whole ritual observance ...and you expose yourself in that activity. Then it was a way for me to drop the mask and it is very much related to myself. I have several records, many things related to the black culture in Brazil ... I preserve very much this type of culture.

(* )capoeira is a mixture of dancing and fighting which was developed by Africans who were brought to Brazil as slaves.
The irreverent way of capoeira. In a certain way I am irreverent ... It is not irreverence with somebody, no. It is the informality of things.

This teacher is very timid and tries to identify himself with a group as a way to have support (in this case the group involved with capoeira and, more generally, with a national identity). The informality may be related to insecurity.

Teacher 2 talked about his object – a packet of cigarettes.

Teacher 2: My object is a packet of cigarettes ... I'm very much related to the packet of cigarettes but it is not just due to smoking itself, it is not just due to the addiction itself. Because, as teacher 1, I'm also very timid and always was timid. Then, in the past, I used the cigarette as a defence, as a way to break my shyness, not to be empty-handed without knowing where to put my hands. I used the cigarette to buy time, to recover, to get time to calm down, to take a position. Always as a time mechanism... Always as a defence mechanism, not as an addiction, on the contrary, because I don't smoke every day ... I think that it was present in all decisions in my life.

Student 1: Another habit, you could change from this...

Teacher 2: But I'm not looking for another habit.

Student 1: If you changed this habit...

Teacher 2: For me, I don't consider the cigarette as something that is damaging, on the contrary, I'm aware of that. But I take it as a good thing, as a reason for satisfaction, that smoking is a pleasure ... You live in a society, you are afraid of your weaknesses. People are always putting measurements, postures on you ... you have to behave this way, you have to do this way, this and that way.

Teacher 2 is also very timid. He uses the cigarette as a mechanism for defence and support. He does not like impositions. Even when he knows the disadvantages of a certain position, he prefers to concentrate on the aspects he considers as relevant and to ignore the rest.

These personal characteristics may be relevant in a situation where the person has to face a challenge, for example, start a new way to teach with a group that
is not interested at all. The difference between these teachers seems to be that Teacher 2 tries to solve his problems alone while Teacher 1 always uses a group to get support.

Student 2 presented his object - a music centre.

Student 2: ... my music centre ... is related to me because it brings me, not only me but maybe the whole group in my home, through songs, news, a bit of happiness, keeps us informed. And it is similar to me regarding liveliness. It brings liveliness to home and I feel that I do the same. Because I'm a lively person ... I relax persons, I bring happiness to my home. This object is also very important to me because I've bought it myself. Although I did not have one for many years, because I never had the possibility to buy one before, it was a fruit of my labour, also a fruit of what I've learned at the University, because through what I've learned here I could work, using what I've learned here, and obtain this object. For me it is an object of esteem because it was the first object obtained through my profession, through the profession I've chosen .... I'm a modern person ... Modern, a lively thing, that brings liveliness ... that relaxes, right? Participates ... brings music and music is part of every moment in our lives ... it's an important thing.

Student 2 is proud of his achievements. He is worried about relaxation although he does not seem a relaxed person.

In the following phase I have asked participants to give their views about the others. Student 1 started to talk about myself.

Student 1: I could make a comparison with several things with myself. The impatience with objects in contact with the body. I saw a great similarity with myself. You were talking, I've noticed that I have a great impatience in wearing a watch, in wearing something that keeps moving on my body, that pressures my body ... In respect to punctuality. Punctuality - I hold it in high esteem. These things that you've said, a lot of them are related to me. You are a more conservative type. I don't like the modernism very much, because behind the modern is the exaggerated consumption ... This consumption is what is destroying the community. Another thing that you have talked about, was the flexibility in attitudes. Indeed, comparing with me, I'm not very much the type
that gives an order and stick to my position. I'm always a bit flexible ... I don't know if it is my fault but I like to be more complacent with my attitudes ...

When making comments about the others, the aspects Student 1 highlighted were those he found in common with his way of being. Indeed, his analysis was more about himself. All his comments were based on what I have said and not on how I behaved in general. He used his own point of view as central for his conclusions.

Teacher 1: What I have to say is, more or less ... what you have said confirms what we think about you. The aspect, mainly the aspect of being serious. Serious in manners, ok? It is not in the serious way of being with people, no, it is serious in ... frankness. In dressing, alright? In facing work ... by the way you plan your activities ... It is a question of confirming what you have stated and that we have been observing for some time.

Teacher 2: Just to reinforce ... I, in my case, already have some information about you.

Researcher: What I have said today changed or added something you've already known? This is what is important.

Teacher 2: Your, that is ... the fact that you have said that you were changeable, flexible, you could change your position, change your opinion or ... It changed very much, it changed a lot because until now I still had the impression that it was not so changeable, that it was more rigid.

Researcher: This, for example, is important because I may see myself as a flexible person and you may not.

Teacher 2: I don't think you are as flexible as you have said. Because, due to your rigidity in your timetable, in your everyday life, in your day plan, in your life plan.

Teacher 1 spoke in first person plural. He highlighted only one aspect, planning or organization, that, according to his point of view (or group's point of view, it is not clear due to the way he talks) confirms previous observations. There was
no exploration of new aspects nor elaboration of this one. His comments were
general, without reporting to specific details to support them.

Teacher 2 compared some new information with his old ideas and used it to
corroborate them.

Student 2: In relation to, I mean, by our recent acquaintance, by the interviews,
by the timetable, I could feel that you are an organized person. You are
organized, you plan in advance what you intend to do, perhaps that is why you
gave the watch as example, because the one who plans and is organizes always
bases himself on time, doesn't he? ... It was possible to feel that you ... maybe ...
want everything to be like that, everything organized, everything in its time ... 
fix the time for everything, isn't that so? ... so things will be in perfect order,
because you have planned it this way ... it is a very good thing. Maybe I'm
learning, everybody else too...

Student 2 used the information available, together with his previous
experiences, to try to explain the choice of the object as well as to anticipate
my intentions.

Then I asked Teacher 1 to start with the comments about Student 1, who was
the second to present himself.

Teacher 1: I, as far as I'm concerned, I think that Student 1 is an introvert. That
was my impression, is my impression about him.

Researcher: Based on what?

Teacher 1: Based on the questions he put. On the question of moral, on the
question of ... concentration on study, on his behaviour, ok? And ... a person that
although an introvert is open to dialogue, by the way he presents himself as a
person that has changed due to ..., as you say, to ...

Student 1: ...a philosophy of life.

Teacher 1: A philosophy of life. ...I think he is open to change.
Teacher 2: ...the information was scarce but considering the object related to him it is clear that he is a deeply concerned person.

Student 1: With what?

Teacher 2: Concerned with an ideal, with a way of life, with a social posture, concerned, not in a pejorative way but religiously, in a religious way.

Student 1: Has an ideal...

Teacher 2: Has an ideal. But it is an ideal that is very confining, although he is a person... he is a person open to... to talks, but I think he is very firm in his... posture.

Student 2: Because I know him a little, a little better than you, I may perceive that he is a person that... uses religion frequently to explain certain things that happen in his life and... he is very concerned about it as the ideal thing... for him, the right things are in the bible... Maybe to him, because he read the bible, because he dedicated himself to this... then he considered the bible, he previously judged it as right... and no other book would explain another truth but the bible...

During this round, Student 1 kept asking questions to clarify the opinions about him. Teacher 1 supported his conclusions with oral information. This information, however, was not conclusive but was used to activate some of his own ideas. Teacher 2 highlighted the aspects of religion and the ability to compromise (he is very concerned with them), and came to conclusions derived from his own experience. Student 2, instead of coming to conclusions about Student 1, tried to explain him and his choice of an object. In an indirect way he presented student 1 as a person who values things with which he is involved.

Then I asked Student 1 to start the comments about Teacher 1.

Student 1: I always like to compare people with my way of being. I, when Teacher 1 spoke, showed the cord, a search of a defence to break his shyness, I see this as one of the things I also tried to do. I was very, but really very, timid, and I had no defence at school...
Teacher 2: I always thought that Teacher 1 was an open person, he was young in spirit. That's my impression... he is not connected to any kind of formalism, neither in his way of life nor religious, nothing... Since he chose a, for me it's a game... a capoeira, for example, then it was a way he discovered to break his shyness. I think that it's exactly due to this that he behaves like he does... His object helped me just to reinforce my impression.

Student 2: Look, the object that Teacher 1 brought... I came to the following conclusion: it was through a sport that he could, I don't know... get rid of a bit of his shyness, could be free of it... maybe... capoeira is a sport... it is not individual, it's collective, isn't it? And you are never alone, you are always in a circle with people, with music, aren't you? ... Concerning his personality, as Teacher 2 said, through our recent acquaintance, it is possible to perceive that he is a joyful, lively person and that... due to this he appears to be young. In general people that are lively inside, we look at them as if they are young...

Student 1 continued to connect new information with his own ideas in order to come to his conclusions. He presented this kind of behaviour openly. Teacher 2 also used new information to reinforce his own ideas. Student 2 presented his view based on the new information available as well as on exterior aspects of Teacher 1. It was not easy to perceive his own ideas.

When talking about Teacher 2, Student 1 described him as an open person, associating this characteristic with talking to students (Teacher 2 was his teacher), and nervous due to his smoking. He did not pay attention to other details and came to this last conclusion based on his personal feelings. Teacher 1 emitted a very subjective opinion based on his previous knowledge about Teacher 2. Student 2 mixed his view of a nervous person with the view presented by Teacher 2 himself - that of a timid person. He gave an explanation involving both aspects. At the end he made an apparent incoherent statement when he said that Teacher 2 was a relaxed person. On this occasion, however, he was associating relaxed with lively and funny - some ideas he used to present in himself.

Finally, the participants gave their opinions about Student 2.

Student 1: I perceive in Student 2... the relaxed way of talking, in some places... the sensitivity to... some things, as listening, in the case of... his object, the
Teacher 1: Look, I had a very different image before today. I had an image of a
mute person, a person... and I think that the image I have today is very different.
It is the image of a really joyful person, of a person that really likes to... to
play, a person that likes music, a person... much more relaxed than I've imagined,
than I've thought, at least.

Teacher 2: The fact that Student 2 relates himself with the music centre, by my
little acquaintance of him... I think that it still explains, it explains a lot, for
me it doesn't change much my impression about him, because, considering his
position at school, as a student, he presents himself as a listener... I think that
it is the connection with the music centre to assimilate knowledge, to
assimilate the news, doesn't it? To test, I think, even the society in itself and
then to liberate himself. I think that he didn't change too much yet in my
opinion. ...

After this round of comments, I started to talk about the way they expressed
their opinions. I highlighted the following characteristics: 1- each one stressed
different aspects, as if he does not have the whole picture of reality; 2- the
same aspect is seen in a different way by different persons, depending on his
previous experiences; 3- other types of information, besides the orally
transmitted, were used to give an opinion.

ACTIVITY No.3
GROUP DISCUSSION "THE NATURE OF SCIENTIFIC KNOWLEDGE" (6/8/87)

Objectives:
- To appreciate some theories of knowledge;
- To compare the two research paradigms.

Development:
Before this session I have given participants a copy of the article "O
Empirismo", from Zylbersztajn (1985), and asked them to read it and to answer
the following list of questions:
- What are the main aspects (positive and negative) you see in the different
theories?
- Do you see any relation between these theories and the results we found during the last session?
- Do you see any relation between these theories and the learning process students undergo in a classroom?

I intended to invite each group member to talk about his answers and then open the discussion. At the end I would present the characteristics of paradigms 1 and 2 and explain why I intended to work with paradigm 2.

At the beginning of the session the participants said that they had read the article but it was very complex and they could not answer the questions. I decided, therefore, to give a general view of the article and to move on to the second objective, that is, to compare the two research paradigms.

Results/Discussion:
While I was explaining the theoretical bases for paradigms 1 and 2, participants were making comments, asking questions and giving examples of situations that could be explained by this theory.

Teacher 1, when we were talking about behaviourism, started to analyse the influence of it on the textbooks we adopt, on the way we give lessons and evaluate students during our practice.

During my explanation about qualitative methods, when I was stressing that they are based on the assumption that persons are different and come to different conclusions when in contact with the same instruction, Students 1 and 2 started to link what I was saying with the activities they had done in our first meeting. Student 1 reminded us that during the first workshop, when persons were giving instructions to others, about the same picture, each one was doing it in a different way (because they were perceiving the picture differently). Student 2 stressed the different interpretations of the set of instructions.

At the end of my presentation I explained to them why I was adopting paradigm 2 in my research. Then I decided to make explicit the objectives I had when I asked them to read that article, i.e., to enable them to reflect about their own visions about knowledge and its construction and to criticize and improve them.
At this point Student 1 highlighted the importance of my presentation, as well as the questions I had distributed before the meeting, to make him realize that he was not reading the article in a critical way but just generally, looking for information. He said that after the presentation he could perceive the main points in the article and would read it again criticizing these aspects.

Student 2 stressed that we always read texts to reproduce them afterwards (in tests, etc).

At the end of the meeting Teacher 2 started a discussion about the objectives of teaching and the importance of evaluation and content. Teacher 1 joined the discussion talking about the pressures he faced in several schools to value the transmission of knowledge and the preparation of students to pass the exams, which give access to universities. Student 1 gave an example where solving problems was the only aspect which was valued.

**ACTIVITY No.4**

**GROUP DISCUSSION "THE NATURE OF SCIENTIFIC KNOWLEDGE" (13/8/87)**

**Objectives:**
- To appreciate some theories of knowledge;
- To compare the two research paradigms.

**Development:**
Each question on a list previously given to the participants was discussed one at a time. At the end we discussed the possibility of adopting the Ideas presented in the article.

**Results/Discussion:**
At the beginning of the session Teacher 1 made some comments about the article I gave them to read, stressing its complexity and the necessity of reading other texts in order to understand it. Teacher 2 highlighted the problem of terminology and added that this article was especially important in creating an interest in this subject, as well as giving Teacher 1 an opportunity in bringing other articles to the group.

In relation to the last meeting, I said that I was afraid of having influenced their ideas in a certain direction. Student 1 and 2 affirmed that it did not
happen to them and due to my explanation they read the article more carefully and understood it much better.

After this introduction we passed to the discussion of the questions I had given them previously.

Student 1 highlighted as a positive aspect the possible use of Bacon's methodological ideas to enable persons with a modest intelligence to do research. It would avoid the necessity of geniuses to carry out the scientific progress. His main concern was related to the diffusion of scientific knowledge to other sectors of society beyond the scientific community.

Student 1: ...Because it would enable the diffusion of science not only among the elite but to everybody, that is, a powerful science that could help even the public in general. As he [Bacon] says in here... for persons with a modest intelligence. It would mean that a carpenter could do an experiment that could be useful for himself and for his community... .

Teacher 2 held a different point of view. For him the text was not referring to science for all, to do something for people in general, but to the possibility of persons, even with a modest intelligence, to learn how to solve a differential equation, to learn how to do research.

Teacher 1 saw Bacon's ideas as an opportunity to open the discussion about science to the public. His view about the method, however, is not positive:

Teacher 1: ...I don't believe that the method, a method to train people, is capable to guide them through a certain way. Everyone, I think, has his own method. That's my vision. Of course you have points in common but you have an intuition and it has no method at all. And there is intuition in discovery.

Student 2 put more emphasis on personal creativity than on a method for everybody:

Student 2: By the way Student 1 talked, it is possible to feel that Bacon has created something that would inhibit the individual to think, to create, to be more creative. Bacon's vision was to give a recipe and the individual would follow it and would succeed. But it would not be like that because every person,
with his own way of thinking, with his creativity, would bring some benefit to science that would be better than what the other, who was imposing something, would do.

It is possible to perceive the different visions of teaching embedded in these comments. Teacher 2 follows with a more illuminating one:

T2: I think that this method doesn't have enough instruction.

Student 1 also presented his view of teaching implicitly in his comment:

Student 1: I wouldn't say that he is imposing, but that he, at least, gave a starting point for you to conduct some experiments, about certain subject, and you would follow it more or less.

Teacher 1: You have some basic instructions.

Student 1: You have some basic instructions. That is what happens in general. For example, to develop a new method, I must previously have something to support it.

This problem led to a discussion about the way the curriculum is organized in our university. Its prerequisites and lack of flexibility were compared to a "scientific method" which was developed to guarantee that students, after getting through it, would have the necessary knowledge to exert their professions. These results were contested.

Another aspect highlighted by Teachers 1 and 2 as positive was the support given by Bacon's ideas to the return to observation.

During the discussion of Bacon's ideas about the absolute apprehension of reality, teacher 1 concluded that, since different persons may have different visions, including adults compared to children, the way to teach in universities should be different from the way used in secondary or in primary schools.

Teacher 1: The logic depends on everyone's point of view.
The Importance of a personal experience in order to be sensitive to problems related to different contexts was stressed by Teacher 2. For him it is not possible for a teacher that has always taught Physics in a university to understand the different conceptions about Physics, held by different people, depending on their age and experiences.

The present situation in our university, where different disciplines are taught without consideration of students' previous knowledge, as well as the way Physics is taught in secondary school, based only on mathematical formulae with no regard to concepts, were also discussed by participants.

The use of language in Physics teaching was another aspect under discussion. Teacher 1 stressed the problem of an esoteric language developed by scientists. Student 1 saw this language as a way to give names to things which did not exist previously or to organize knowledge.

Teacher 1: There will be a moment when only those persons who are inside the group will understand that language. As it is now.

Student 1: It is like to define each term of a formula.

These two points of view are very different.

I tried to deepen the discussion about the relation between language and learning. Student 1 presented the following point of view:

Student 1: ...A person who doesn't read very much is not capable of absorbing certain terms.

Researcher: And if he reads more? Would he absorb?

Student 1: Yes, he would absorb... It would also depend on the teacher making some analogies involving what he had read.

Student 1 was presenting a point of view where comprehension would depend directly on previous contact between the student and some words, during reading, and on the analogies the teacher would draw between the present content and the one in the readings.
From this situation we moved to examine our expectations in a classroom, when all students receive the same explanations and, therefore, we think that all of them will come to the same conclusions about that content. This expectation was detected not only in relation to our classrooms but also in relation to our lives in general.

After realizing that we assume a positivistic position in our way of teaching and living, we started a discussion on the problems we would face if we would try to change. The participants started to point out several social and political consequences of a teaching based on constructivist ideas and possible pressures against changes.

ACTIVITY No.5  
WORKSHOP "HIDDEN ASSUMPTIONS" (18/8/87)

Objectives:
- To introduce and discuss the problem of alternative conceptions;
- To consider the interactions between different conceptual frameworks occurring in the teaching-learning process.

Development:
After explaining the objectives of the session, I provided a sheet of paper with the following story and gave fifteen minutes for the participants to read it and answer the question at the end in writing.

"Paul went for a walk in his environment and met a small animal, which he called Charlie, which appeared to be lost. Since he did not see anything that could help him in determining Charlie's origin, he decided to take it to his home. There he gave some food to Charlie, provided a comfortable place for it to sleep and then he went to bed. Next day, when the cleaner came to Paul's home, she found Paul dead, the place in chaos and no sign of Charlie. What had happened?"

Each participant read his own answer and then made comments about the possibility of the answers given by the others. At the end I discussed the results.

Results/Discussion:
At the beginning, when I was explaining the objectives, Student 1 presented his
view that alternative conceptions were, in fact, wrong analogies.

Student 2 thought that Paul had died suddenly. He considered that Paul was murdered by a burglar who was looking for valuables in the house (this would be the cause of the disorder). The animal was scared by the burglar and escaped.

Teacher 2 considered that Paul was robbed and murdered and the animal was taken by the robber to avoid being recognized by it. Presumably this animal would be a cat or a dog which could recognize the robber.

Teacher 1 thought that the owner of the animal discovered that Paul had taken his dog to his home. He went there and after a strong discussion the owner killed Paul.

Student 1 started to read the text and to point out the bases for his conclusions. Initially, in relation to the environment, he thought of it as a forest. Paul was close to a forest and he found a cub of a wild animal (he gave some examples of wild animals found close to small towns in the place where he lived as a child). The mother went to Paul's house looking for her cub. She entered the house, had a fight with Paul (this caused the disorder and Paul's death) and went out with the cub.

Student 1 was the only one to give the bases for his conclusions. I started, then, to ask questions to others in order to identify how they came to their conclusions. After this I started to discuss the plausibility of the answers.

Student 2: The answers of Teacher 1 and 2 - I think they were plausible. They could happen if they were thinking about a city, because we have a vision linked to a city, since there is a cleaner, a woman who goes there once a week. So we think about a city. Student 1 was a bit distant from what we have thought and may be he has thought about something... he created something, he was creative when he was construing the story.

Student 2 thought that the probability of occurrence of Student 1's story was very low because in the houses in small towns it is not usual to find cleaners going to homes on a weekly basis. This detail was the most important for Student 2.
Teacher 2 associated the term cleaner with big cities.

Student 1 explained that from his experience in living in a small town, he knows that there are people who sometimes go to help people who live alone.

Participants, then, started to discuss their views and the plausibility of them. I used the opportunity to point out some details. The first one was the relation between our views and our present reality in a city, with robbers, etc. Another point was the possibility of all answers. Each one was based on one detail or another as well as on previous experience.

I stressed that most of the elements in the story were not defined and this story was the opposite of what we want when writing a text in Physics. In this case we try to define everything so that everybody reading the text would come to the same conclusions. Even in this case, however, a phrase or sometimes a word, could be interpreted in a different way, leading to different conclusions.

At this point I started to talk about accessory and defining characteristics of concepts.

The acknowledgment of the existence of alternative conceptions led to another discussion this time in relation to evaluation. Participants started to discuss the objectives of evaluation and the characteristics to be assessed.

**ACTIVITY No.6**
**GROUP DISCUSSION “ALTERNATIVE CONCEPTIONS” (25/8/87)**

**Objectives:**
- To discuss the relation between alternative conceptions and teaching methods;
- To appreciate some research findings concerning alternative conceptions.

**Development:**
Before this session participants received a copy of the article "Um esquema conceitual para o ensino das ciências", Zylbersztajn (1985a), and the following list of questions:
- What are the main aspects, positive and negative, you see in this article?
- Do you see any consequence of these aspects to the teaching-learning process?
- Can you make any comparisons between these ideas and your own about the teaching-learning process?

After the discussion of participants' views, I presented an overview of research findings in the field of alternative conceptions.

Results/Discussion:
Due to a technical problem the cassette with this session was damaged.

The participants found the article easy to read and agreed with its content.

In relation to the origin of alternative conceptions, Students 1 and 2 stressed students' lack of access to books and lack of interaction with curricular science as the most important causes.

Teacher 1 was interested in the ways to change students' conceptual framework. For him, it would involve changes in the school's objectives as well as in curricular structure.

**ACTIVITY No. 7**
**WORKSHOP "LISTENING ACTIVITY" (27/8/87)**

**Objectives:**
- To introduce the problem of oral transmission of information;
- To discuss the efficiency of a teaching method based on oral transmission of knowledge.

**Development:**
One participant had 10 minutes to talk to another about a specific topic. The other

stayed listening without asking questions. Then he had to give the same information to the other members of the group.
The first participant criticized the information given by the second. The activity was repeated by another pair of participants and discussed by the group.

Results/Discussion:
Student 2 started the activity explaining the way he received shooting instructions in the army. He talked about his subject without any attempt to give a structure to the information or to speak slowly. He finished before ten minutes and then decided to do a review.

Teacher 1 repeated the explanation to the whole group in five minutes.

After the explanation of Teacher 1, Student 2 acknowledged his own lack of structure as a problem in the transmission of information:

Student 2: ... He was much more organized. He organized the ideas.... Maybe this was the reason for him finishing quicker than me. Because I was trying to say everything, and at the same time...

He also stressed that Teacher 1 did not talk about some points that he had highlighted.

Teacher 1 also included some information that was not given by Student 2, who did not perceive this aspect.

Then Teacher 2 spent 10 minutes talking to Student 1 about his work in a secondary school. He did not try to organize the information he intended to transmit. In the beginning he was speaking very slowly but after some time he started to speak normally and even quickly.

Student 1 managed to repeat the information almost in the same way as Teacher 2 until the point when this one started to give same examples.

For Teacher 2 the presentation of Student 1 was very good, like a tape recorder, until the point when he did not stress an aspect considered as very important by Teacher 2 - the use of analogies. Other aspects considered important, however, were acknowledged:
Teacher 2: ... The most important aspect that I wanted to emphasize, this aspect he really transmitted. That is, I ask students to give a verbal answer before writing in their notebooks...

The problem of emphasis was discussed when Teacher 2 pointed out that Student 1 did not understand the way he used in his lessons to transmit the ideas of velocity and acceleration. I asked him if he was speaking slowly in this moment or emphasized this information in another way. He remembered that in this moment Student 1 was looking at his watch and he was worried about having enough time. He could not, therefore, speak slowly or repeat the information.

It is interesting to note that, for Teacher 2, the presentation of two examples he usually uses in his lessons to introduce some concepts was a kind of emphasis. He acknowledged his mistake, however, in considering that what he was saying was so simple, so easy to understand, that sometimes he did not even look at Student 1. According to Student 1 the examples were simple for Teacher 2 because he was used to them. The situation would be very different for a student who had never seen them before.

I took the opportunity to make a comment about the interference of time restrictions on participants’ concentration and consequent capacity to retain and transmit information. Participants agreed that this is a very common problem for teachers as well as for students in our university and in secondary school.

Student 1 observed that he needs to repeat the information until he is sure that he has understood everything before he can keep it. I used his observation to talk about short and long duration memories, the limitations of the operational memory and the necessity to organize information in order to transfer it to long duration memory.

Teacher 2 spent some time reflecting about this information and came to the conclusion that either students must spend more time in their courses or content must be reduced.

After discussing the organization of the information, participants started to discuss its relevance for the receiver. Student 1 suggested the use of analogies
based on students' daily experiences. Student 2 stressed the use of examples as the basis for comprehension. If the examples are related to the individual's experiences he will assimilate much more.

Returning to the problem of organization, Teacher 2 noticed that sometimes he repeats the same lesson to four different classes. For him this situation is a little boring, but the last lesson may be the best one, because he could test it and organize the time to include some topics interesting to the students, during the previous lessons. In relation to the students, however, the situation may be different:

Researcher: *In this better lesson, do the students make more or less questions than in the previous lessons?*

T2: *They make less questions. That is why I say that maybe they miss something because I give all the information without being asked.*

Teacher 2's opinion seemed a bit controversial, specially when he started to describe a lesson which he considered as successful. On this occasion the students were actively involved in analysing the movement of a small ball. Although the students gave the right answer at the end of the lesson, Teacher 2 was aware of possible difficulties in the future:

Teacher 2: *...At the end I explained that although everybody was convinced at that time, it would be possible that tomorrow, the day after tomorrow, or some other day, somebody would make the same mistake again because this was the first time they encountered that situation, analysing it critically and since they had had a different orientation for a long time, it would be possible that tomorrow they would make the same mistake.*

By this comment it is possible to conclude that Teacher 2 was aware of the importance of a personal experience to change students' ideas, but also that solely this would not be enough.

For me it was not clear what type of lesson Teacher 2 preferred. When I asked him, the answer was a mixture of both, because:
Teacher 2: ...if there is no information for him to take notes, if I don't force him to come to some conclusions, to write something... First of all he is not used to it... then, tomorrow, things might be very loose for him... where is my material?...I'm also changing my style due to our discussions in here. But it is not possible to change it radically in a short time...

Again the preoccupation with enabling time for change. The students need some time to get used to a new teaching style, with more participation.

I took the opportunity to draw a parallel between structuring information in the notebook and doing the same in the long duration memory. Even when students participate actively in a lesson they still need some structuring to keep the information, otherwise they will forget it.

I also explained that we have to work with the long duration memory and that was my reason for recording our meetings - to keep the information. The taperecorder was my "long duration memory". I asked them to record their views on blank cassettes in order to investigate what aspects of our meetings were retained in their memories. At this time I was not formalizing conclusions. My objective was to discuss, to identify problems and start to think about them.

I stressed the amount of time we were dedicating to this reflection and that students also need time to work with content.

**ACTIVITY No.8**

**GROUP DISCUSSION "TEACHING METHODS I" (1 and 3/9/87)**

**Objectives:**
- To present an alternative teaching method;
- To discuss the possibility to adopt it considering our reality;
- To present different uses of a traditional teaching method.

**Development:**
A copy of the papers "Brainstorming in the classroom to invent a model: a case study", Nussbaum and Novick (1981), and "The lecture", Beard (1978) were distributed before the meeting.
The papers were read and analysed.

**Results/Discussion:**

The participants were not able to understand the first paper due to problems with the language. I decided, therefore, to read the whole article again, stopping at several points to discuss them with the participants.

Before reading the paper, I explained its structure, emphasizing its theoretical bases.

The participants agreed with paper's authors in relation to the relevance of the methodology adopted. At the same time, however, they expressed their concerns in relation to the time necessary to implement such methodology because, as Teacher 1 pointed out, a teacher applying the traditional methodology would use three minutes to tell the students the conclusions they had spent four hours to reach.

The adoption of a teaching methodology very different from the traditional would involve other risks:

Teacher 2: *...the student perceives very well that this [content] would be imposed during only one lesson or even less... you run the risk to be called a crook. Maybe they call you insecure, because you didn't give the answer. ...when you try to innovate you risk breaking with tradition...*  

Student 1: *But this innovation must not be done so abruptly...*  

Teacher 2: *Of course... if you don't go slowly you may even destroy students' interest.*

This distance from our traditional teaching methodology to one which is based on active participation of students, acknowledged by participants, was considered in our planning for the second phase of our research. Instead of changing the whole course of basic Physics, just three topics will be altered.

Teacher 2 presented an example of a successful innovation he had tried in one of his classes due to our discussions in the last meeting. He asked the students to write a report about an activity they had developed during a previous lesson.
Although they were not used to write reports, they enjoyed the activity specially when Teacher 2 decided to read some reports during the lesson. Despite its good results, Teacher 2 pointed out the impossibility to carry out such activities more frequently due to time restrictions.

After this discussion I presented the second paper, which discusses some research findings about the uses of the lecture. This article was chosen because lecturing is the prevalent teaching methodology in our university.

Other teaching methods were also discussed and examples of their uses given by participants.

**ACTIVITY No.9**
**GROUP DISCUSSION “TEACHING METHODS II” (8/9/87)**

**Objectives:**
- To present different teaching methods;
- To reflect about the possibility of adopting these ideas;
- To emphasize the theoretical bases of different teaching methods.

**Development:**
Presentation and discussion of three articles about teaching methods ((Cañal, 1986), (Northedge, 1977) and (Zylbersztajn, 1985b)).

**Results/Discussions:**
During the discussion of the article of Cañal (1986) one point was emphasized by participants – the lack or shortage of activities to encourage work on previous ideas and on new information at the same time. This led to questioning about the objectives and ways of conducting laboratory work. The necessity of dealing with everyday problems was stressed by Teacher 1.

Teacher 2 pointed out the excessive disconnection between everyday life problems and the ones dealt with during lessons. This, according to him, is a way of avoiding mixing up scientific and alternative conceptions held not only by the students but also by the teachers.

During the presentation of the second article I stressed the three types of group discussions we had so far: 1- Giving the article and some questions about it
before the meeting, 2- Giving the article but no questions, 3- Giving the article at the beginning of the meeting. I asked participants to record their impressions about the efficiency of these methods. I intended to give them an opportunity to reflect about these situations and possible uses of them in their lessons.

The other methods presented during our meeting, including some related to group work, were not tested by the participants.

The problems of relationship between group members and the difficulty in discussing freely their own views was acknowledge by Teacher 2. He gave as an example the experience he had some years before when he was being observed during his lessons by a colleague. For him, this was very different from talking about his lesson with another teacher:

Teacher 2: ... It is an even harder problem. You tell your problem... but when you are telling you do that in the way you want me to listen to it. Another thing is when I'm in your classroom and you make a mistake... Because when you come to tell me, you may change it a little bit, you may say that you have forgotten, even if you really didn't know it.

The main concern of participants in relation to the teaching method described in this article was related to time constraints and group size.

Teacher 1 saw an inconsistency in the method due to excessive control. For him, if the teacher wanted to encourage free discussion between students he could not control all the steps of it. In other words, for him it was not possible to have total control together with free presentation of ideas.

At this point Student 1 intervened to suggest that the teacher was only putting some discipline in the whole process.

It is interesting to observe that participants are always stressing the points they consider as the most relevant in the teaching-learning process.

The final part of this session was dedicated to the presentation of a paper by Zylbersztajn (1985b) where he draws a parallel between learning and Kuhn's ideas about progress in science.
This meeting was much more monotonous than the previous one, with few interventions from participants despite the evident relevance of the topic under discussion.

**ACTIVITY No.10**  
**WORKSHOP "BRAINSTORMING" (15/9/87)**

**Objectives:**  
- To elicit participants' ideas about evaluation;  
- To discuss the difficulties in carrying out an evaluation process;  
- To suggest instruments of evaluation which could be used in a Physics course.

**Development:**  
I started the meeting asking participants about the objectives of evaluation and registering their answers on the blackboard. The answers were used as bases for other questions about what evaluate and how.

**Results/Discussion:**  
The first question posed to participants was: What is evaluation useful for?

The answers varied from a general - to verify something - suggested by Student 1, through a more conventional - to verify if the courses' objectives were attained - suggested by Student 2, until non-conventional answers given by Teacher 2 - to act as an incentive to those who are being evaluated, to motivate teacher and students, and to control payment of fees in private schools and universities.

Other answers such as probing students' knowledge, to measure what the student knows and what he does not know, to follow the development of students, to remind the student that he has signed a contract, is receiving goods and must honour the contract, were also given by the participants.

I suggested that when we think about evaluation we mean evaluating the course and the students. At this point Teacher 1 acknowledged that there is no evaluation of teachers and Student 1 stressed the necessity of it.
The participants tried to justify why they concentrate on the evaluation of the students:

Teacher 1: *I would like to do this type of evaluation [including the course and the teacher]. Due to work load, the objectives passed to us by the schools, we do only this type [with students].*

Teacher 2: *I would say more... due to work load the evaluation becomes boring*

Teacher 1: *You don’t have a real evaluation.*

Student 1: *And this evaluation, for the student, the only thing that counts for him is the grade.*

I asked them to think about what they do or would like to do to evaluate the course. When asked about the aspects of the course they would consider in their evaluation, participants revealed their emphasis on course’s content through the choice of the programme and schedule before thinking about methodology.

Teacher 2 also stressed the importance of teacher’s capacity to teach, meaning teacher’s mastering of content. For him a course may have bad results because the teacher was not able to transfer the content.

The aspects suggested by participants to base student evaluation on, were: learning (Teacher 1 and Student 1), interest in learning (Student 2), attitudes and change in behaviour (Teacher 1), capacity to reason and to verbalize what the person is thinking (Student 1), questions and criticisms (Teacher 2).

It is interesting to notice that the aspects pointed out by participants are characteristics which they view as important to enhance learning, though they can not define them precisely.

In order to evaluate the teacher, participants suggested the use of the following aspects: students’ grades (Student 1), students’ performance (Teacher 1), teacher’s mastering of content (Teacher 2), students’ criticisms (Student 1), teacher’s interest in giving the course (Student 2), teacher’s interest in knowing what students think about him (Teacher 1).
It is possible to distinguish two views of the teaching-learning process through the aspects suggested by participants: teacher-centred, given by Teacher 2 and Student 2, and student-centred, given by Teacher 1 and Student 1. These aspects are, again, not easy to define or measure, but constitutes, in the participants' beliefs, the desirable characteristics for enhancing the teaching-learning process.

After eliciting the aspects to be evaluated I asked participants to think about the means for conducting the evaluation. Then we started to discuss how to evaluate some aspects suggested by participants.

The first aspect was the programme. Student 1 suggested analysing whether it had been updated. Teacher 1 pointed out the difficulty of doing that without considering in what school it would be used, because the content would vary according to students' social class. Teacher 2 observed that the content should be the same with different objectives. Teacher 1 agreed and this aspect was discussed no more.

The constraints on the choice of the programme were pointed out by Teachers 1 and 2, who presented the situation as if they had no opportunity to choose what they wanted to include in their courses, because they receive a "programme" already defined by the University. I emphasized that what they receive are the guidelines for a programme which details must be defined by the teacher.

It is important to notice that Teachers 1 and 2 seemed to accept situational constraints and used them to justify their "impossibility" to criticize and work on the programme of their courses. This situation was also detected by Benson (1989) when analysing the practice of biology teachers in Canada.

I returned to the problem of evaluating a programme, stressing its adequacy to the course and the possibility of attaining the course's objectives with it.

Instead of making comments related to these aspects, Teacher 2 returned to the necessity of fulfilling the prerequisites of other disciplines in the curriculum.

This comment reflects a prevalent content-centred way of thinking about a course, in which the objective is perceived as the transmission of it. This point of view may be so strong that, although I have stressed a position where
objectives come in first place, the participants could not understand it and suggest possible ways of using it.

Teacher 1 tried to return to the problem of how to evaluate the programme. He suggested a discussion between the teachers who will give the course. Students 1 and 2 suggested the inclusion of students in this discussion. Teacher 2 disagreed with the inclusion of students because they do not have an idea of the knowledge they would need in other disciplines which they would have to learn in their academic courses. After a short debate, Teachers 1 and 2 agreed to include students who were in the final year of their academic courses, in these discussions.

I suggested that if they considered the prerequisites as important, they should include teachers from the other disciplines which were related to this one.

The evaluation of objectives also sounded as something strange to the participants. Teacher 2 was confounding general objectives with content and, at the end of the discussion, the attainment of objectives was thought of as learning of content.

I asked them if the students should give their opinions about the attainment of the objectives. For this they needed to know these objectives. All participants agreed that it was very important, especially since it would enable auto-evaluation by students. Student 1 stressed that he was in the last semester of his degree course and until that moment nobody had told him the objectives of this course. Besides, his own objectives, when he entered the course, were completely different from the objectives he held at the end of it.

Student 2 highlighted that with the objectives given to students they could also find out the reasons for not attaining the objectives. This would give them some control over the results obtained in the course.

At this point participants were confused about evaluating objectives, per se, or the attainment of them.

I asked them if they establish the objectives of their courses. Teacher 1 admitted that he does not work with objectives and that the majority of teachers he knows do not use them either. Teacher 2 tried to justify this
situation by bureaucratic constraints and gave the example of one course which he was giving, "with liberty to decide the programme". In this case he could decide what to teach according to the objectives which he considered important for this course.

Student 1 suggested the inclusion of students' opinions about what they wanted to study during the course, in the establishment of objectives.

Teacher 2 took the opportunity to say that he was becoming convinced that reports written by students were good instruments to evaluate a course. Teacher 1 stressed that these reports should be written during lesson time. Teacher 2, then, agreed with him, emphasizing the necessity to ask students to do some work during the time they were supposed to be thinking about the course.

These comments reflect the serious problem of time constraint that we face in the Brazilian educational system, with students having to study and work at the same time.

In relation to the methodology, I pointed out that we accept lecturing as a "natural" way to teach and never question its effectiveness for different objectives. If we want to change the methodology, however, it is important to evaluate it in order to have some basis to defend or attack it.

Teacher 1 acknowledged that he had never thought about methodology and participants gave no suggestions on how to evaluate it. The same results were obtained in relation to the evaluation of teachers.

In terms of learning, the discussion started with its definition. Participants were not sure about it and some suggested using the capacity to reason as a measure of it. Another problem was the existence of alternative conceptions and how to deal with them in terms of evaluation. Participants did not know how to measure learning if what students "learnt" was not what was intended.

Teacher 2 thought about attainment of objectives as a measure of learning. This would be, according to him, the only way of measuring it.
Student 1 suggested that extensive use of discussions and questions during lessons would lead to the destruction of alternative conceptions.

At the end of the meeting I stressed that we had several doubts concerning evaluation and we should think more about this topic and start testing some ideas.

**ACTIVITY No.11**
**GROUP DISCUSSION "EVALUATION" (17/9/87)**

**Objectives:**
- To elicit participants' ideas about evaluation;
- To present some ideas about evaluation.

**Development:**
At the beginning of the meeting we reviewed the information obtained during the brainstorming about evaluation. Then participants were asked to suggest ways of evaluating a Physics course and which aspects should be evaluated.

The articles previously given to participants (Elton (1982) and Mathias and Rutherford (1982)) were presented and discussed.

**Results/Discussions:**
During the review it became clear that the students needed to know the objectives to make an auto-evaluation. The objectives were also related to the programme, schedule and even to the methodology, which is never evaluated in our courses.

In relation to the student, one aspect to be evaluated was learning. The question then was to define whether it occurred when the student reproduced what the teacher wanted or when he was thinking by himself.

Another aspect to be evaluated, according to Student 1, was student's capacity to verbalize. It is a problem in Brazilian schools, specially in the area of Physics and Mathematics, where students generally use numbers to answer the tests. They only have to use words when theoretical questions are included in the tests, which is very unusual.
Student 1 suggested the use of questions during lessons to make the students speak. For him it is important that they speak out loud in order to overcome their shyness.

Teacher 2 suggested the use of students' reports to evaluate the teacher. I introduced the idea of using teachers to evaluate their peers. Then Teacher 1 stressed the importance of other teachers' opinions, since they know the content and the students do not.

The conflict of roles (teacher/evaluator), discussed in Elton's paper, was acknowledged by participants, who stressed the need to evaluate the teacher. For them, the problems in Physics courses are due both to teachers and students and not only to students as the majority of teachers think.

In relation to Mathias and Rutherford's paper, they found this kind of experience very difficult to be reproduced in Brazil because teachers do not accept criticisms from their peers.

**ACTIVITY No. 12**

**WORKSHOP "CONCEPTUAL MAPS" (22/9/87)**

**Objectives:**
- To discuss the problem of curriculum change;
- To introduce an instrument to elicit students' Ideas.

**Development:**
I started the session explaining what conceptual maps are and giving examples of them. Each participant was asked to draw a conceptual map about curriculum change in Physics 1 course.

The maps were used to discuss participants' views about curriculum change, which were compared with the view of Driver and Oldham (1986).

**Results/Discussions:**
Teacher 1's conceptual map was the first to be analysed. It's central element was the discussion about change, which was linked to the programme. The emphasis was given to the content, and evaluation appeared isolated, as if
something external to the process. It is interesting to notice that there are no links between objectives and programme.

Teacher 2’s conceptual map was organized like a fluxogram and emphasized the change of the programme (which came before the definition of course’s objectives). The evaluation was represented after the course.

Student 1 emphasized student’s learning, but it appeared as a consequence of changes in the course’s content and in the teaching methods.

Although Student 2 put planning in the centre of his map, the central idea was the content. It was implicit in all parts of his map.

In general, participants associated curriculum change with change in the course’s content. This position was discussed and compared with the one held by Driver and Oldham (1986), which emphasized student’s skills.

The conceptual maps are shown in the following pages.
Teacher 1's conceptual map

01 - To include or exclude topics
02 - More emphasis on some topics
03 - Order of treating topics
04 - Programmes
05 - Objectives
06 - Student's conditions (*to consider what the student knows about the topic)
07 - Discussion about the change (+ 1st teacher versus teacher, student versus student; 2nd student versus teacher)
08 - Teaching methods
09 - Other methods, laboratory, etc
10 - Person's agreement about the need to change
11 - Time distribution
12 - Evaluation
Teacher 2's conceptual map

1. Knowledge about previous programme
2. Academic courses which include the discipline
3. Discussion with discipline's teachers
4. Change in the programme, enlargement, reduction or change in order
5. Teachers' training
6. Objectives
7. Presentation of the new course to students
8. What are the methods?
9. Evaluation criteria
10. Available time
11. Classes start
12. Elaboration of a questionnaire to be answered by students about the course
13. Evaluation
14. Answer to the questionnaire
15. Discussion with teachers and then with students
16. Reflection for the next course
Student 1’s conceptual map

01- Teaching of vector Physics
02- To prepare the teacher better in content and methods
03- Themes present in student’s thought
04- Teaching of Classical Physics - related to everyday life
05- To correct teachers who do not respect the curriculum, limiting the content to the topics of their preference
06- To change the types of lessons
07- Student learning
08- Better performance of student in practical lessons (experiment)
09- Type of lesson (which involves student in verbalizing)
   - lecture; lessons prepared by teacher and student; readings
10- Teacher provides more didactic resources
01- Teacher's mastery of content
02- Presence of all teachers in this planning (common interest)
03- To take into account students' help to make this planning
04- Planning
05- To reduce the content
06- To improve laboratory experiments, i.e. experiments more simple and related to everyday life, including topics treated during theoretical lessons
07- One lesson to present the topic, other to solve exercises, and experiments related to that topic
08- The teacher presents the topic (to be treated during the lesson) and says what he expects from the students (specific objective)
ACTIVITY No.13
GROUP DISCUSSION "CURRICULUM CHANGE" (24/9/87)

Objectives:
- To present a scheme for curriculum change (Driver and Oldham, 1986);
- To reflect about the parallels between these ideas and the ones presented by participants in their conceptual maps.

Development:
In the first part of the meeting I presented the scheme suggested by Driver and Oldham (1986). Parallels between it and the conceptual maps prepared by participants were discussed. Suggestions to change the Physics 1 course were analysed, considering the conditions in our university.

Results/Discussions:
According to Driver and Oldham’s scheme (shown below), the curriculum is a programme of activities which allow learners to develop their comprehension of
what is being presented to them. It is not a body of knowledge to be transmitted. The project includes three phases, starting with a reflection about teaching practice. It is followed by meetings to discuss this practice and finally the preparation of new teaching materials.

During the discussion of the scheme, Teacher 1 stressed the possibility of using the results of the course to change the programme. For that, the teacher should see his classroom as a place to do research, that is, to be involved in action research. This would require some infrastructure, which would allow the teacher to dedicate more time to reflect about his work. It was not possible under the current conditions faced by participants, who had to teach in several schools to support themselves.

To change from a view centred on the content to another centred on learning activities is very difficult, in the opinion of participants, due to the constraints put by our educational system, which emphasizes the necessity of transmitting a body of knowledge, on teachers’ and students’ minds.

The lack of evaluation in Student 1 and 2's maps and the positions of that in Teacher 1 and 2's was considered in our discussions about their conceptual maps. Another point was the agreement between the people in a changing process, concerning the necessity for change. This led to the idea of involving other teachers of Physics 1 in our process, through their suggestions concerning changes in this course.

ACTIVITY No.14
GROUP DISCUSSION "OBJECTIVES IN A COURSE" (24/9/87)

Objectives:
- To introduce the problem of defining objectives;
- To reflect on objectives in the affective domain.

Development:
This meeting was held some hours later than the previous one. We had some problems with our schedule due to public holidays.

After introducing what objectives are and the domains used to work with them I tried to discuss the objectives for Physics 1 course.
Results/Discussions:
We started discussing the domains, specifically the affective domain. This discussion highlighted participants' lack of preparation in this area. Although they had studied this topic during their academic course they had never thought about it and never used that to plan their practice.

We spent the time trying to define the domains and the relationship between the use of them and a constructivist perspective of teaching-learning process. At that moment the main preoccupation of participants was the definition of the objectives for Physics 1 course. They agreed that they needed more time to reflect about them.

ACTIVITY No.15
WORKSHOP "SQUARE GAME" (25/9/87)

Objectives:
- To discuss the instructional process;
- To discuss the teacher's and student's roles in this process.

Development:
After being told about the activity, one pair of participants tried to assemble one puzzle while the others observed. The pair had some time to try and then we discussed some points observed by participants during their activity.

The second pair tried to assemble the other puzzle and we discussed other aspects related to teacher's and student's roles in a course.

Due to the interest of participants, two other pairs tried to assemble the first puzzle.

Results/Discussions:
The first pair of participants included Teacher 1, who was supposed to give the instructions, and Student 1, who was supposed to use the instructions to help in assembling the puzzle. Teacher 1 had five minutes to see the puzzle assembled.
Student 1 tried to assemble the puzzle alone and Teacher 1 was quite confused because he was not sure about the instructions he was giving, since he could not remember the positions of the pieces very well.

After some time I interrupted the pair and we discussed some points. First of all, I reminded Teacher 1 of some features of the puzzle which I had stressed and he did not seem to care about. Teacher 1 observed that he tried to use those characteristic but Student 1 dismissed them. Then the lack of concern shown by Student 1, in relation to the instructions given by Teacher 1, was highlighted. Two reasons for this attitude were considered: the vacillation shown by Teacher 1, and the self-sufficiency of Student 1.

Teacher 2 formed another pair with Teacher 1, who, this time, was receiving instructions. In five minutes they assembled a different puzzle, which was observed for about fifteen minutes by Teacher 2.

When asked about his excessive interference in the process, Teacher 2 agreed that he conducted Teacher 1’s steps too much. Teacher 1 also thought that he had almost nothing to do. I stressed the basic structure, given by Teacher 2 to the pieces, when he organized them at the beginning, and its importance for Teacher 1’s understanding of the whole puzzle.

Teacher 2 formed a pair with Student 2, who joined the meeting at that moment, and tried to interfere less in the process. According to Student 2, although Teacher 2 were trying to organize the pieces in his own way, Student 2 was not paying attention to that because he was working with his own mental image of the whole puzzle. This point was discussed by Teacher 2, who came to the conclusion that the best way to work was starting from Student 2’s perspective, trying to understand it and then interfering.

Student 1 formed a pair with Student 2, using the first puzzle. Teacher 2 observed carefully the instructions given by Student 1, because he was convinced that it was impossible to be non-conductive if each person in the pair was dealing with one piece each time. We discussed the different ways of dealing with the piece.

During the pair activity, it became clear to the participants that the students need time to reflect and work alone. The teacher should help when the student
could not progress alone. The teacher should also give an holistic idea instead of paying attention only to small details.

**ACTIVITY No.16**
**GROUP DISCUSSION "INSTRUCTIONAL PROCESS I" (01/10/87)**

**Objectives:**
- To present an example of instruction involving conceptual change (Gunstone, Champagne and Klopfer, 1981);
- To compare this example with participants’ practice;
- To discuss the problem of conceptual change.

**Development:**
The paper was presented, its parts being discussed by the participants who were presenting comparisons with their teaching practice.

**Results/Discussions:**
This paper dealt with the cognitive frameworks of children related to the concepts of force and movement. It presented a series of instructions given to children and their reactions.

One aspect discussed in this paper was the way children perceive an experiment. It was surprising to the participants, who were used to thinking about experiments as a way to demonstrate some physical laws.

Another point was the establishment of relationships between concepts. The use of situations where children could verbalize their ideas was considered very important for the organization of these ideas. This aspect was acknowledged by the participants, who had already tried to work with their students in a similar way.

**ACTIVITY No.17**
**GROUP DISCUSSION "INSTRUCTIONAL PROCESS II" (06/10/87)**

**Objectives:**
- To present another example of instruction involving conceptual change (Champagne, Klopfer and Gunstone, 1982);
- To compare this example with participants’ practice;
- To discuss the problem of conceptual change.

Development:
The paper by Champagne, Klopfer and Gunstone (1982) was presented and discussed. The participants related its content to their previous teaching experience.

Results/Discussions:
During this meeting participants related the paper being presented to papers presented previously. Thus, it was like a summary of our previous discussions.

Teacher 2 suggested that teachers should try to disprove students' ideas, when these are wrong, starting from their points of view and showing them that the situation could not be explained using these ideas. It led to a discussion about the best way to treat alternative conceptions.

During this discussion it was possible for me to perceive that Teacher 2 had adapted some ideas introduced during our meetings to his original view about the teaching-learning process and teacher's roles. Thus, he was trying to find ways to conduct students through a series of small changes devised by him.

Another aspect discussed by participants was the importance of a qualitative analysis to the restructuring of students' ideas. This analysis is usually made by Teacher 2 and Student 1 when they solve problems. Thus, problem solving was seen as an important technique to foster the organization of students' ideas.

ACTIVITY No.18
GROUP DISCUSSION "CHOOSING THE TOPICS" (08/10/87)

Objectives:
- To choose the topics to be prepared for the Physics I course;
- To discuss the strategy to test this material.

Development:
We started the meeting discussing the time availability of the participants to prepare some didactic materials. Then we discussed the conditions we would
have in the next phase of the study. Finally, we concentrated on the topics we wanted to work with.

**Results/Discussions:**
At the time of this meeting Teachers 1 and 2 were very insecure about their situation at Catholic University, which had serious financial problems at the time. They were expecting to receive a research scholarship from the Brazilian Government to reserve more time to our work. This did not happen afterwards.

We decided to test the materials we were going to produce, with secondary school students, because it would be very difficult to find students at the University who were available to do it.

Students 1 and 2 did not prepare any topic due to lack of time. Thus, it was decided that we were going to work with three topics, Teachers 1, 2 and myself being responsible for one topic each.

Teacher 1 was in doubt between two topics: energy and collisions, Teacher 2 decided to work with the topic projectiles and I preferred to prepare the topic work of a force.

We finished the meeting with the compromise to prepare some material to be presented afterwards.

**ACTIVITY No.19**
**GROUP DISCUSSION "INSTRUCTIONAL PROCESS III" (13/10/87)**

**Objectives:**
- To discuss the problems of organizing information;
- To present another examples of instruction using constructivist ideas (Driver and Oldham, 1986; Zylbersztajn, 1985a);
- To compare this example with participants' practice.

**Development:**
I started the meeting discussing some ideas related to the organization of information in memory. Then I presented the models of instruction described in the papers of Driver and Oldham (1986) and Zylbersztajn (1985a).
Results/Discussions:
Teacher 1 stressed the importance of knowledge structure. For him, students have problems when they do not perceive the structure of the knowledge they are working with. This leads to the necessity of storing more information than would be necessary if the students had a structure.

When we were discussing the problem of restructuring students' ideas, Student 2 asked me who would restructure these ideas: the teacher or the students? This was interesting because reflected his view about teacher's roles - with the teacher conducting the students.

Teacher 1 was interested in the use of conflict to change students' ideas. He applied the idea to the change in the curriculum of the Physics I course. In this case the teachers would be motivated to change if they were aware of the failure of the current curriculum.

The model presented in the paper of Zylbersztajn (1985a) was much more discussed than the one presented in the other paper. It is interesting to observe that the use of a paper written in another language prevents participants to feel free to criticize it. Their reaction to the paper written in Portuguese was completely different.

At the end of the meeting I asked each participant to prepare his model of instruction to bring in the next meeting to be discussed by the group.

ACTIVITY No.20
GROUP DISCUSSION "PREPARING THE INSTRUCTIONAL MATERIAL I"
(20/10/87)

Objectives:
- To discuss the ideas concerning the instructional material.

Development:
Teacher 2 started the meeting presenting his ideas, which were discussed by participants. Then I presented the basic structure of what I intended to do, beginning with my own objectives.

Teacher 1 also presented his ideas.
At the end of the meeting Teacher 2 stressed the differences between the way I intended to work and his own.

Results/Discussions:
Teacher 2 intended to use questions to motivate students and start his teaching sequence. He was very worried about having enough time to do that. He also wanted to stress the difference between lack of air resistance and absence of gravity, which he considered to be a very common student misunderstanding. Finally, he wanted to introduce the equation for a trajectory and to work with it.

I stressed the necessity to prepare the teaching material. He wanted to record his ideas, using the taperecorder because it would be easier for him. I suggested the use of written material which he could use afterwards to prepare a paper.

This attitude of Teacher 2 highlighted the difficulty felt by participants in registering their ideas. They do not feel comfortable when they have to write something, preferring to base their practice on what they have in their minds. Maybe this type of attitude reflects the conditions they have in their profession, with no time nor support to sit down and write their new ideas.

I started to ask Teacher 2 some practical questions concerning the initial survey. He changed his mind several times while answering the questions. I also asked about his objectives. After defining them, he did not know what to do afterwards to complete his teaching sequence - whether to think about content or about teaching methodology. He finally decided to think about methodology.

Teacher 1 was worried about my intention to use cards with drawings to investigate students' ideas concerning work of a force. According to him, depending on the drawing it would direct students' attention. Then we decided to use photographs cut from magazines.

Teacher 1 decided to work with questions, instead of pictures, to elicit students' views about conservation of energy. He intended to use the answers to those questions to develop other questions to conflict those views.

We finished the meeting with Teacher 2 stressing the differences between his way to teach and mine.
ACTIVITY No.21
GROUP DISCUSSION "PREPARING THE INSTRUCTIONAL MATERIAL II"
(29/10/87)

Objectives:
- To discuss the use of the Instructional material.

Development:
At the beginning of the meeting Student 2 presented a teaching technique adopted by his teacher in the secondary school. Then I presented the material I had prepared and opened the discussion about its use.

Several techniques of group work were discussed as well as the importance of its use for student learning.

Teacher 2 prepared some material but forgot to bring to the meeting. Thus, he could only talk about it in general terms. Teacher 1 also presented his objectives.

Results/Discussions:
Student 2 started the meeting talking about a group technique which he considered to have some points in common with the ideas I had presented in the last meeting.

I brought the pictures I intended to use to motivate and elicit students' ideas, and opened the discussion about the best way to use them. Thus, the whole group was involved in planning the teaching sequence, with emphasis being given to the theoretical aspects which I wanted to consider. This led to the suggestion of different group techniques and to the discussion of their advantages and disadvantages.

One aspect considered by Teacher 2 was the positive influence among group members. The necessity of space in the classroom was considered as an obstacle to the use of group activities.
6.2 - QUESTIONNAIRE

The questionnaire was developed to detect differences between teacher's and students' views about various aspects of the course, such as teacher's and students' roles, uses of curriculum materials and their performances.

The original questionnaire and its translation are shown in Appendix II. The results obtained with Teacher 1's and Teacher 2's students are presented below. Some questions were also answered by both teachers and these answers are presented together with the students' answers.

The questionnaire was answered by 23 out of Teacher 1's 35 students and 17 out of Teacher 2's 32 students. The comments refer to the sample and not to the whole population.

6.2.1 - RESULTS OF QUESTIONNAIRE - TEACHER 1'S STUDENTS

Q1 Identification data

<table>
<thead>
<tr>
<th>Degree course</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>04</td>
<td>17</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>17</td>
<td>74</td>
</tr>
<tr>
<td>No answer</td>
<td>02</td>
<td>09</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Entrance(y/s)</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>83/1</td>
<td>01</td>
<td>04</td>
</tr>
<tr>
<td>84/1</td>
<td>01</td>
<td>04</td>
</tr>
<tr>
<td>84/2</td>
<td>02</td>
<td>09</td>
</tr>
<tr>
<td>85/1</td>
<td>02</td>
<td>09</td>
</tr>
<tr>
<td>85/2</td>
<td>03</td>
<td>13</td>
</tr>
<tr>
<td>86/1</td>
<td>05</td>
<td>22</td>
</tr>
<tr>
<td>86/2</td>
<td>01</td>
<td>04</td>
</tr>
<tr>
<td>87/1</td>
<td>04</td>
<td>17</td>
</tr>
<tr>
<td>87/2</td>
<td>03</td>
<td>13</td>
</tr>
<tr>
<td>88/1</td>
<td>01</td>
<td>04</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>100</td>
</tr>
</tbody>
</table>
The majority of students are in the Civil Engineering course, which means that they are not particularly interested in the Physics I course. Only 13% of the students entered in 87/2 and were in their second semester at the university, which is when they are supposed to take the Physics I course. The student who entered in 88/1 probably came from another university or has been submitted to another entrance exam. Therefore, 87% of the students are delayed, in relation to the curriculum, either due to failing the Physics I course or a pre-requisite to it.

48% of the students are 23 years old or above. It means that they probably work to maintain themselves and their families, with negative implications for their time availability to follow the course.
<table>
<thead>
<tr>
<th></th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noticeable difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>10</td>
<td>91</td>
</tr>
<tr>
<td>No</td>
<td>01</td>
<td>09</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>100</td>
</tr>
</tbody>
</table>

**Differences from the previous time**

The student participated more and the teacher encouraged him.
More contact with the course.
Lessons better explained and methodology which facilitated learning.
In the last time the teacher was not clear.
Better level and preoccupation with student.
Complete liberty to solve one's doubts.
More detailed explanation of content.
Better teaching method.
Better teacher performance.
More teacher attention to comprehension of content.

48% of students repeated this course and amongst these 91% noticed a positive difference from the previous time.

**Q3 Teacher's most important attitudes and activities**

<table>
<thead>
<tr>
<th>Attitude/Activity</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-To encourage student participation</td>
<td>18</td>
<td>78</td>
</tr>
<tr>
<td>02-To probe students' level of knowledge</td>
<td>12(T)</td>
<td>52</td>
</tr>
<tr>
<td>03-To give texts and lists of exercises</td>
<td>12(T)</td>
<td>52</td>
</tr>
<tr>
<td>04-To develop students' reasoning skills</td>
<td>12</td>
<td>52</td>
</tr>
<tr>
<td>05-To discuss evaluation criteria</td>
<td>10</td>
<td>43</td>
</tr>
<tr>
<td>06-To communicate course objectives</td>
<td>07</td>
<td>30</td>
</tr>
<tr>
<td>07-To relate content to everyday life</td>
<td>07(T)</td>
<td>30</td>
</tr>
<tr>
<td>08-To transmit knowledge</td>
<td>06</td>
<td>26</td>
</tr>
<tr>
<td>09-To clarify students' doubts</td>
<td>06</td>
<td>26</td>
</tr>
<tr>
<td>10-To have interest in students' ideas</td>
<td>05(T)</td>
<td>22</td>
</tr>
<tr>
<td>11-To exchange opinions with students</td>
<td>04(T)</td>
<td>17</td>
</tr>
</tbody>
</table>
12-To communicate evaluation criteria 04 17
13-To be a friend 04 17
14-To be comprehensive 04 17
15-To communicate course planning 04 17
16-To give notions of the History of Physics 04 17
17-To evaluate learning at each step 03 13
18-To ask questions 03 13
19-To guide students on how to study 03 13
20-To keep discipline 02 09

There was an agreement between Teacher 1 and the majority of students in only two aspects—*to probe students' level of knowledge* and *to give texts and lists of exercises*. The other three aspects selected by Teacher 1 were also chosen by 30%, 22% and 17% of the students.

**Q4 Student's most important attitudes and activities**

<table>
<thead>
<tr>
<th>Attitude/Activity</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-To attend lessons</td>
<td>15(T)</td>
<td>65</td>
</tr>
<tr>
<td>02-To solve exercises</td>
<td>15</td>
<td>65</td>
</tr>
<tr>
<td>03-To clarify his doubts with teacher and peers</td>
<td>14</td>
<td>61</td>
</tr>
<tr>
<td>04-To consult books</td>
<td>13</td>
<td>56</td>
</tr>
<tr>
<td>05-To adopt a method of study</td>
<td>12(T)</td>
<td>52</td>
</tr>
<tr>
<td>06-To have interest in content</td>
<td>08(T)</td>
<td>35</td>
</tr>
<tr>
<td>07-To study the theory</td>
<td>06</td>
<td>26</td>
</tr>
<tr>
<td>08-To be a researcher</td>
<td>06</td>
<td>26</td>
</tr>
<tr>
<td>09-To listen with attention</td>
<td>05</td>
<td>22</td>
</tr>
<tr>
<td>10-To relate content to everyday life</td>
<td>04</td>
<td>17</td>
</tr>
<tr>
<td>11-To be a member of a group</td>
<td>04</td>
<td>17</td>
</tr>
<tr>
<td>12-To take notes during classes</td>
<td>03</td>
<td>13</td>
</tr>
<tr>
<td>13-To transform knowledge</td>
<td>02(T)</td>
<td>09</td>
</tr>
<tr>
<td>14-To be curious</td>
<td>02</td>
<td>09</td>
</tr>
<tr>
<td>15-To propose changes in teaching methodology</td>
<td>02</td>
<td>09</td>
</tr>
<tr>
<td>16-To exchange opinions with teacher</td>
<td>01(T)</td>
<td>04</td>
</tr>
<tr>
<td>17-To fulfill his duties</td>
<td>01</td>
<td>04</td>
</tr>
<tr>
<td>18-To be critical</td>
<td>01</td>
<td>04</td>
</tr>
<tr>
<td>19-To be a receptor of information</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Again an agreement in only two aspects - to attend lessons and to adopt a method of study. The other three aspects selected by Teacher 1 were also chosen by 35%, 9% and 4% of the students. The disagreement in relation to students' attitudes is more noticeable than in relation to teacher's attitudes.

Q5 Use of the blackboard

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>YES (No/%)</th>
<th>NO (No/%)</th>
<th>NEUTRAL (No/%)</th>
<th>NA* (No/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depends on teacher's ability</td>
<td>15/65(T)</td>
<td>03/13</td>
<td>04/17</td>
<td>01/04</td>
</tr>
<tr>
<td>Enhances learning fixation</td>
<td>17/74</td>
<td>02/09</td>
<td>03/13(T)</td>
<td>01/04</td>
</tr>
<tr>
<td>Is essential to teaching-learning process</td>
<td>09/39(T)</td>
<td>08/35</td>
<td>05/22</td>
<td>01/04</td>
</tr>
<tr>
<td>Facilitates content presentation</td>
<td>19/83(T)</td>
<td>02/09</td>
<td>01/04</td>
<td>01/04</td>
</tr>
<tr>
<td>Leads to a lecture-type lesson</td>
<td>09/39</td>
<td>06/26(T)</td>
<td>05/22</td>
<td>03/13</td>
</tr>
<tr>
<td>Is useful to learn concepts</td>
<td>09/39(T)</td>
<td>06/26</td>
<td>06/26</td>
<td>02/09</td>
</tr>
<tr>
<td>Is useful to introduce new concepts</td>
<td>05/22(T)</td>
<td>05/22</td>
<td>09/39</td>
<td>04/17</td>
</tr>
<tr>
<td>Develops student's critical sense</td>
<td>06/26</td>
<td>07/30</td>
<td>09/39(T)</td>
<td>01/04</td>
</tr>
<tr>
<td>Generates more student interest</td>
<td>09/39</td>
<td>04/17</td>
<td>09/39(T)</td>
<td>01/04</td>
</tr>
<tr>
<td>Involves student in an active way</td>
<td>09/39</td>
<td>04/17</td>
<td>08/35(T)</td>
<td>02/09</td>
</tr>
</tbody>
</table>

* No answer

The opinion of Teacher 1 coincided with the most common opinion amongst the students in six out of ten options. A major disagreement was in relation to the use of the blackboard to enhance learning fixation - the students believed in it while the teacher was neutral. Students' opinions were quite divided in relation to the other three options.
Q6 Use of written tests

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>YES</th>
<th>NO</th>
<th>NEUTRAL</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are useful to evaluate students</td>
<td>11/48(T)</td>
<td>09/39</td>
<td>02/09</td>
<td>01/04</td>
</tr>
<tr>
<td>Develop student's critical sense</td>
<td>05/22</td>
<td>09/39(T)</td>
<td>08/35</td>
<td>01/04</td>
</tr>
<tr>
<td>Involve student in an active way</td>
<td>10/43</td>
<td>06/26(T)</td>
<td>06/26</td>
<td>01/04</td>
</tr>
<tr>
<td>Are useful to learn concepts</td>
<td>07/30(T)</td>
<td>09/39</td>
<td>06/26</td>
<td>01/04</td>
</tr>
<tr>
<td>Develop student's reasoning skills</td>
<td>09/39</td>
<td>09/39(T)</td>
<td>04/17</td>
<td>01/04</td>
</tr>
<tr>
<td>Are essential to teaching-learning process</td>
<td>09/39(T)</td>
<td>06/26</td>
<td>08/35</td>
<td>-</td>
</tr>
<tr>
<td>Are a teacher's support material</td>
<td>16/70(T)</td>
<td>02/09</td>
<td>04/17</td>
<td>01/04</td>
</tr>
<tr>
<td>Test learning</td>
<td>05/22(T)</td>
<td>09/39</td>
<td>06/26</td>
<td>03/13</td>
</tr>
<tr>
<td>Develop students' creativity</td>
<td>05/22</td>
<td>08/35(T)</td>
<td>07/30</td>
<td>03/13</td>
</tr>
<tr>
<td>Enhance learning fixation</td>
<td>07/30</td>
<td>06/26</td>
<td>07/30(T)</td>
<td>03/13</td>
</tr>
</tbody>
</table>

The teacher and the largest group of students agreed in seven out of ten options. The disagreements concerned the way written tests involve students - active or not, usefulness to learn concepts, and if they test learning or not. In general the opinions were quite divided among the three possibilities, although it was possible to perceive an overall negative attitude toward this instrument.

It is interesting to highlight an apparent incoherence when the majority of students considered the written tests useful to evaluate students, essential to teaching-learning process, and, at the same time, that they do not test learning. It seems to reflect an idea that evaluation is not a process to give feedback to students and teacher about learning, but a kind of formality, which is an intrinsic aspect of all courses.

Q7 Student's performance

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>YES</th>
<th>NO</th>
<th>NEUTRAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have learned the content</td>
<td>09/03</td>
<td>-</td>
<td>14/61</td>
</tr>
<tr>
<td>Could solve the exercises</td>
<td>13/57</td>
<td>01/04</td>
<td>09/39</td>
</tr>
<tr>
<td>Had difficulty in following lessons</td>
<td>06/26</td>
<td>13/57</td>
<td>04/17</td>
</tr>
<tr>
<td>Have studied enough</td>
<td>07/30</td>
<td>10/43</td>
<td>06/26</td>
</tr>
<tr>
<td>Have developed your reasoning skills</td>
<td>13/57</td>
<td>01/04</td>
<td>09/39</td>
</tr>
</tbody>
</table>
Have wasted your time in following this course - 22/96 01/04
Have widened your horizons 16/70 01/04 06/26

Although the majority of students agreed that they had no difficulty in following the lessons, could solve exercises and have developed their reasoning, they also stated that they had not studied enough and were neutral concerning learning the content. This gives support to the idea that students need time to reflect about the content in order to learn it.

Q8 Teacher's performance

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>11</td>
<td>48</td>
</tr>
<tr>
<td>Good</td>
<td>10</td>
<td>43</td>
</tr>
<tr>
<td>Average</td>
<td>02</td>
<td>09(T)</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>100</td>
</tr>
</tbody>
</table>

Students' opinions were divided between excellent (48%), and good (43%), while Teacher 1, himself, considered his performance as regular. The disagreement may be a result of different objectives. While Teacher 1 concentrated on the content, expecting that the students had interest and transformed it, the students appeared to concentrate on solving exercises, attending lessons and developing reasoning without regarding the content.

Q9 Suggestions to improve the course

- To solve more exercises (6 students)
- To change the laboratory (2 students)
- To encourage students to read other books (2 students)
- Use of demonstrations to encourage student participation
- To relate theory and practice
- No control of attendance
- Distribution of lists of exercises and resolution included in the student evaluation
- More group work
- To improve the laboratory using more sophisticated materials
- The teacher should raise the curiosity and interest of the student
- Better teaching materials
- More efficient teachers and change in the laboratory
- To encourage the student showing the relationship between content and everyday life
- More teacher enthusiasm, especially in the laboratory
- To give individual or group research projects
- More student participation during the lessons
- To detect student level of knowledge and use lists of exercises to improve it

Two students did not suggest anything.

The most common suggestion may reflect students' objectivity concerning evaluation.

6.2.2 - RESULTS OF QUESTIONNAIRE - TEACHER 2'S STUDENTS

Q1 Identification data

<table>
<thead>
<tr>
<th>Degree course</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>14</td>
<td>82</td>
</tr>
<tr>
<td>Chemistry Engineering</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Entrance(y/s)</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>83/1</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>84/2</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>85/1</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>85/2</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>86/1</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>87/1</td>
<td>09</td>
<td>53</td>
</tr>
<tr>
<td>No answer</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17</strong></td>
<td><strong>100</strong></td>
</tr>
<tr>
<td>Age</td>
<td>No. of respondents</td>
<td>%</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------</td>
<td>----</td>
</tr>
<tr>
<td>18</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>19</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>03</td>
<td>18</td>
</tr>
<tr>
<td>21</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>22</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>23</td>
<td>04</td>
<td>23</td>
</tr>
<tr>
<td>25</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>33</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sex</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>12</td>
<td>71</td>
</tr>
<tr>
<td>F</td>
<td>05</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100</td>
</tr>
</tbody>
</table>

As had happened in Teacher 1's group, the majority of students are in the Civil Engineering course, which means that they are not particularly interested in the Physics 1 course. All students are delayed in relation to the curriculum, since they entered before 87/2. 41% of the students are 23 years old or above.

Q2 Information about course attendance

<table>
<thead>
<tr>
<th>Number of repeated attendances</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>09</td>
<td>53</td>
</tr>
<tr>
<td>One</td>
<td>03</td>
<td>18</td>
</tr>
<tr>
<td>Two</td>
<td>03</td>
<td>18</td>
</tr>
<tr>
<td>Three</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>Four</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Noticeable difference</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>07</td>
<td>88</td>
</tr>
<tr>
<td>No</td>
<td>01</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>08</td>
<td>100</td>
</tr>
</tbody>
</table>

Differences from previous time
- The content was more explained (2 students)
- The teacher was interested in the student learning the content
Better teaching method
The previous teacher was too fast in his presentation
The theory was included and the content was more detailed
The content presentation was slower
Teacher performance

47% of the students repeated this course and amongst these 88% perceived a positive difference in relation to the previous time.

Q3 Teacher's most important attitudes and activities

<table>
<thead>
<tr>
<th>Attitude/Activity</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-To probe students' level of knowledge</td>
<td>11(T)</td>
<td>65</td>
</tr>
<tr>
<td>02-To encourage student participation</td>
<td>10(T)</td>
<td>59</td>
</tr>
<tr>
<td>03-To clarify students' doubts</td>
<td>09(T)</td>
<td>53</td>
</tr>
<tr>
<td>04-To give texts and lists of exercises</td>
<td>08</td>
<td>47</td>
</tr>
<tr>
<td>05-To transmit knowledge</td>
<td>08</td>
<td>47</td>
</tr>
<tr>
<td>06-To relate content to everyday life</td>
<td>06(T)</td>
<td>35</td>
</tr>
<tr>
<td>07-To be a friend</td>
<td>05</td>
<td>29</td>
</tr>
<tr>
<td>08-To develop students' reasoning skills</td>
<td>05</td>
<td>29</td>
</tr>
<tr>
<td>09-To guide students on how to study</td>
<td>05</td>
<td>29</td>
</tr>
<tr>
<td>10-To communicate course objectives</td>
<td>03</td>
<td>18</td>
</tr>
<tr>
<td>11-To discuss evaluation criteria</td>
<td>03</td>
<td>18</td>
</tr>
<tr>
<td>12-To have interest in students' Ideas</td>
<td>03</td>
<td>18</td>
</tr>
<tr>
<td>13-To communicate evaluation criteria</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>14-To exchange opinions with students</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>15-To communicate course planning</td>
<td>01(T)</td>
<td>06</td>
</tr>
<tr>
<td>16-To evaluate learning at each step</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>17-To keep discipline</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>18-To give notions of the History of Physics</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>19-To ask questions</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>20-To be comprehensive</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

There was an agreement between Teacher 2 and the majority of students in three aspects – to probe students' level of knowledge, to clarify students' doubts and to encourage student participation. The other two aspects selected by Teacher 2 were also chosen by 35% and 6% of the students.
Q4 Student's most important attitudes and activities

<table>
<thead>
<tr>
<th>Attitude/Activity</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-To clarify his doubts with teacher and peers</td>
<td>13(T)</td>
<td>76</td>
</tr>
<tr>
<td>02-To adopt a method of study</td>
<td>12</td>
<td>70</td>
</tr>
<tr>
<td>03-To solve exercises</td>
<td>10</td>
<td>59</td>
</tr>
<tr>
<td>04-To attend classes</td>
<td>09</td>
<td>53</td>
</tr>
<tr>
<td>05-To have interest in content</td>
<td>07(T)</td>
<td>41</td>
</tr>
<tr>
<td>06-To consult books</td>
<td>05</td>
<td>29</td>
</tr>
<tr>
<td>07-To study the theory</td>
<td>04(T)</td>
<td>24</td>
</tr>
<tr>
<td>08-To take notes during classes</td>
<td>03</td>
<td>18</td>
</tr>
<tr>
<td>09-To be critical</td>
<td>03</td>
<td>18</td>
</tr>
<tr>
<td>10-To exchange opinions with teacher</td>
<td>03</td>
<td>18</td>
</tr>
<tr>
<td>11-To listen with attention</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>12-To be curious</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>13-To be a researcher</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>14-To fulfill his duties</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>15-To know teacher's evaluation method</td>
<td>02</td>
<td>12</td>
</tr>
<tr>
<td>16-To relate content to everyday life</td>
<td>01(T)</td>
<td>06</td>
</tr>
<tr>
<td>17-To transform knowledge</td>
<td>01(T)</td>
<td>06</td>
</tr>
<tr>
<td>18-To propose changes in teaching methodology</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>19-To be a member of a group</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>20-To be a receptor of information</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

In the first five most preferred aspects, there was an agreement between Teacher 2 and the students in only two - to clarify his doubts with teacher and peers and to have interest in content. The other three aspects selected by Teacher 2 were also chosen by 24%, 1% and 1% of the students. As happened with Teacher 1, there was more disagreement in relation to students' attitudes than in relation to teacher's attitudes.

Q5 Use of the blackboard

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>YES</th>
<th>NO</th>
<th>NEUTRAL</th>
<th>NA*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(No/%)</td>
<td>(No/%)</td>
<td>(No/%)</td>
<td>(No/%)</td>
</tr>
<tr>
<td>Depends on teacher's ability</td>
<td>12/70(T)</td>
<td>01/06</td>
<td>04/24</td>
<td>-</td>
</tr>
<tr>
<td>Enhances learning fixation</td>
<td>13/76(T)</td>
<td>-</td>
<td>04/24</td>
<td>-</td>
</tr>
<tr>
<td>Is essential to teaching-learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The opinion of Teacher 2 coincided with the opinion of the majority of the students in four out of ten options. The major disagreement was relative to the development of critical sense - Teacher 2 believed in it while the students did not.

Q6 Use of written tests

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>YES (No/%)</th>
<th>NO (No/%)</th>
<th>NEUTRAL (No/%)</th>
<th>NA (No/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are useful to evaluate students</td>
<td>10/59</td>
<td>06/35</td>
<td>01/06(T)</td>
<td>-</td>
</tr>
<tr>
<td>Develop student's critical sense</td>
<td>05/29</td>
<td>10/59</td>
<td>02/12(T)</td>
<td>-</td>
</tr>
<tr>
<td>Involve student in an active way</td>
<td>07/41(T)</td>
<td>06/35</td>
<td>03/18</td>
<td>01/06</td>
</tr>
<tr>
<td>Are useful to learn concepts</td>
<td>06/35</td>
<td>09/53</td>
<td>02/12(T)</td>
<td>-</td>
</tr>
<tr>
<td>Develop student's reasoning skills</td>
<td>11/65</td>
<td>03/18</td>
<td>03/18(T)</td>
<td>-</td>
</tr>
<tr>
<td>Are essential to teaching-learning process</td>
<td>08/47</td>
<td>06/35</td>
<td>02/12(T)</td>
<td>01/06</td>
</tr>
<tr>
<td>Are a teacher's support material</td>
<td>13/76(T)</td>
<td>02/12</td>
<td>02/12</td>
<td>-</td>
</tr>
<tr>
<td>Test learning</td>
<td>06/35</td>
<td>06/35</td>
<td>03/18(T)</td>
<td>02/12</td>
</tr>
<tr>
<td>Develop students' creativity</td>
<td>05/29</td>
<td>07/41</td>
<td>03/18(T)</td>
<td>02/12</td>
</tr>
<tr>
<td>Enhance learning fixation</td>
<td>06/35</td>
<td>06/35</td>
<td>03/18(T)</td>
<td>02/12</td>
</tr>
</tbody>
</table>

The teacher and the major number of students agreed in only two out of ten options. A relevant agreement concerned students being involved in an active way by written tests, although the opinions about this aspect were quite divided. In general, Teacher 2's opinions coincided with the opinions of the minority of students.
Q7 Student's performance

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>YES (No/%)</th>
<th>NO (No/%)</th>
<th>NEUTRAL (No/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have learned the content</td>
<td>01/06</td>
<td>01/06</td>
<td>15/88</td>
</tr>
<tr>
<td>Could solve the exercises</td>
<td>03/18</td>
<td>01/06</td>
<td>13/76</td>
</tr>
<tr>
<td>Had difficulty in following lessons</td>
<td>04/24</td>
<td>07/41</td>
<td>06/35</td>
</tr>
<tr>
<td>Have studied enough</td>
<td>02/12</td>
<td>09/53</td>
<td>06/35</td>
</tr>
<tr>
<td>Have developed your reasoning skills</td>
<td>03/18</td>
<td>-</td>
<td>13/76</td>
</tr>
<tr>
<td>Have wasted your time in following this course</td>
<td>-</td>
<td>17/100</td>
<td>-</td>
</tr>
<tr>
<td>Have widened your horizons</td>
<td>09/53</td>
<td>01/06</td>
<td>07/41</td>
</tr>
</tbody>
</table>

It is interesting to observe that although the majority of students was neutral in three out of seven options (the ones concerning content learning, exercise solving and development of reasoning skills) and the opinions were quite divided in other three options, all students agreed that they did not waste their time in following this course. Thus, what do they want when they follow a course?

Q8 Teacher's performance

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>01</td>
<td>06</td>
</tr>
<tr>
<td>Good</td>
<td>11</td>
<td>65</td>
</tr>
<tr>
<td>Average</td>
<td>05</td>
<td>29(T)</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100</td>
</tr>
</tbody>
</table>

The majority of students found that Teacher 2's performance was good (65%), while Teacher 2 and the rest of the students (29%) considered his performance as regular. The different opinions may be related to the objectives of Teacher 2 and students. While students concentrated on transmission of knowledge and problem solving, Teacher 2 wanted a closer relationship with everyday life phenomena and more student autonomy.
Q9 Suggestions to improve the course

- To eliminate some disciplines from the Physics degree course curriculum (3 students)
- More time for this course
- More applications in everyday life
- To deepen the treatment of the content
- More teacher interest
- To use literal and demonstrative questions in the tests
- To motivate students, be more practical, and give more emphasis to the topics related to the Physics degree course
- Not to stop for small details, but, at the same time, to keep the quality of teaching, and not the quantity
- More incentive to students through support and comprehension of their difficulties
- To probe and follow student development closer
- To give lists of exercises
- To solve problems in detail, together with students
- More objective books
- Smaller classes
- Broader variety of exercises
- More research, with student participation

Two students did not suggest anything

6.3 - INTERVIEWS WITH STUDENTS

At the beginning of the interviews I explained to the students that my intention was to identify their views about several concepts studied during Physics I course. To do that I presented either one or in some cases two situations, described orally to the student, and asked him or her about the development of the situation, in time, and about the presence or not of some concepts.

During the interview the students were encouraged to use drawings to represent what was happening.

The following situations were used to explore their conceptions:
1- A stone thrown upwards, which falls onto a spring;
2- A ball thrown obliquely.

Using these situations I explored the following concepts and the relationships between them: reference system, velocity, acceleration, force, weight, work of a force and conservation of energy.

Three students from Teacher 1's group and two students from Teacher 2's group were interviewed. The alternative ideas presented by the students are listed below.

1- REFERENCE SYSTEM
- The origin of the reference system must be located at the origin of the movement;
- The reference is taken in relation to a plane or an object;
- The orientation of the reference axis may vary during the problem;
- Direction and orientation are mixed up;
- The sign of the quantities is mixed up with the orientation;
- The trajectory is mixed up with the displacement and axis direction;
- Trajectory, distance and displacement are concepts poorly discriminated;
- A stone thrown upwards does not return in the same direction due to air resistance. Its trajectory is a parabola;
- The origin of the reference system should be at the initial instant;
- The origin of the axis is at the intersection point with another axis. Thus, it is always necessary to have two axes.

2- VELOCITY
- The sign of the velocity is linked to the sign of the acceleration;
- The uniform and varied movements are not discriminated;
- Time interval and instant are mixed up (the body stops for some time at the maximum height)
- The movement is not precisely defined (the final velocity is reached after the body hits the ground);
- The velocity is not related to its components;
- The velocity is mixed up with its components;
- There is a relation between the direction of the velocity and the trajectory only for circular movement;
The sign of the velocity changes when the body comes down and passes through the origin of the axis;
Variations in position are mixed up with variation in velocity;
The direction of the velocity is the same as the direction of the trajectory;
In an oblique movement the body stops at the maximum height.

3- ACCELERATION
A body with zero velocity will not move at any time, irrespective of the body's acceleration;
Acceleration, velocity and force are poorly discriminated;
Variation of velocity causes acceleration;
Velocity equal to zero means acceleration equal to zero;
The sign of the acceleration is linked to the sign of the velocity.

4- FORCE
The resultant force is the vector sum of the velocity and the gravitational acceleration;
The resultant force is the vector sum of the velocity and the weight;
Force is linked to velocity and not to acceleration;
The force causes variation in velocity, which causes acceleration;
The only force against movement is friction;
The force which throws the body upwards, is consumed as the body moves;
The velocity must be greater than gravity, otherwise the body will not move upwards;
Newton's first and second laws are mixed up;
The Earth attracts the body and the body attracts the Earth, but the force exerted by the Earth is much stronger than the force exerted by the body (misunderstanding Newton's third law).

5- WEIGHT
The weight has no relation to gravitational attraction;
The weight is linked directly to the variation in velocity;
There is no gravity and no weight when there is vacuum.

6- WORK OF A FORCE
Work is always weight times height;
Work is always positive;
Work is force times displacement;
Since the differences between the statements made by the students before and after learning, within each category, were negligible, and also considering the small number of students who were interviewed, I decided to just list the alternative ideas presented in all interviews as an orientation for physics teachers. More interviews would be necessary in order to try to discover possible links between teachers' practice and the change of students' ideas, which was not an aspect emphasized in this study.
- The angle in work's formula is in relation to the horizontal direction;
- The angle in work's formula is between the velocity and the horizontal direction;
- The angle in work's formula is between the force and the trajectory;
- If there is displacement there is work;
- The work done by a constant force is independent of the trajectory and the direction of movement. It depends only on the distance between the two points.

7- CONSERVATION OF ENERGY
- It is possible to calculate the kinetic energy using only one component of the velocity;
- The kinetic energy is always maximum;
- The transformation of kinetic energy into potential energy is not clear;
- The nature of mechanical energy, as a whole, is not clear;
- There is no conservation of energy;
- There is no relation between the velocity and the conservation of energy;
- It is not clear how to define the height to calculate the potential energy.

The ideas presented above were presented by the students during the interviews at the beginning and at the end of their courses. It is interesting to notice that the majority of their alternative ideas did not change due to the teaching. The ideas discussed during the course were not integrated to the existing ones, but kept apart, poorly organized, as can be noticed in the following situation.

* In the case of the ball thrown obliquely, supposing that there was no force in the horizontal direction, I asked the student about the horizontal velocity and he said that it was equal to zero.

S: In this case, the body could be at rest or with a straight line movement, and it would keep this movement if there were no force to change the movement.

R: Have you thought about what you have said? If there is no force applied on the body...

S: The body will stay in inertia.
R: If you link this to the horizontal velocity...

S: The velocity should be constant.

Thus, if I help him organizing the ideas he may come to the right conclusion, but does not integrate them with his own previous ideas.

6.4 - SUMMARY

The results obtained during the workshops, group discussions and the alternative ideas presented by a group of students in relation to some concepts discussed during the Physics 1 course, were presented in this chapter.

It is important to emphasize that the activities performed by the participants during this development process, had three objectives:

1- To give them an opportunity to reflect upon their ideas about teaching and learning and their teaching practice, in order to improve them;

2- To participate in a process organized according to constructivist ideas, in order to reflect upon the possibilities and limitations derived from the adoption of such a perspective of learning;

3- To have contact with different research techniques in order to develop their knowledge about these techniques and possibly using them to do research.

Since the objective of these meetings was not to exhaust the discussion about the topics, but to provide some information and to arouse the interest of the participants for these topics, I consider that they have attained the objective.

During this phase, student teachers participation brought an intermediate point of view to discussion, besides giving them an opportunity to observe classroom teaching from backstage.

The implications of these results to the case studies will be considered in Chapters 7 and 8.
7.0 - INTRODUCTION

In this chapter I shall present the case study report about Teacher 1. I shall describe Teacher 1's interactions with the different phases of the development process, and analyse the changes in his ideas and teaching practice.

I shall start by presenting Teacher 1, his previous experiences in science teaching, and his personal approach to teaching and learning. Then I shall follow his learning experiences during the process and the consequences on his ideas and practice. I shall also compare the perspective of his students with his own, in relation to the course he gave at the second phase of the development process.

At the end of the chapter I shall summarize the main findings obtained in this case study.

7.1 - PERSONAL CHARACTERISTICS

Teacher 1 graduated at UNICAP and started to teach there before my arrival in 1980. He spent some years teaching at a private primary school, and still teaches at private and public secondary schools. He was one of the teachers in our Department interested in starting a research group to study the problems related to science teaching. Therefore, it was not surprising when, after participating in the workshop in which I presented the plans for my work, he volunteered to be a participant in the development process.

During this first workshop, described in Chapters 4 and 6, when I asked the participants what they found most difficult in receiving and in giving information, Teacher 1 made the following comment:

*During explanation the major difficulty was the impossibility of dialogue... and lack of visual aid to show it, as well as oral*
language. When receiving information, the language itself and dialogue too.

(Teacher 1, Activity no.1)

Teacher 1's first thought was directed to the dialogue, which is the basis of his teaching style. He also stressed lack of visual aids, although he almost never uses them during his lessons. It is interesting to notice that he was sensitive to the importance of both an aspect which he uses frequently, and also to another, which he does not.

The emphasis on the dialogue is a personal characteristic of Teacher 1. Although he is very communicative with people, he is very timid and usually tries to identify himself with a group as a way of having support. These characteristics, which I had observed during our long experience of working together, were disclosed by himself during the second workshop, described in Chapters 4 and 6, when the participants in this study were introduced to each other:

Since 1971 I have contact with capoeira ... a sport and a culture, basically national, basically Brazilian, and I started to identify myself a lot with it. First, because I always had a very timid temperament. In the period of my adolescence, in the classroom, I was scared of writing on the blackboard ... capoeira helped me to overcome these things.

(Teacher 1, Activity no.2, my emphasis)

Another important aspect of Teacher 1's personality is his informal behaviour. This characteristic, which he also acknowledged during this workshop, is clearly observable in every situation he is involved with, including his lessons.

He also tends to be more general or imprecise when he faces a situation where he does not feel secure. It can be exemplified by his comments about me, during Workshop 2:

What I have to say is, more or less... what you have said confirms what we think about you. ... It is a question of confirming what you have stated and that we have been observing for some time.

(Teacher 1, Activity no.2, my emphasis)
Despite being used to work with me for a long time, he was a bit embarrassed about making comments about me. In this situation, he started to speak in first person plural, and to make very general comments, without reporting specific details to support them.

He also employed this general way of speaking when he made his comments about Teacher 2, in the same workshop:

I have never had the impression that you were timid and that the cigarette was... never... not for me. I have never noticed, never perceived this... Teacher 2 appears to me as a person, a person very... interested in things, committed to his profession, a person who takes his profession, due to what I know from other places, I think that... the cigarette, this small quantity, a pack of cigarettes, I think that he is a person very conscious about his profession, very... interested in his profession, he takes it seriously...

(Teacher 1, Activity no.2)

Teacher 1 seemed to be defending Teacher 2 from the "attack" of Student 1, who talked previously against cigarettes and associated them to nervous persons. In his attempt, he emitted a very subjective opinion, which apparently had nothing to do with the aspect highlighted by Student 1. Since he did not complete his statement about cigarettes, it was not possible to conclude whether he linked them to an uncommitted professional, or he was just stressing Teacher 2's good aspects.

These personal characteristics may be relevant in a situation where Teacher 1 would have to face a challenge, for example, implementing a new teaching method. Since he generally relies on the group for support, to work with an aggressive group of students or just a group that would want something different from what he intended to give, would constitute a critical situation, which would lead to more problems for him.

7.2 - PERSONAL THEORIES OF TEACHING AND LEARNING

After deciding who would participate in this work, I started to elicit participants' views about several aspects related to teaching and learning,
using a series of repertory grids. These grids were completed twice: at the beginning and at the end of the process.

Teacher 1 had never completed a repertory grid before, and found it very difficult to do, especially to define the constructs. Therefore, we had to use two sessions, of one and a half hours each, to complete the first grid. The other grids were completed in less time.

Despite the initial difficulty, Teacher 1 considered the completion of grids as an activity which helped him to clarify his ideas, as stated by himself in his evaluation cassette:

The first activity was the repertory grid. The activity was very different, I didn’t know the technique, and I experienced a great difficulty in the identification, especially of the constructs. The positive aspect I’ve found in this type of activity was the reflection I could make about some concepts which were not very developed in my mind. Then I had the opportunity to reflect more about them.

(Teacher 1, Evaluation Cassette)

I started the elicitation process explaining the procedure and asking Teacher 1 to think about the elements which were important for the teaching-learning process and which were related to the production of knowledge. I stressed that in this process I was not looking for right or wrong answers, but for his own conception about the teaching-learning process and its relation with the nature of knowledge.

For Teacher 1 the fundamental element in this process was the dialogue, followed by the interest of the teacher and the student. He also thought about the work conditions, especially time to prepare the lessons. The textbook was seen as a strong support for the process, but not the strongest. It can be included in the extra-class orientation, together with lists of exercises, texts, etc.

Other fundamental aspects were the knowledge, by the teacher, of students' conceptions, and the historical context of the content. The material conditions of the classroom (a good blackboard, adequate acoustics, illumination, etc) also influenced the process.
The student was seen as participating in the process through the dialogue and his interest. He would be supported by the extra-class orientation, and his conceptions were important for the teacher.

For Teacher 1, the teaching methodology derived from the dialogue. Thus, although the dialogue was not "the" teaching method, it was considered a more general aspect which included the methodology.

*I think that a lesson only develops through a questioning, a problematization of the content. This problematization is a kind of methodology which I consider very important.*

(Teacher 1, TLP1)

He also did not believe in transmitting knowledge.

*I am convinced that the teacher in the classroom, talking and writing on the blackboard, it does not lead to effective learning of the content.*

(Teacher 1, TLP1)

After eliciting the elements (shown in Chapter 5), I used the triadic method to elicit the constructs. The elements were combined randomly, and after the construct was elicited, the other elements were rated in a five-point scale.

Teacher 1 found it difficult to determine the constructs. His tendency was to think about the elements in a cause and effect relationship, instead of in terms of contrasting poles.

Considering the construct and element trees, and the comments given during the completion of the grid, it is possible to come to some conclusions in relation to Teacher 1's perspective of the teaching-learning process.

The construct tree contains three main clusters. In the cluster with most constructs, the ideas involving creativity and production of knowledge are closely related. This cluster also includes ideas involving the participation of students, learning and dependency on the teacher. The grouping of these constructs reflects a vision where the source of intellectual production, and the aspects related to it, depend on the teacher.
The ideas related to organization are grouped in another cluster, which is linked to the cluster formed by the ideas related to dependency on the student and development of critical sense. Thus, while the development of critical sense depends on the student, the part related to information, intellectual production and control of learning, is led by the teacher.

The majority of constructs are in the teaching methods category. These constructs are linked to others, which are in the affective factors and curriculum categories.

The element tree has four clusters. The one with the elements most closely related, contains dialogue linked to teaching method. It reflects the necessity, seen by Teacher 1, to base his teaching on dialogue. These two elements are linked to historical context of content, which is another component considered fundamental by Teacher 1, and to teacher's interest.

This cluster is linked to another, which contains knowledge of students' conceptions and planning of content. This may reflect the necessity to consider students' ideas when the teacher is selecting the content:

In my conception he [the teacher] has to know what the man is thinking to be able to teach him that content.

(Teacher 1, TLP1)

The third cluster is composed by time to prepare lessons and by student's time to study, linked to the elements student's interest and extra-class orientation. Thus, the student's interest is seen as connected to his possibility of studying and of having access to information outside the classroom.

Quite isolated from the other elements is the cluster composed by compatible salary and classroom infrastructure.

The three main clusters are organized around the teacher, the content and the student.

In summary, there are two aspects in Teacher 1's view of the teaching-learning process which could be highlighted. First, that lack of definition leads to reflection and active participation of students in the process. This
Idea may be detected through his comments concerning the use of dialogue and the historical context of content. In relation to dialogue, he perceived it as the source of knowledge, in opposition to transmission. The textbook, for example, was seen as a transmitter of knowledge because it "is more finished,...is more structured...is more mechanical". On the other hand, "in the historical context you have one thousand variables... you may analyse...". In this situation, it is difficult to establish a dominant view. Therefore, he came to the conclusion that what was necessary was "knowledge in a less elaborated way, in which he [the student] will reflect". Then, the use of the historical context together with the dialogue was perceived as a way to teach (elements 1, 11 and 9 in the element tree) which is completely open to reconstruction (rates 1, 1 and 2, in figure 5-1, respectively), and lead the student to reflect about the content.

The other aspect was the relationship teacher-student. Although Teacher 1 considered that "the knowledge of students' conceptions and the teaching method tend to respect the individuality of the student", when he rated the elements, he considered that the teaching method and the planning of content did not depend on the student. Furthermore, he considered that teacher's interest was more influential on learning (rate 1) than the teaching method (rate 2) or the planning of content (rate 3). On the other hand, this interest was almost totally independent of the student (rate 4). This seem to indicate that the teacher-student relationship was not very clear to Teacher 1.

A better picture of Teacher 1's ideas concerning teaching and learning can be formed with the aid of the results obtained from the other three repertory grids.

After completing a grid which focussed on the teaching-learning process as a whole, I asked Teacher 1 to complete three other grids focussing on more specific aspects of this process. These grids were about curriculum materials, teacher's roles and student's roles in a specific course.

**FIRST REPERTORY GRID ABOUT CURRICULUM MATERIALS (CM1)**

I started the elicitation of the elements, asking Teacher 1 to think about the materials he uses during the teaching-learning process, as well as about the ones he would like to use. Therefore, this grid had a more "theoretical" approach because it focussed on his previous experiences regarding the uses of
curriculum materials, but it also concentrated on his perspective about an ideal use of these materials.

The elements, constructs, and the trees relating them are shown in Appendix I. The clusters in these trees are shown in Chapter 5.

The construct tree has three clusters. In one, the ideas of avoidance of evaluation, no relation with skills and content presentation are linked. The close relationship between these ideas may reflect the perspective adopted by Teacher 1 in relation to evaluation, as something negative that happens at the end of the process. It is illustrated by the way he denied the use of the probe test as an instrument of evaluation, despite considering it to check the situation of the student.

This negative approach to evaluation may be related to the type of evaluation carried out at UNICAP. It is restricted to assessment of students, who are submitted to two tests during the whole course. If the students obtain a grade equal to or above five, they are approved. Otherwise, they have to do a final test. These tests last one and a half hour, and teachers, as well as students, agree that they are not enough to evaluate the students' work.

Another important aspect in this cluster is the relation between lesson preparation, no relation with skills and content presentation. For Teacher 1, the development of skills was linked to active participation:

*The written test and the laboratory develop intellectual and manual skills. The student is answering a test, he is writing, thinking, he is developing a text. Laboratory is the same thing. You are there manipulating the equipment, preparing a report, while with a transparency you are looking at, you are visualizing... it does not develop a skill.*

(Teacher 1, CM1)

For Teacher 1, when students followed the presentation of content, they were not actively involved in the lesson. They had to do some activity, or to talk to the teacher to participate in the teaching-learning process.

In the second cluster the ideas concerning students' initial conditions and methodology were put together. They were then linked to the ideas of
concrete/abstract, which Teacher 1 had some difficulty to define. For him the intellectual aspects were abstract, while the approachable aspects of reality were concrete. Therefore, the laboratory was seen as concrete because the student could manipulate the equipment, while the report of activities was considered abstract because it was prepared in student's mind.

This second cluster was linked to the first and then to the idea of concept learning/concept demonstration. Thus, concept demonstration was linked to evaluation, while concept learning was something abstract which was linked to the content.

The third cluster linked the idea of essential to the process to teacher's support material, and the idea of complementary to the process to student's support material.

It is interesting to notice that the majority of elements were considered as materials to support only the teacher, including the tests. These were not considered as feedback for the students, but as source of information for the teacher, who could use this information to change his behaviour.

In the element tree, the traditional instruments of evaluation were not directly related to what happens during the whole process. It may be a reflection of Teacher 1's perspective about the written test as an instrument to evaluate both student's and teacher's work, in order to give information to the teacher.

FIRST REPERTORY GRID ABOUT TEACHER'S ROLES (TR1)

This time I asked Teacher 1 to think about the roles he could assume in the Physics 1 course. He found it difficult to do because he had never thought about these roles before.

The matrix relating elements and constructs, as well as the element and construct trees, are shown in Appendix I. The clusters which appear in these trees are shown in Chapter 5.

The elements concentrated on the teacher controlling the development of the student in terms of content and as a person.
The elements encouragement giver and connection between Physics and Basic Departments were probably chosen due to the specific characteristics of Physics 1 course. This is the first discipline with a physics content in the Physics undergraduate course, and is considered as fundamental for the other disciplines in this course. It is also the reason why several students, who failed, changed to other undergraduate courses. In addition, students entering the university are not directly linked to their respective departments, but to the Basic Department, which deals with all students in the University. This type of organization, intended to give a broad formation to students before their specific formation, leads to students feeling lost in the University, with no connection with their future department.

The dialogue was seen as the central element in the teaching-learning process, which was used to detect students' ideas in order to change them. During this process the teacher controls the content and gives support to the students.

Teacher I was strongly influenced by the idea that if he used the blackboard, he was transmitting knowledge, which was boring and did not lead to learning.

**FIRST REPERTORY GRID ABOUT STUDENT'S ROLES (SR1)**

In this grid, I asked Teacher 1 to think about the roles of the student during the Physics 1 course. The objective of this reflection was to identify how each role influences the teaching-learning process. It was my idea, at this stage, to use this identification of teacher's and student's roles to negotiate these roles with the students at the beginning of the course. Afterwards, the participants in this study decided not to negotiate roles because the teachers were not prepared to do this and we thought that the students were not prepared either.

The element and construct trees are shown in Appendix I. The clusters in these trees are shown in Chapter 5.

In the construct tree, the ideas of 'expression of thoughts' and 'development in group' are closely related and quite isolated from the other cluster, which includes the analysis of alternative conceptions. This may suggest that group activity is seen more as a way to develop a student's capacity to discuss, rather than to reflect on his ideas.
The element tree has a large cluster with elements related to the roles assumed by the student during his relationship with other persons in the course. In another cluster, the element related to production of knowledge is linked to the one related to study habits. This may suggest a perspective where the production of knowledge is made by the student alone, outside the classroom, when he studies.

In relation to the discipline, for Teacher 1 it derived from the consideration which students should show to the teacher and his classmates.

During the interview to complete this grid, I tried to help Teacher 1 to give more specific constructs, instead of general ones. Therefore, after choosing the elements, I asked him to think about specific aspects of the teaching-learning process, for example types of learning, ways of processing information, etc, in relation to those elements. Despite my attempt, the constructs were still quite general and it seems to reflect lack of previous thought about the roles assumed by students in the teaching-learning process.

**AN OVERVIEW**

From the results of these four repertory grids, it is possible to construct a picture of Teacher 1's conception of teaching and learning. For him, teaching and learning occurred through the dialogue conducted by the teacher. This dialogue was used to detect students' ideas and to change them. It was also used to transmit information in a less structured way, so the students could reflect about them and learn more effectively.

The emphasis on the dialogue was also linked to the idea of encouraging students to participate actively in the teaching-learning process. When students followed the presentation of content on the blackboard or by other visual means, like transparencies, they were seen as not actively involved in the lesson. They had to do some activity, or to talk to the teacher, in order to participate.

Therefore, the dialogue was seen as the basic element of the process, because it enabled the existence of **activity** and **openness to reconstruction**, which Teacher 1 considered as the necessary conditions for production of knowledge.
The teacher was considered as the central figure of the process. He controlled the development of the student, in terms of content and as a person. It happened because he acted, at the same time, as the source of intellectual production and as a model for students' ideological and moral development.

Despite the emphasis given to the role of the teacher, the responsibility for learning to occur was attached to the student. He had to structure his ideas, supported by his studies outside the classroom. His interest, which was considered as very important for his learning, was linked to the possibility of conducting these studies, and to have access to extra-class information. He was seen as a producer of knowledge, when he reflected, during his studies, upon the ideas discussed in the lessons.

The teacher, as the guide of the process, needed support for his actions. This support came mainly from the curriculum materials, including the tests, which were considered as a source of information for the teacher and not as feedback for the students.

This picture of Teacher I's conception of teaching and learning was formed by the recollection of different parts of his construct system. It is one possible picture, considered from my point of view. Therefore, although it is presented as a single piece, it is composed by parts which may not be directly connected in Teacher I's mind and may be used to deal with events in different contexts. Thus, possible inconsistencies which may appear here are not necessarily present in his construct system.

In the next section I shall analyse the changes in Teacher I's conception due to the activities carried out during our work. I shall start considering the influence of the workshops and group discussions.

### 7.3 - LEARNING EXPERIENCES

The first workshop was designed to introduce the participants to each other and to start the discussion about the nature of knowledge.

It is interesting to consider the opinion of Teacher I about this activity:
The second activity was linked to the integration of the group. During this activity... I was not feeling very relaxed, but I could point out the questions which I considered as fundamental, consider the opinions of the other persons, and have an idea about how they see each other in terms of behaviour, attitudes, etc. I think that this activity was very interesting, especially to break the tension.

(Teacher 1, Evaluation Cassette)

In his opinion, this activity was adequate to attain its first objective, that is, to give participants the opportunity to present themselves and, at the same time, to establish a more relaxed atmosphere amongst them.

He also pointed out that, despite my remark, during the activity, about using previous ideas, he only realized that he had used his own about two weeks later! This type of comment is interesting because it highlights the time which is sometimes necessary for a person to come to conclusions, which seem trivial to others. It also suggests that, although oral communication is not enough to promote understanding, it is important to enhance it, as can be observed when he could remember my comment.

During the first discussion about the nature of knowledge, Teacher 1 stressed the influence of behaviourism on the textbooks we adopt, and on the way we give lessons and evaluate students. He also pointed out the pressures he has faced in several schools, for valuing the transmission of knowledge, and preparation of students to pass the exams which give access to universities. Hence, information available in the material distributed before the meeting, was used to emphasize his own ideas and experiences, instead of being treated as a unity or something which makes sense by itself.

During the second group discussion about the nature of knowledge, Teacher 1 pointed out the problems created by the use of an esoteric language, developed by the scientists, in the teaching of Physics. He called attention to an aspect which he considered important and which he has tried to avoid during his lessons.

He interpreted the ideas contained in the material he received, according to his own perspective. Thus, he found in these ideas an opportunity to open the
discussion about science to the public. He disagreed, however, with the possibility of using a method to guide people in a certain direction.

Although we had used two sessions to discuss this topic, the participants felt that they needed additional readings to develop their knowledge about it. Teacher 1 stressed the superficiality of our discussion, due to lack of time, in his evaluation cassette.

During the next meeting, I conducted a workshop to introduce the problem of alternative conceptions (see Activity no. 5, Chapter 6). I tried to make an analogy between participants' conclusions and what may happen during a lesson.

Teacher 1 perceived this activity in the following way:

...the text didn't have much information about the characters. Then each group member interpreted the story in a different way. It means, in my opinion, that when we say something in the classroom, each student may interpret it in a different way. ... I don't remember now, but there were different connotations for each character and for each situation. Then, the same story generated several interpretations.

(Teacher 1, Evaluation Cassette)

It is also interesting to analyse the way participants came to their conclusions. While Student 1 pointed out each detail and constructed his answer step by step, Teacher 1 presented his idea complete, without determining the points which contributed to it, nor how.

The text given for the next meeting presented some ideas of Thomas Kuhn. Teacher 1 appreciated it very much, especially because he had read about Kuhn before, and he could relate what was presented in the text with his classroom experiences. One analogy drawn by him, was:

Research problems are seen as puzzles to be solved within the framework of the dominant paradigm. When solutions for the puzzles are not found, this is credited to scientists' lack of capacity, and not to theoretical or methodological weaknesses. This may be related to the classroom ... when the solutions for the problems are not found, we always blame the students and
never the teaching system, or ourselves. The failure may also be due to the teacher.

(Teacher 1, Evaluation Cassette)

Although this type of analogy was not explored during the meeting, it was drawn by Teacher 1 during the recording of his evaluation cassette. It shows the importance of availability of time and materials to further the reflective process, and, therefore, learning.

In relation to the text given for the previous group discussion, this one was considered by Teacher 1 as much more important. This type of conclusion seems to derive from his capacity to relate this material to his previous knowledge. It highlights the link between personal relevance and intelligibility of a certain material.

The next activity was a workshop to introduce the problem of verbal transmission of information. Teacher 1 perceived the analogy with what happens in the classroom, in the following way:

...it's very similar to the situation in a classroom, where students usually stay silent, listening to the teacher without engaging in a dialogue, engaging in a conversation. At the maximum they ask and the teacher repeats exactly what they have said before.

(Teacher 1, Evaluation Cassette, my emphasis)

It is interesting to notice that the aspect he highlighted in his comment was lack of dialogue and not the aspects on which we concentrated during the activity, such as lack of structure of the information being transmitted, loss of information and problems with emphasis. Despite our concentration on other aspects, he perceived what he considered as the "real" problem with oral transmission of information. Therefore, although he participated in an activity where some problems were emphasized and discussed, it was not enough to provoke major changes in his perspective. The aspects discussed during the workshop may have been introduced in his conceptual system linked to his previous ideas, which were kept at a superordinate position within the system.

This type of connection may also be perceived in Teacher 1's comments about the article of Nussbaum and Novick (1981), which was analysed during another
group discussion. In this article the authors presented the use of brainstorming, during a lesson, to invent a model of a gas. Teacher 1 perceived this lesson as a mixed process of discovery and construction:

*It was a different way to treat the content. Everything was construed. Students' hypotheses, students' ideas about the content, they were construed and the ideas became students' ideas through experience.* ... *The students were discovering through a process of group discussion, discussion in a big group, discussion in a small group, and through all this discussion they came to perceive, they created a concept which became their concept and not the concept transmitted by the teacher. Then it was a process of discovery.* ... *the content was treated using dialogue.*

(Teacher 1, Evaluation Cassette, my emphasis)

It is possible to perceive that the type of construction which Teacher 1 was talking about, was one which happened outside students' minds and where everybody came to the same conclusion by following the discussions. The parts emphasized in his comment seem to indicate that he held an idea of discovery closely linked to reception of information. The difference was the use of experiments and dialogue as ways to convey this information.

Therefore, Teacher 1 was presenting a perspective where constructivist and transmissionist ideas were held together with no perception of inconsistency. The introduction of constructivist ideas in his construct system was made at a level which permitted the co-existence with his previous ideas, which were kept at a higher level.

During the group discussion about curriculum change, Teacher 1 pointed out the pressure against changes in the teaching methodology. Since secondary school, students and teachers are used to emphasize transmission of course's content, instead of concept learning. This happens due to the selective exams which give access to universities. At university level, the changes introduced in the basic courses, such as Physics 1, are generally associated with changes in the textbook. This reflects the emphasis given to the textbook, and also the lack of other curriculum materials to support teachers and students. Therefore, a change in the course organization which involved the adoption of a structure
centred on students' experiences, instead of on the course's content, would be very difficult to implement in our reality.

Other practical aspects of the teaching-learning process, such as teacher-students communication, learning and teaching styles, and teacher's knowledge about course's content, were discussed in the last workshop. I used an activity where one participant had to help another to solve a puzzle (see Chapters 4 and 6). During the development of the activity, the participants highlighted the necessity to allow the person who was solving the puzzle, to have time to reflect about his ideas, instead of just following the instructions of the other one.

This need for time to reflect and, as a result, to organize ideas, was also emphasized by Teacher 1 in his evaluation cassette:

*I think that I need more time to reflect and discuss, discuss again some questions which were not discussed enough. I think that what we need is time to meet more frequently to reflect about what we have already discussed.*

(Teacher 1, Evaluation Cassette)

In general, the workshops and group discussions were useful to raise participants' awareness about their ideas concerning teaching and learning, as well as to present other perspectives to them. Teacher 1 referred to these meetings as useful to develop critical sense about what is being done in the classroom (Evaluation Cassette).

Although he referred to reflection about some aspects, he did not mention any practical consequence from his participation in these meetings. From his comments during these activities, as well as in his evaluation cassette, it seems that he changed his construct system by including new conceptions. These, however, were not well organized and were subordinated to his previous ideas. The range of convenience of these conceptions was also quite narrow, and he needed to put these new ideas in practice to enlarge it, and then enhance the integration of his construct system.
7.4 - IMPLEMENTING THE IDEAS

The practical phase of this study started with the meeting to choose the topics of the Physics I course, for which teaching sequences would be prepared. Teacher I was satisfied with the possibility of preparing the teaching material in a group. He had to decide between two topics he would like to present: Conservation of Energy or Conservation of Linear Momentum. In relation to teaching method, however, he had no idea about what to do.

Along the discussions, Teacher I decided for Conservation of Energy, because he already had some written material about it. He was quite concerned about the time necessary to prepare the teaching material. Thus, the availability of some texts about Conservation of Energy was a decisive factor for his choice.

This aspect - lack of time to reflect about his ideas, to prepare teaching materials, to test them, and to evaluate them - appears as an important factor to inhibit change. It is especially significant in the case of a person like Teacher I, who is always looking for support to carry on his activities. If he does not have enough time to prepare himself to try something new, he will not run the risk to do it.

Two meetings later, the group was discussing the teaching methods. Teacher I’s ideas about what to do were still very vague. He decided to base his teaching method on conflicting questions which he would prepare after making a survey among his students. The problem was that he intended to start thinking about these questions after collecting students’ answers. Since his time availability after the beginning of the course would be very limited, this would mean that he would not develop his method properly.

He also thought about discussing these questions in small groups and then in the whole class. He intended to emphasize the concepts instead of numerical problems.

Until this meeting, Teacher I’s ideas about the method he intended to use, were not very clear yet. While we were asking him questions about the details, however, he improved his perspective. As a result, in the next meeting, he came with the objectives for the teaching sequence. He also decided to give a copy of
a text, about the historical development of the use of energy, to introduce the topic and to motivate the students.

It is interesting to notice the gradual development of his ideas, and the mixture of them with some ideas which were discussed during the meetings. The process of organization of the details necessary to prepare the teaching sequence, however, was very slow. Other participants' presentations were useful to enhance this organization, by pointing out different approaches, and also by discussing various points which would create problems during the instruction.

After four meetings dedicated to choose the topics and prepare the teaching materials, we started to test them with different groups of students, during the pilot lessons.

7.4.1 - PILOT LESSONS

Teacher 1 used two lessons of ninety minutes each, to test the material he prepared for the Physics 1 course. His topic was Conservation of Energy, and he intended to use a teaching method based on dialogue.

He asked four second-year Physics students, who had attended the Physics 1 course that semester, to participate. The lessons were given in the Physics Department, at the beginning of the summer holidays.

FIRST PILOT LESSON

At the beginning of this lesson, Teacher 1 explained its objective in relation to my work. Therefore, he presented this lesson as part of my work and not as a test of his teaching material.

When he started the lesson only two students were present. The other two arrived half an hour later. This type of delay is not unusual in Brazil, especially in the beginning of the summer holidays.

Teacher 1 intended to use a transparency to introduce the topic, but he could not prepare it. I suggested that he showed us the drawing directly, considering our small group.
At the start he said that the objective of the lesson was "to talk about the topic Conservation of energy". Then he suggested beginning with the historical evolution of energy. He showed the drawing and asked the students to think about a specific question.

The answers of this question were summarized and more information was given, followed by another question. New information was then introduced orally, since the only written material used by Teacher 1 was the drawing, which contained a table with some dates and events.

During the presentation of the ideas, the students tended to stay quiet, because they no longer knew how to answer the questions asked by Teacher 1.

After presenting these introductory ideas, Teacher 1 said that his objective was to discuss two concepts: Kinetic and Potential Energy. He used the example of a brick falling from a wall to talk about Work and Energy. At this point he remembered that he had not talked about Work before, and asked the students if they knew what Work was, and if they had the concept of Work as a variation of Energy.

There was a short break at this point to discuss the relationship between Work and Energy. Then Teacher 1 continued to present the example of a brick falling from a wall. He insisted on the point that the brick would "carry out a task" due to its fall from the wall, and asked the students if the height was related to the "execution of work".

After one student said that it was related through the Potential Energy, which was the weight times the height, Teacher 1 asked if there would be any change if the brick were made of a lighter material. This question arose a long debate around the problem of the weight and the resistance of the air, which led to a discussion about force, acceleration and velocity. This discussion lasted twenty minutes.

After the discussion Teacher 1 went back to the example of the brick, using different words to mean Work. Some questions asked by Teacher 1 led to another debate, this time about Force and Newton's laws.
Finally, Teacher 1 wrote on the blackboard that the work done by the brick was proportional to its mass and its height. I argued that the students already knew how to calculate the Potential Energy and that his problem was to discuss the Conservation of Energy. He started to define Mechanical Energy, but he had to finish the lesson because we had no more time available.

ANALYSIS OF THE FIRST PILOT LESSON

The first point about this lesson was the way Teacher 1 perceived its role. Instead of considering it as an opportunity to test the material he had prepared, he saw it as an occasion for me to collect data for my work.

In relation to the structure of the lesson, although Teacher 1 adopted a negative perspective in relation to the transmission of knowledge, the objective of this lesson was to "treat the topic conservation of energy". For him, however, if the teacher uses a conversational approach, he is not transmitting knowledge, but giving students the opportunity to construct knowledge with him.

The only written material used by Teacher 1 was the table with some dates and events. He also used the blackboard in some occasions, but his basic support was the oral presentation of the topic. He did not use lesson notes nor seemed to have planned the lesson in detail.

During the discussions about other topics, he seemed to enjoy them, and made no attempt to return to the main topic. Thus a considerable period of time was used for these discussions and it was not possible to accomplish the objective of the lesson. It did not seem to represent a problem for Teacher 1, who considered the other discussions as highly relevant, because the students participated actively.

Although Teacher 1 wanted to use the dialogue to present the topic, in several occasions the students were not able to participate, because they had no idea about the subject under discussion. In these occasions Teacher 1 kept talking about the content, without perceiving the situation as a problem.

In relation to the content itself, Teacher 1 tried to elicit students' views and to elaborate them, although he did not try to present a scientific conception, or to
structure the information he was disclosing. He used several terms to represent Work, but did not emphasize the ways Work is used in physics.

The students were a bit confused during the discussions, but they seemed to appreciate the opportunity to clarify their views.

In general, my impression was that this lesson was organized in accordance with Teacher 1's deepest beliefs in using the dialogue as the main conveyor of information, giving students opportunity to discuss their doubts, and avoiding a rigid lesson plan. On the other hand, the problems caused by the lack of a more structured lesson plan and written material, to the full presentation and discussion of the main topic, were not considered as such by Teacher 1.

Another lesson was used to complete the test of the teaching material.

SECOND PILOT LESSON

Teacher 1 started this lesson writing the expressions for Kinetic and Potential Energy on the blackboard. Then he distributed a picture of a piling driller, and asked the students to determine the Mechanic Energy immediately prior to the hammer hit the pile.

During the discussion about the picture, it became clear that the students did not know how to calculate the energy. Although it was demonstrated in the previous lesson that the Kinetic Energy at the bottom was equal to the Potential Energy at the top, the students kept thinking that they were different.

The lesson was conducted in a similar way to the first pilot lesson, with Teacher 1 exploring the dialogue as a medium to present the content. The whole lesson was used to discuss different ways to calculate the Mechanic Energy of the system in terms of Kinetic and Potential Energy.

ANALYSIS OF THE SECOND PILOT LESSON

After a second lesson based on a conversational approach, it became clear that this method would not work in a group with sixty students. Teacher 1 recognized the weakness of this approach, and was expected to think about alternatives to overcome them.
Despite his previous experience during the first pilot lesson, Teacher 1 did not use this second lesson to introduce any observable change in his teaching method. He maintained the emphasis on the oral communication and on the dialogue with the students.

As a result of these two lessons, we decided to change the content because there was an interference between the content I had selected to use in my lessons, with part of the content selected by Teacher 1. Therefore, the main changes derived from these tests were related to the content, and not to the teaching method itself.

Besides the problem of interference, after the pilot lessons given by the two teachers and by me, we realized that the students in the different groups, all had problems with the concepts of velocity and acceleration. Therefore, we decided to pay more attention to these concepts, which appear at the beginning of the course. Hence, it was necessary to modify the schedule of the course, as a whole, to introduce the emphasis we wanted.

7.4.2 - MEETINGS TO PREPARE THE SCHEDULE

During three meetings, held at consecutive days, the group discussed the schedule of the Physics 1 course. Although we had finished a series of meetings, where we highlighted the necessity to plan activities for the students, the discussions were centred around the content and different ways to present it.

Teacher 1 prepared a draft, which was used as a basis for our discussions. I pointed out the necessity to prepare written materials to be given to the students, to contextualize the discussions, and used the draft as an example. Both teachers, however, emphasized their lack of time to prepare these materials.

In relation to the evaluation, Teacher 1 reminded us that it should be done based on objectives, and, therefore, these should be given to the students. In practice, however, he did not prepare the objectives.

During the second meeting we decided to change the topics. Teacher 1's topic about Conservation of Energy was included in my topic, and he decided to
prepare a teaching sequence about Newton's First Law. He intended to distribute a text, during his lesson, comparing the ideas of Galileo and Aristotle.

At the end of the third meeting we had a schedule (see Appendix III) which was accepted by everybody. Afterwards I prepared copies of it, and gave them to the participants. This schedule, however, was not followed. Teacher 1 justified the non-use of the schedule by excess of activities, and absolute lack of time to stop and read it. I pointed out that the schedule could help to organize these activities. Teacher 1 agreed, but said that he was not used to schedules.

Another aspect which influenced the non-use of the schedule was lack of space, at home and at work, to organize the material used in the course. This aspect is especially relevant if we remember that both teachers were working simultaneously at three different places, in the morning, afternoon and evening, giving five different courses, to groups with around forty students each.

Here, again, lack of opportunity to organize the ideas, by reflecting upon them or by dealing with materials, appeared as an important aspect inhibiting change.

7.4.3 - MEETING TO PRESENT THE TEACHING MATERIAL

After the pilot lessons, Teacher 1 decided to change his topic for Newton's First Law. He had no time to test this new material with students, so he presented it to the group, for discussion and suggestions.

He based his approach on the knowledge that the majority of students relate force with velocity. This was confirmed by the results of the interviews which I conducted with some students. He intended to start with a relationship between these variables, and then try to falsify it using a counter-example. Thus, he would adopt a methodology based on a conflict between different perspectives.

He also intended to use an experiment, to motivate the students, and a group activity. It was decided, therefore, that he would give the lesson in the laboratory, to facilitate the manipulation of the apparatus, and the division of the class in groups.
At the beginning of the lesson, Teacher 1 would ask a question which could lead to a conclusion that to exist velocity it is necessary to exist a force. He would then use the experiment to challenge this conclusion.

It is interesting to notice that, although he said that he was starting from students' conceptions, he was in practice basing the whole lesson on the development/challenging of only one false conception. What was really happening was a guided instruction, where another perspective was introduced at the beginning, instead of the scientific one.

_I want this question. I am asking this question. In other words, may we say that the body's velocity is linked to the action, is linked to the force? ... That is the question which I want the students to be confused with._

(Teacher 1, Meeting to present the teaching material)

The students would be asked to answer to this question in writing, individually, and then they would discuss it in groups. The answers of the groups would be written on the blackboard. This type of structure resembles one technique analysed during our meetings. Thus, its use indicates that this information was considered relevant by Teacher 1, and was now part of his conceptual framework. In addition, the use of the blackboard to organize the presentation of the ideas, was coherent with Teacher 1's perspective elicited with the repertory grid.

During the presentation, the participants suggested different answers which the students could give to Teacher 1's question, as well as arguments which could challenge it. Another aspect, highlighted by Teacher 2, was the use of the whole lesson to consider just the relationship between force, velocity and acceleration, to discuss Newton's First Law. He thought that it was too much time to invest in this discussion. Teacher 1 disagreed, and emphasized the importance of this question.

Here appears one dilemma, suggested by Olson (1982a), which occurs when the teacher does not see clearly the reason or the objective of a certain teaching material. The tendency in these cases is the adoption of a strategy, which can give him answers for these questions, even if these answers are not the same
thought out by the producer of the material. In this specific case, fortunately, Teacher 2 was able to present his doubts, and to clarify them with Teacher 1.

Another aspect to be noticed is that, despite our discussions about the use of experiments to change students' conceptions, Teacher 1 and Teacher 2 still believed that experiments were meaningful by themselves, that is, that they would be perceived by the students in the same way as by the teacher. This was challenged again, when Teacher 2 and I did not come to the conclusion desired by Teacher 1.

The lesson plan was organized as a series of statements and questions, without any mathematical formula. It was also a bit vague, and its statements were not very precise. These characteristics are linked to Teacher 1's central ideas, and despite the criticisms given by the other group members, they can still be found in his later lessons. This adherence to previous ideas, especially when they are central to somebody's conceptual framework, is an important characteristic which must be considered in change processes.

7.4.4 - LESSONS OBSERVED DURING THE COURSE

Teacher 1 was observed during a total of twenty hours, while he was using both traditional and innovative methods. Out of these, sixteen hours were recorded.

I was introduced to the class at the first lesson, as somebody who was there to collect data for a research. This first lesson was used to introduce the course as a whole, and at the end Teacher 1 asked me to talk to students about my work. This was important to enhance my communication with them, who had then an opportunity to ask questions to clarify the objectives of my presence in their classroom. After this first lesson the students seemed to accept my presence quite naturally, whereas Teacher 1 was paying too much attention to my reactions.

The group was very heterogeneous in several aspects. First, there were students from different undergraduate courses (Physics, Civil Engineering, Chemistry Engineering). Furthermore, several students were following the course for the second or third time, hence their interests were quite varied. As a result, there was no sense of unity in this group, and communication between its members was difficult.
The classroom where the lessons were given was located in a block different from the one in which Teacher 1 used to give his other lessons. It resulted in loss of time to move to there, and consequent delay in the beginning of the lessons. The classroom was also very small and overcrowded, what contributed to parallel talks between the students during the lessons. These talks were very disruptive, and reflected the lack of interest of the majority of students in the course.

The teaching style was the same, independent of the teaching material used by Teacher 1. He emphasized the oral communication, asked questions to the students, and avoided calculations. When using the teaching materials prepared by others, he showed lack of familiarity with these materials and, consequently, lack of confidence on the development of the activities. These feelings were acknowledged by Teacher 1 during the evaluation meeting held at the end of our study:

I think that we have the material ready but I felt the necessity to prepare more what was already prepared. I felt the necessity to sit down and to discuss more, to prepare more what was there. Then you have a bit of insecurity regarding that new material which you will use. .... Then you use it, but not with the confidence you have with your own material.

This necessity to "prepare what was already prepared", or in other words, to analyse and restructure the material, reflects the requirements teachers have to fulfil in order to use teaching materials, prepared by other persons, in their lessons. In addition to studying the materials, they have to adapt them to their teaching styles. It implies in solving possible discrepancies between their own ideas and the ones implicit in these materials. The lack of time to consider these aspects leads to sub-utilization or even to distorted use of the materials. For example, during the lesson in which he used the teaching material prepared by Teacher 2, Teacher 1 presented a table included in the material, but did not use it to calculate the parameter intended by the author. As a result, he missed completely the objective of the author, and that part of the lesson became meaningless.

The students used to ask Teacher 1 to solve problems. Their intention was to observe how he would do it, to repeat during the assessment. While they concentrated their attention on the assessment, Teacher 1 tried to emphasize
the learning of concepts. This was a constant source of tension and influence on the teaching style. For instance, during a lesson with problem solving, Teacher 1 used to give much less emphasis to students' ideas than during the introduction of concepts. In the first case, after asking some questions to students, he used to solve the problem alone, giving the answers without discussion. In the second, he refused to give a direct answer, and tried to elicit it from the students.

An example of problem solving is given below. It was part of a lesson given in 16/5/88, when Teacher 1 was using teaching material developed by myself, about work of a force. In this part he was solving a problem, where a person holds a body which is sliding along an Inclined surface, with constant velocity. T1 represents Teacher 1's utterances and Ss students'.

T1: The problem tells me that the velocity is constant. If the velocity is constant, how much is this? (referring to the resultant force).

Ss: Zero (in choir).

T1: Then PsenO minus the friction force, minus F, equals to zero. Well, the P is easy to determine, isn't? The P is equal to what?

Ss: mg (in choir).

T1: 50 times 9,8.

He, then, waited for the students to tell him the result of the calculation and wrote it on the blackboard.

T1: Well, we have determined P. The sine of this angle here is easy to see, isn't? The sine of this angle is the ratio between the opposite side and the hypotenuse. Then sine of O is equal to 0,90... Tell me please...

At this stage, although he continued to ask questions to the students and to come back to explain some details, he started to answer by himself the questions he posed. He also started to short his revisions, and omit some emphases required in the teaching material. At the end, the problem required the calculation of the work done by the force of gravity:
T1: The component of P which is causing the body to slide is PsenO. Then, what is the work of this force? Work, as before, is F scalar d. Our F now is PsenO. Are you understanding this?

Some students said no and he tried to explain:

T1: Where is the movement to? Isn't in the direction of this axis? The weight is here, isn't? What is responsible for the movement of this body? It is the component of the weight in this direction. It will cause the sliding of this body, isn't? Then I want to know the force of gravity. It will be the force of this component here, to slide him [the body] along this slope. Then, how will it be?

Ss: \( P \cos \text{ of the angle} \) (in choir).

T1: What angle will be?

Ss: Zero.

Then Teacher 1 continued to solve the problem. It is interesting to notice that this time he gave the solution directly, without asking for suggestions, and without justifying why he could use the component of the force, instead of the force itself, to calculate the work. He also mixed force with work.

In contrast, when giving the lesson using the teaching material prepared by himself, Teacher 1 gave the students the opportunity to reflect about their ideas, to discuss them in groups, and to present them to the whole class. During this lesson, the emphasis was on the concepts involved, and no calculations were used.

T1: Let's start our study considering Newton's laws. But before, I would like to know the following. Let's imagine a body, an object, and I want to study its movement. The body is at rest, and to move it is necessary what?... That we do, exert some influence on this body, isn't? What means an influence for us? To push, pull, pick up, ok? Then I would like that each one of you answered individually, in writing, answered and explained. ... May we say that the velocity of a body is linked to the action? Or in other words, for a
body to be moving is it necessary that I act upon it, that I exert a force on it? Is it necessary? Say yes, or no and why.

Then he gave ten minutes to the students and collected the answers afterwards.

T1: Well, now I shall give you five minutes at maximum, for you, in groups of four, six at maximum, to discuss your answers. I want one answer per group.

The students organized themselves in groups. Then Teacher 1 explained again his question:

T1: Just to reinforce what I've said... I have this small car here. This small car is at rest. It is stopped here. To move this car I need a force, isn't? What I want you to analyse is: to exist velocity is it necessary to exist a force acting on this small car? For this small car here to have velocity is it necessary to exist a force?

The students discussed their ideas and then Teacher 1 asked them to write their answers on the blackboard. After that, he continued the discussion using the experiment, before coming to the conclusion.

Besides the aspects already discussed, it was possible to observe others which seemed important for students' learning. The first one was related to time constraint. The majority of students had to work during the whole day, and had lessons every night during the week and the whole Saturday morning. Hence, the students had practically no time available to study. This led to the reduction of their learning experiences to the ones occurring during their lessons. In addition, the course's content was very extensive. These two aspects contributed for the content being not sufficiently explored and structured.

Another aspect was the mixture in Teacher 1's teaching style. Despite his emphasis on students' ideas, in several occasions he did not further the discussions, but told the answers directly. In the assessment he used numerical problems, although he avoided them during the lessons. As a result, the students seemed to be a bit confused and could not either develop their ideas properly, nor structure the ideas presented by him.
In brief, it is possible to conclude that Teacher 1 had internalized some ideas discussed during our meetings, but still had to integrate them with his own in order to develop a coherent way of teaching. Since the opportunities to integrate these ideas during our study were very limited, it was not a surprise to detect this. The important question here is if he will be able to do it alone, from now on, during his practice.

7.5 - CHANGES IN PERSONAL THEORIES OF TEACHING AND LEARNING

The influence of this study on Teacher 1's ideas about teaching and learning was analysed more specifically through four repertory grids (see Chapter 5) completed at the end of the study.

It should be emphasized that the grids cannot be considered as a kind of pre and post-test. During their completion, what is elicited is part of a person's conceptual system, and not the whole system. Moreover, this conceptual system is not static, but changes continually. Therefore, if the same person completes two grids in subsequent occasions, they will probably be different from each other. Hence, what can be obtained from the analysis of these grids is not an absolute measure of the changes which occurred in the system, but an idea about these changes.

SECOND REPERTORY GRID ABOUT TEACHING-LEARNING PROCESS AND NATURE OF KNOWLEDGE (TLP2)

This second grid was completed after Teacher 1 finished the course where he implemented his new ideas. This time he was more relaxed and could easily think about the constructs. We started eliciting the elements, and then the constructs, adopting the triadic method.

The first element was, again, the dialogue. However, he felt that his perspective concerning the dialogue had changed:

*I think that many things have changed... even the dialogue itself, we think that it is happening... and in reality it is not happening in the way you would like it to happen in the classroom, in relation to learning. There is the dialogue, but in relation to...*
learning... how it occurs... I know that it is a bit modified in my mind.

(Teacher 1, TLP2)

The second element was the time for students to reflect about the aspects treated in the classroom. The choice of this element may reflect his own experience during the development process, when he stressed his necessity to have more time to reflect about the questions discussed during the workshops and group discussions.

The course planning was another element, including planning of activities and content. The inclusion of activities may also be linked to our discussions during the development process. The same may be said about the choice of course and students evaluation as another element.

Students' alternative conceptions were also considered as an element, according to the following perspective:

The alternative conceptions, I think they are useful for... the first positioning of the teacher in relation to the situation of the group, the first evaluation of how things are. The evaluation of the course and students would be a process... after the whole process of developing that content, that concept.

(Teacher 1, TLP2)

In relation to the construct tree, it is possible to observe that the constructs are not closely linked. The closest ideas are the activity developed in the classroom, the affective question and the preparation of the student as person. These ideas reveal the importance given by Teacher 1 to the affective question and to the development of the person.

Through the element tree it is possible to notice that the idea of teaching-learning process held by Teacher 1 has the teacher and the dialogue as central elements, similar to the first grid (TLP1). The content, however, is no longer at the centre of the process, but linked to the central elements at a lower level of correlation.
The students are more involved in the process, with their interest directly linked to the dialogue, instead of to extra-class activities, as in the first grid. Their working conditions are also included in the main cluster, while the working conditions of the teacher are less related to these ideas. This may be connected to Teacher 1’s perspective about the role of the student in the teaching-learning process:

\[
\begin{quote}
The working conditions of the teacher do not compromise the process completely, but the working conditions of the student do. ... To exist production of knowledge, to exist teaching and learning, I think that the student has to work much more than the teacher.
\end{quote}
\]
(Teacher 1, TLP2)

The evaluation appears quite isolated, as a reflection of Teacher 1’s idea about it as something apart from the process. Although there was a special session during the training, when evaluation and its possible uses were discussed, Teacher 1 continued to think about it just to verify content acquisition:

\[
\begin{quote}
... if the student really articulated in the way he [the teacher] wanted ... If it [the content] was worked out by the student... in a way to modify it.
\end{quote}
\]
(Teacher 1, TLP2)

Although in this grid the element course planning was defined including activities and content, during one meeting to discuss the grids, Teacher 1 said that he still thought about planning a course as to determine the content.

SECOND REPERTORY GRID ABOUT CURRICULUM MATERIALS (CM2)

The construct tree has two clusters. The one with the closest ideas relates the development of skills with the communication in the classroom, the development of creativity and the use of student’s reasoning.

The ideas of evaluation of the work in the classroom, and presentation of content appear quite isolated from the others directly involved in the teaching-learning process. Since Teacher 1 used presentation of content to represent the moment when students show what they have learnt, both ideas are related to evaluation.
It is interesting to notice that the organization of ideas is linked to the oral communication, and the development of skills is linked to communication in the classroom. These links reflect the emphasis given by Teacher 1 to the dialogue as a way to enhance learning. This aspect was probably strengthened by the emphasis given to oral aspects during our work. The use of workshops and group discussions did not give relevance to the uses of reading and writing in the teaching-learning process.

The element tree has four clusters. The taperecorder, which was intensively used during our work, was introduced in the cluster which included the course's planning.

The blackboard was seen as an element developing teacher's skills, because:

> When the teacher is using the blackboard, he is talking, he is criticizing, he is writing, he is organizing.

(Teacher 1, CM2)

The overhead projector was also seen as a support for the teacher, because it helped him to organize what he intended to present during the lesson.

The written and oral tests were perceived as a moment when the student was no longer developing the content, but "giving it back", so the teacher could know if the student had learnt it or not. Here, again, the evaluation was seen occurring after the teaching-learning process.

Teacher 1 emphasized the development of students' oral skills as a way to enable them to ask questions during the lessons, and then participate actively in the dialogue with the teacher. This dialogue was considered very important to students' learning.

The laboratory and text reading and interpretation were seen as similar elements, because they could give the students an opportunity to reflect about the concepts:

> I believe that he [the student] can think more about the concept when he is either in the laboratory or reading a text, than when he is in the classroom attending a lecture... because he is working, he is thinking in the laboratory and when the teacher is
giving a lecture using the blackboard... [he] is talking all the time and is not giving time to the students to think about ... The laboratory and the reading lead the student to think more about the content.

(Teacher 1, CM2)

In relation to the first grid about curriculum materials (CM1), in this second grid (CM2) more emphasis was given to student participation in the learning process, and to student's activities.

Although the teacher was still at the centre of the process, through the dialogue with the student, the present organization of the elements showed a clear distinction between those used by the students to support their learning (first cluster), from those used by the teacher to organize the course, to evaluate and to present the lessons.

It seems that Teacher 1 is now perceiving learning as more dependent on the student and on the opportunities for him to study alone.

SECOND REPERTORY GRID ABOUT TEACHER’S ROLES (TR2)

The construct tree has three groups of two constructs. In the first group are the ideas linked to the activities developed by the teacher and the student during the course. The next group is composed by the ideas related to the development of the student as person. The third group is related to the content.

In the element tree, the course planning and the didactic materials were seen related to the selection of content. Despite our emphasis on selection of activities, the idea of presentation of content during the lessons was still very strong.

One important aspect for Teacher 1 was his role as a moral example for the students. This was a role he had to assume during his lessons at the secondary school and it was interfering with his performance at the University, where students did not expect him to assume such a role. It was interesting, however, because it revealed the influence of the environment on the behaviour of the teacher.
In relation to the first grid about teacher's roles (TR1), we can observe that the role of evaluator was included in this second grid. Teacher 1 considered that it happened because:

*It means that I'm giving, I think, more emphasis to evaluation, which I practically didn't care at all.*

(Teacher 1, Discussion of TR1 and TR2)

I pointed out that evaluation did not appear in the first grids but it appeared in the seconds.

Another role which appeared in this second grid was producer of didactic materials. This may also be a consequence of our work.

**SECOND REPERTORY GRID ABOUT STUDENT'S ROLES (SR2)**

The construct tree has two clusters. One relates the work with the content to the development of reasoning and development of critical sense. The other is composed by organization of work linked to student's participation and student's emancipation.

Therefore, the student develops reasoning and critical sense when he works with the content. Although this work is considered very important, it is not clear how it is conducted.

It is interesting to notice, in the element tree, that the student has to be obstinate to establish contact with the teacher outside the classroom. It is a reflection of our conditions at UNICAP, where the majority of teachers stay at the University just during their lessons, and the majority of students do the same. There are no tutorials, and the contact between teacher and students outside the classroom is very scarce.

In this grid, Teacher 1 showed a different perspective from the one presented in the first grid about student's roles. The first grid was connected to an ideal situation, while the second was more practical, more related to what really happened during the course. He did not choose, for example, the role of producer of knowledge. This was a direct result from his experience:
I would like to have the student as a producer of knowledge but I didn't feel that in the classroom, nor in the course, neither in the student's receptivity to do this type of activity.

(Teacher 1, Discussion of SR1 and SR2)

I suggested that it occurred because several students in his class were repeating the course and they were used to assume a passive role.

Another aspect observed in relation to this group, was lack of integration between the students. Since it was basically composed by students repeating the course, their only contact was during these lessons. Furthermore, Teacher 1 did not stimulate integration between them. Therefore, the relationship between the teacher and the students was an one to one interaction, instead of between the teacher and a group of students.

Despite our emphasis on the importance of group work, this type of activity was scarcely used by Teacher 1, and was not appreciated by the students. The tradition of using the blackboard is still very strong among the teacher and students.

7.6 - EVALUATING THE RESULTS

Although the study concentrated on the teachers involved, I also conducted interviews with some students in their classes, to detect influences of teaching methods on their ideas. The main results of these interviews are shown in Chapter 6.

Some aspects, which seem to be related to Teacher 1's way of teaching, are discussed below:

- The trajectory, displacement and distance traveled by the body are poorly discriminated concepts. These concepts were introduced to the students in the secondary school. At that level, however, they are treated very superficially. Moreover, while the distance traveled by the body is a concept found in students' everyday lives, trajectory and displacement are specific terms used in their science lessons. Since these concepts are not explored deeply, students tend to associate them to their existent concept of distance.
During this course, Teacher 1 also left the difference between these concepts unexplored. Moreover, sometimes he referred to one in the place of another.

- The origin of the reference system has to coincide with the origin of the movement. This is the way it is usually presented at secondary school books, and used by teachers in their lessons. The use of examples showing the origin of the movement in other points, as well as emphasizing its location in relation to the reference system, were not considered by Teacher 1.

- The sign of the velocity is defined in relation to the direction of the acceleration and not in relation to the reference system. Hence, if the velocity and the acceleration point to the same direction, the velocity will be positive, whereas if they point to opposite directions, the velocity will be negative, regardless the direction of the axis of reference. This confusion is enhanced in secondary schools by the change of direction of the reference axis during the problem, in order to keep the velocity always positive. The links between the signs of velocity and acceleration, and the direction of the reference axis, were also not stressed by Teacher 1.

- The relationship between force, velocity and acceleration is not precise. From a direct relation between force and velocity, the students changed their views towards a relation between force and variation of velocity. This last relationship was stressed by Teacher 1 during his lessons about Newton's First Law. The link between variation of velocity and acceleration, however, was not sufficiently explored. As a consequence, the relationship between these concepts was not clear to students, who tended to consider the variation of the velocity as responsible for the existence of the acceleration, and not the other way round.

- In general, the concepts are not integrated and their definitions are imprecise. Although it is not our intention to establish a relation of cause and effect, the way these concepts were treated during the course by Teacher 1, together with lack of opportunities for students to explore by themselves, contributed to the present organization of students' ideas.

The changes detected in students' conceptions were usually limited to specific aspects treated during the course. This point reinforces the idea that major
changes in a person’s conception are initialized by fragmentation, that is, they are linked to specific contexts.

In the evaluation meeting, held at the end of this study, the discussions concentrated on the activities developed during the last semester: the Physics I course, observations of lessons, and weekly meetings. During this meeting, besides talking about the schedule and the teaching materials, Teacher 1 also highlighted the importance of the observations:

*I think that the observations were worthwhile. Because there are many things, many things, for example, the teacher has given the lesson then you come and tell him: look, in your lesson you didn’t see this, you did this, you skipped that, things that I would never perceive.*

(Teacher 1, Evaluation Meeting)

The feedback provided by our meetings after the observations were especially useful to point out some inconsistencies in Teacher 1’s teaching style, as well as unintended deviations from the objectives stated in the teaching materials. This type of feedback seems to be extremely important to enhance the reflective processes necessary to develop the conceptual framework of the teacher. It also helps to develop his capacity to observe himself during his practice, what is necessary in order to conduct action research.

Another aspect discussed during the evaluation meeting was student evaluation. Teacher 1 agreed that evaluation was a problem, but did not suggest any solution. Although we had suggested alternative ways to evaluate the students, during our meetings in the first phase of the study, we had no opportunity to implement them before the Physics I course. Any type of evaluation, however, implied in using time dedicated to other activities. Since Teacher 1 was thinking about evaluation as source of information just for the teacher, this transference of time would seem disadvantageous for the students. Thus, Teacher 1 would have to change his conception of evaluation before solving this problem.

In this last semester the group had only one meeting a week. These meetings were planned to follow the development of the course and discuss the reactions to the innovation. Teacher 1 considered that we should have dedicated more time to our meetings, to deepen our discussions. The other participants agreed,
but there was no more time available, due to other participants' activities. Especially in the case of Teacher 1, the work in group was very important to develop his self-confidence and organize his ideas.

A questionnaire (see Chapter 6 and Appendix II) was developed to detect differences between teacher's and students' views about various aspects of the course, such as teacher's and students' roles, uses of curriculum materials and their performances. The answers given by Teacher 1 and the students in his class, shall be considered to point out possible sources of conflict.

In relation to teacher's attitudes and activities, Teacher 1 considered the following as the five most important:

1- To probe students' level of knowledge  *
2- To give texts and lists of exercises  *
3- To relate content to everyday life applications *
4- To exchange opinions with students
5- To have interest in students' ideas

These answers are not ordered, that is, it does not mean that the first answer was considered more important than the others.

Among the alternatives considered as the five most important by his students, there were:

1- To encourage student participation..........................78%
2- To probe students' level of knowledge.................. 57% *
3- To give texts and lists of exercises......................52% *
4- To develop students' reasoning skills...................52%
5- To discuss the evaluation criteria......................43%
6- To communicate course objectives......................30%
7- To relate content to everyday life applications..30% *
8- To transmit knowledge.......................................26%
9- To clarify students' doubts................................26%

Among the items selected by Teacher 1, item 4 was chosen by only 17% of students, while item 5 was chosen by 22%. There was an agreement between the teacher and the majority of his students in only two aspects - to probe
students' level of knowledge and to give texts and lists of exercises. The other three aspects selected by Teacher 1 were also chosen by some students, but not by the majority of them. Despite the agreement in these items, the models of teaching-learning held by them were very different. While Teacher 1 aimed an active student participation in order to develop their ideas, the students assumed a position of dependence in relation to the teacher, who they considered as conductor of the teaching-learning process and source of knowledge.

When presented to these results, Teacher 1 agreed that the models of teaching-learning held by himself and by the students were not the same. He stressed that the model used at schools leads the students to passivity. He also believed that it would be very difficult for the students to change in just one semester, and that it would be a reason for just 17% of the students choosing item 4. During last year he observed that the majority of students tended to become impatient when a question was posed to be discussed during a lesson, because they expected a direct answer by the teacher. Nevertheless, when asked to give their impressions about that lesson, they tended to find it very interesting.

The students' attitudes and activities considered by Teacher 1 as the five most important, were:

1- To adopt a method of study *
2- To attend lessons *
3- To have interest in content *
4- To transform knowledge
5- To exchange opinions with teacher

The students selected the following alternatives as the most important:

1- To attend lessons.................................................................65% *
2- To solve exercises.............................................................65%
3- To clarify his doubts with teacher and peers....................61%
4- To consult books...............................................................57%
5- To adopt a method of study..............................................52% *
6- To have interest in content..............................................35% *
7- To study the theory............................................................26%
8- To be a researcher.............................................................26%
Among the items selected by Teacher 1, item 4 was chosen by only 9% of students, while item 5 was chosen by 4%. The majority of students agreed in five aspects, among which only two were chosen by the teacher.

The model of teaching held by Teacher 1, which was based on the dialogue as a way to encourage students' learning, as well as on students studying alone, in an organized way, with interest, in order to transform knowledge, was confirmed by the items he selected. The students, however, although recognizing the necessity to study alone, still emphasized learning by repetition, using the material presented during lessons (items 1 and 2).

In relation to the use of the blackboard, the opinion of Teacher 1 was the same as the major number of students in six out of ten options. A major disagreement occurred in relation to the use of the blackboard to enhance learning fixation. While Teacher 1 was neutral, the students believed in it.

It is interesting to stress that, although Teacher 1 considered the blackboard essential to teaching-learning process and useful to introduce as well as to learn concepts, he did not use it frequently in his lessons with these purposes. For him, the blackboard would be indispensable only if a traditional approach were adopted. In the case of an alternative methodology, the blackboard would be used more as a support, since other resources could be used to give information to the students, and they could also take notes in their notebooks.

In relation to written tests, the teacher and the largest group of students agreed in seven out of ten options.

According to Teacher 1, written tests are useful to evaluate students and test learning. On the other hand, although they are useful to learn concepts and essential to the teaching-learning process, they do not involve the student in an active way. Therefore, the students may learn concepts without being actively involved.

These opinions disclose a perspective which is different from the one assumed verbally by Teacher 1. It is very important because it reveals an inconsistency which was not perceived by the teacher.
The students also presented an apparently inconsistent perspective, when they considered the written tests useful to evaluate students and were neutral in relation to their capacity to test learning. In this case, however, their perspective about evaluation may not include testing learning, but regard it just as a formality.

Students' opinion about Teacher 1's performance together with their suggestions to improve the course, revealed their interest on practical results. Although they did not have enough time to study and did not know if they had learnt the content, they considered the teacher's performance excellent and good, and asked for more exercise solving. For them, solving exercises leads to approval in the course and that is what matters.

On the other hand, Teacher 1 considered his performance as regular, because he felt that he was unable to involve the students, increase their interest and facilitate content learning. Therefore, his suggestions to improve the course included planning and preparation of teaching material before the course.

In general, the students were satisfied with Teacher 1's performance because he fulfilled their expectations, especially in relation to teacher's roles. Although Teacher 1 had different opinions about the most important attitudes and characteristics in a teacher, he acted according to the attitudes and characteristics considered as most important by the students. The students, on the contrary did not fulfil Teacher 1's expectations.

7.7 - SUMMARY

The main change in Teacher 1's ideas was related to student's passivity in carrying out his work. During the first grid, he saw student's work as not developing the critical sense. This time he saw it as developing the critical sense, depending on the type of work. Thus, it was possible for him, this time, to identify some activities which would lead the student to analyse his conceptions.

Several aspects were identified as relevant for the development process undergone by Teacher 1. The most Important, were:
The emphasis given to his previous ideas, and to the existence of different perspectives about the teaching-learning process, reassured his self-esteem and enabled the establishment of a critical attitude towards these ideas. This psychological support was fundamental to give him conditions to face the threat posed by the perspective of changing his ideas.

The access to new ideas and written materials seemed to be extremely important to introduce new perspectives in his conceptual system. These perspectives, however, were not immediately integrated in the system, nor were able to change the existent ideas. They were, on the contrary, kept subordinated to the previous ideas, and their integration depended on the experiences undergone by Teacher 1, as well as on the time dedicated to reflect about them. Therefore, while the access to information and willingness to change seemed to enhance changes by fragmentation, reflection upon the results of experiments seemed to enhance the development of the conceptual system by integration.

Group discussion appeared as a catalyst for the change process, because it enabled a more comprehensive analysis of the results of the experiences undergone by the group members. It also helped in the organization of Teacher 1's ideas, and development of oral communication. Furthermore, it may have given the psychological support necessary for him to change.
8.0 - INTRODUCTION

In this chapter I shall present the case study report about Teacher 2. I shall describe Teacher 2's interactions with the different phases of the development process, and analyse the changes in his ideas and teaching practice.

I shall start by presenting Teacher 2, his previous experiences in science teaching, and his personal approach to teaching and learning. Then I shall follow his learning experiences during the process and the consequences on his ideas and practice. I shall also compare the perspective of his students with his own, in relation to the course he gave at the second phase of the development process.

At the end of the chapter I shall summarize the main findings obtained in this case study.

8.1 - PERSONAL CHARACTERISTICS

Teacher 2, as Teacher 1, graduated at UNICAP and started to teach there before my arrival in 1980. He also teaches at private and public secondary schools. He is very concerned about the problems in science teaching and participated, in 1985, in an innovation process, together with another teacher and myself, which involved the Physics 1 course. This process lasted for six months and during it we had the opportunity to work in group, discussing our ideas and teaching practice. Thus, it was not a surprise when he volunteered to be one of the participants in this study.

Teacher 2 is a timid person, but he tries to break his shyness alone, using the cigarette.

...I'm also very timid and always was timid. Then, in the past, I used the cigarette as a defence, as a way to break my shyness,
not to be empty-handed without knowing where to put my hands. I
used the cigarette to buy time, to recover, to get time to calm
down, to take a position.

(Teacher 2, Activity n°2)

He is very independent and values his own perspective of every situation above
all others. Although he considers the pieces of information available, he always
tries to use them to corroborate his previous ideas. Therefore, he is more
sensitive to the aspects which he perceives as important.

Due to his personal characteristics, Teacher 2 is a person who needs self-
motivation to participate actively in a development process which requires
changes in his ideas. He also has to test the new ideas by himself in order to
introduce them in his conceptual framework.

8.2 - PERSONAL THEORIES OF TEACHING AND LEARNING

During the completion of the first grid, which was about the teaching-learning
process and the nature of scientific knowledge, I asked Teacher 2 not to
restrict his thoughts to reality, but to think about the ideal conditions too.
Therefore, his perspective is a mixture of the way he perceives this process and
the way he visualizes it.

At the beginning, Teacher 2 had some difficulty in defining the elements. That
was the first time he was completing a repertory grid, and he spent some time
to understand its components. In the definition of the constructs, he tended to
think in terms of cause and effect. Therefore, we spent two sessions to
complete the first grid.

For Teacher 2, the fundamental elements in the teaching-learning process were
the student's interest, teacher's dedication and time availability for both to be
involved in the process. He stressed the role of the teacher, who had to know the
content and teaching methods. Furthermore, the teacher required some autonomy
for adjusting the course to students' needs, in terms of interest and future
necessities in their professional lives.
Teacher 2's view about the teaching-learning process and the nature of knowledge may be analysed, considering the clusters in the element and constructs trees, shown in Chapter 5.

The element tree contains three clusters. In all clusters there are elements related to the teacher, who appears in the centre of the process, linked to student's interest and curiosity, to the conditions and affective factors. Only one element is directly related to teaching methods.

The construct tree has a large cluster where the idea of better learning appears linked to student's interest, to questioning and to valuation of the process. The teacher is linked to knowledge transmission and to the results of the process, whereas the student is linked to prerequisites and knowledge acquisition.

Thus, Teacher 2's perspective about the teaching-learning process is centred on the teacher, who transmits knowledge, adapting the content to students' interest and necessities. The acquisition of content, which is considered as learning, depends on the student, who needs to be actively involved in the process. The prerequisites and conditions, especially in terms of time availability, are necessary to facilitate this acquisition.

The results obtained from the other three grids completed by Teacher 2, were used to enhance the picture of his ideas concerning teaching and learning.

**FIRST REPERTORY GRID ABOUT CURRICULUM MATERIALS (CM1)**

For Teacher 2, the basic curriculum materials were the textbook and student's notes during lessons. He also emphasized the objects present in students' everyday life and Nature's phenomena. These elements were useful to transmit knowledge to the student.

The teacher was again at the centre of the process, motivating the student, transmitting information and testing the knowledge acquired by the student.

Although Teacher 2 emphasized the relationship between the content and Nature's phenomena, he did not consider any relation between these phenomena and the evaluation materials. The former were used to motivate the process, while the latter were used to check the correctness of student's knowledge.
Therefore, the evaluation was perceived as something occurring after the process, instead of contributing to it.

In the element tree, the largest cluster included elements which were used to transmit information to the student or to check student's knowledge. These elements were not directly related to Teacher 2's teaching method. Therefore, the curriculum materials selected by Teacher 2 were perceived as complementary to his work in the classroom.

According to the construct tree, the activities developed in the school depend on the teacher.

**FIRST REPERTORY GRID ABOUT TEACHER'S ROLES (TR1)**

Teacher 2 had some difficulty in defining the roles played by the teacher during the Physics 1 course.

The matrix relating elements and constructs, as well as the element and construct trees, are shown in Appendix I. The clusters which appear in these trees are shown in Chapter 5.

The elements concentrated on the teacher giving information to the student, encouraging his active participation in the reception of this information and checking the correctness of student's knowledge.

For Teacher 2 it was important to know the level of student's knowledge, to plan the course accordingly. This planning, however, was limited to the beginning of the course. This view reflected the conditions faced by the teachers, who had no time, during the semester, to reflect about their planning and change it.

The evaluation should be carried out during the course, to give information to the teacher, who would adjust his methodology to students' characteristics. The current conditions, however, limited this adjustment to the next course, since there was no time availability to evaluate the student at each stage.

The laboratory was perceived by Teacher 2 as an opportunity of showing the phenomena to the students, facilitating their learning. The relationship between
the content and everyday life also emphasized the practical aspects of the course. On the other hand, the texts and exercises provided by the teacher, which were perceived as evaluation materials, concentrated on the theoretical aspects. Therefore, the evaluation was not integrated with the other elements, which were discussed during the course. It was kept apart, and this could be one of the aspects responsible for students failure.

FIRST REPERTORY GRID ABOUT STUDENT'S ROLES (SR1)

It was much easier for Teacher 2 to define student's roles than to define teacher's roles. He concentrated on the gathering of information and study of concepts.

The element and construct trees are shown in Appendix I. The clusters in these trees are shown in Chapter 5.

The element tree has two clusters: one includes the elements related to the access to information, whereas the other groups the elements related to the learning of information. The perspective is similar to the one held by Teacher 1, that is, the production of knowledge is made by the student alone, mainly outside the classroom, when he studies. The discussion with the teacher and colleagues gives the student the opportunity to check if his knowledge is correct.

In the construct tree, the ideas of access to information are linked to the activities developed inside classroom and related to the laboratory. The use of information is made outside the classroom.

AN OVERVIEW

From the results of these four repertory grids, it is possible to understand Teacher 2's personal theory of teaching and learning. For him, teaching means transmission whereas learning means acquisition of information. Both processes, however, are centred on the teacher, who organizes the information and arouses student's interest to participate actively.

While Teacher 1 emphasized the dialogue as a way to detect student's ideas in order to change them, Teacher 2 gave no information about the way he works in
the classroom. He concentrated on the use of several means to give information to the student, as a complement to this work.

The change on student's ideas occurs when he studies, alone, at home. This change requires time and is influenced by the teacher, because he motivates the student when he relates the content with everyday life.

The evaluation was perceived as a source of information for the teacher, which could help him in checking the correctness of the knowledge possessed by the student.

It is interesting to notice a paradox in Teacher 2's view of the teaching-learning process. He expects the students to assume an active role in the process but at the same time he controls almost all aspects involved in the process.

8.3 - LEARNING EXPERIENCES

The overall impression of Teacher 2 about the workshops and group discussions was positive. He acknowledged the importance of considering students' ideas and objectives for having good learning.

...it is not enough that the teacher knows the content very well and lectures as if he was giving an interview on television. To give a lecture without knowing to whom he will give it, without knowing students' objectives... it may guarantee the teacher's competence regarding the content, but the most important, the learning, it would be lost.

(Teacher 2, Evaluation Cassette)

He also emphasized the necessity of spending more time, during the meetings, discussing the themes with more details.

It is interesting to notice the way he perceived the objectives of these meetings:
Our big discussion has been exactly in relation to learning, that is, to know whether what was seen was well understood, was well analysed.

(Teacher 2, Evaluation Cassette, my emphasis)

During the activities it was noticeable that Teacher 2 was considering the information available from his own perspective. It also became clear in his evaluation cassette, where his comments concentrated on specific aspects which he considered as relevant.

For instance, during the Activity nº 7 (see Chapter 6), when we were discussing the problems related to the oral transmission of information, I made a comment about the influence of time restrictions on participants' capacity of retaining and transmitting information. After reflecting about this comment, Teacher 2 came to the conclusion that either students spend more time in their courses or the content must be reduced. In his evaluation cassette he made the following comment:

One of the most discussed subjects was the length of the programme, the quantity of themes, to be seen in a short time interval.

(Teacher 2, Evaluation Cassette)

As happened with Teacher 1, the aspects highlighted by Teacher 2 were linked to his personal view of the teaching-learning process. Thus, he gave the following reason for the failure of a study presented during one meeting:

Although they had the resources, the learning did not occur. I don't know whether it was due to lack of student's interest or due to a more serious problem - due to what the student considered as correct should stay correct, that is, to change. To make a revolution and what was correct before is wrong now, that is not easy.

(Teacher 2, Evaluation Cassette, my emphasis)

He used his personal experience during this study to consider that it is very difficult to change students' convictions.
During the brainstorming for discussing the problem of evaluation, the participants concentrated on the course's programme. Teacher 2 revealed his preoccupation with the content and its transmission, despite my emphasis on course's objectives. It was interesting to observe that his idea about objective was the transmission of the content which best suited the students' needs.

The practical aspects involved in the instruction were discussed during the workshop "Square Game" (see Activity n°15, Chapter 6). Teacher 2 had the opportunity to evaluate his way of giving instructions, and came to the conclusion that the best way to do that was starting from the student's perspective. His personal experience, however, was not enough to change his practice.

The adaptation of the new ideas introduced during our meetings to Teacher 2's personal conception became evident again during the group discussion "Instructional Process II". At that meeting, he disclosed his idea of conducing the students through small changes devised by himself. Thus, he was considering students' ideas as a starting point for a series of changes occurring under his control.

The mixture of old and new ideas, observed in Teacher 1's view was also noticed in Teacher 2's perspective of the teaching-learning process. The inconsistency between Teacher 2's original perspective and some ideas he incorporated, was not perceived by him, who maintained the new ideas subordinated to the previous ones.

Teacher 2 summarized his learning experiences during this study, as follows:

> During our meetings... I started to observe that just by observing , by being preoccupied with the student, it improves a lot the situation. That happens because you start to perceive that you are not the mastermind, the one who knows everything, and that those who did not understand, they are not unintelligent. ...we start to notice that we are unintelligent if we don't care about the student...

(Teacher 2, Evaluation Cassette, my emphasis)
In his evaluation cassette, Teacher 2 acknowledged that he was changing his practice at the university as a result of our study. He also mentioned some experiments he was introducing in a secondary school, inspired by our discussions.

The practical dimension of our study will be considered in the next section.

8.4 - IMPLEMENTING THE IDEAS

Teacher 2 started to apply his ideas during the meeting to choose the topics of the Physics 1 course (see Activity n°18, Chapter 6). He chose the topic of projectiles, in which he intended to emphasize two aspects: the acceleration of gravity and the equation of the trajectory.

When I asked the teachers to prepare some didactic materials to give support to them, Teacher 2 raised the problem of evaluating the topic. He wanted to know if the evaluation would be carried out according to my perspective or to his. This observation was interesting because it revealed his preoccupation with evaluation.

In the second meeting for preparing the didactic materials, Teacher 2 presented his idea about the development of the teaching sequence under his responsibility. He was quite concerned with the time availability, because he intended to use questions for probing the students and for motivating them, and he did not know how much time he could use for this activity.

In respect to the content, he was especially interested in analysing the difference between a situation with no gravity and another with no air resistance, since the students tend to perceive both as similar. He also intended to explore the mathematical aspects related to the equation of the trajectory, and to analyse the movement using graphs.

In addition to his idea of using questions at the beginning of the teaching sequence, Teacher 2 did not give any detail about the way he intended to work with the students. His preoccupation was concentrated on the information which he intended to give to the students and the level of his explanations.
I suggested him to start thinking in terms of objectives and then to think about the minimum time necessary to attain them.

After my suggestion, Teacher 2 talked about his general objective - the students should understand the independence of the vertical and horizontal parts of the motion of projectiles. Then, he asked me whether he should consider next the content of the teaching sequence or another aspect.

It became clear that Teacher 2 was not able to think about the instruction as a whole. He had not developed yet a complete structure including the formal aspects involved in a teaching sequence, even though we had discussed those aspects during our meetings. His situation was similar to that of a novice student who had contact with some physical concepts, but who did not integrate them in an ordered structure.

During this meeting Teacher 2 asked the participants to force him to continue his work, because he was too busy and needed some pressure to keep going. This aspect - lack of time together with work overload - was a constant constraint to the development of our study. In this case, the support (and pressure) given by the group was fundamental for the occurrence of any change in teachers' practice.

In the last meeting, dedicated to discuss the teaching materials (see Activity no 21, Chapter 6), Teacher 2 did not present his material because he had forgot it. Nevertheless, he talked about his intention to apply a questionnaire to elicit students’ alternative conceptions. He did not give, however, any explanation about the teaching method which he intended to use.

8.4.1 - PILOT LESSON

Teacher 2 used only one lesson of ninety minutes to test the material which he had prepared for the Physics 1 course. His topic was projectiles and the lesson was given to a group of fourteen secondary school students, who had already studied the topic, at their school.

At the beginning of this lesson, Teacher 2 talked about our study and its objective. According to him:
We spent one semester trying to discover something, some details about the teacher's way of giving classes, which we know that difficult students' understanding... our idea is to introduce something different in order to modify this situation.
(Teacher 2, Pilot Lesson)

What he intended to introduce was presented in terms of content - some topics, which he considered as fundamental, the sequence of these topics, the time dedicated to each topic.

After this brief presentation, Teacher 2 presented his plans for this lesson. He had thought about using three lessons to discuss his topic (projectiles), analysing several types of launching. After our discussions, however, he decided to concentrate the topic in one lesson, discussing only one type of launching and starting with the concept of acceleration, which he considered as an important concept. Then, he wrote the objective of this lesson on the blackboard - *to work with the launching of projectiles*.

At the start, Teacher 2 used a graph to introduce the concept of acceleration. The variables on the axes were the number of mangoes on a tree and the day of the observation. He constructed the graph and then asked questions about it. He determined the variation of the number of mangoes by day, with the help of the students, and compared it with the concept of acceleration.

After analysing this graph, he made another diagram relating the velocity of a person riding a bicycle, with the time. He continued to ask questions, which the students answered quite willingly. The students also asked him some questions and discussed his answers.

The answers given by the students were summarized by Teacher 2 and written on the blackboard.

Teacher 2 made another diagram, relating the velocity and the time. In this case, the velocity was increasing at a constant rate. The students presented more doubts. Two of them related the rate of variation of the velocity to acceleration. The others misunderstood the units and were not able to identify the acceleration, which was defined by Teacher 2 after this discussion.
In the next part of the lesson, Teacher 2 let go a piece of chalk and asked questions about the motion of this body. Later he analysed the motion of a cigarette-lighter, which fell from his hand, and finally, he considered the motion of both, the piece of chalk and the cigarette-lighter. He was interested in the time which they spent to fall, and in the concept of gravity.

From this time on, the students did not answer the questions made by Teacher 2, who continued the lesson telling the students all the answers.

Finally, he considered the case of a free fall and emphasized the values of the velocity during the motion. The students were mixed up with the sign of the velocity and acceleration. Teacher 2 tried to overcome these difficulties using examples, but they were not understood by all the students. He tried to explain student’s difficulties by the different way used by physics teachers at the secondary schools to work with this topic.

**ANALYSIS OF THE PILOT LESSON**

Teacher 2’s perspective about our study was revealed again at the beginning of the lesson, and it is interesting to notice that he concentrated on teacher’s role and on the content.

In relation to the lesson, his objective was to work with the launching of projectiles. Similarly to Teacher 1, he thought in terms of a specific knowledge, which he intended to transmit to the students. He used analogies to explore the concepts and facilitate students’ understanding.

Instead of exploring students’ views about the topic, Teacher 2 tried to guide the students to some conclusions, using questions and concentrating on specific aspects of the analogies presented by him.

Despite the emphasis given to the oral presentation of his ideas, he also used the blackboard, during the whole lesson, and two materials available in the classroom: his cigarette-lighter and a piece of chalk. Although he did not use lesson notes, the lesson was structured and seemed to have been planned in detail.
The whole lesson was controlled by Teacher 2, who continued to present the topic even when the students stopped to ask questions. The transition from the use of analogies to a more traditional approach was accompanied by less student involvement in the lesson. Teacher 2 seemed to perceive what was happening, but he did not change his behaviour. On the contrary, his main preoccupation seemed to be with lack of time to present the content which he had prepared.

In general, this lesson presented the characteristics identified in Teacher 2's perspective about the teaching-learning process. The teacher was at the centre of the process, controlling the transmission of knowledge, trying to involve the students actively and emphasizing the aspects which would lead to the conclusions he wanted to reach. Students' ideas were used only to reinforce the presentation of the content.

After this pilot lesson we decided to change the schedule of the Physics 1 course, in order to emphasize the concepts of velocity and acceleration. These concepts were chosen due to the difficulties presented by the students.

8.4.2 - MEETINGS TO PREPARE THE SCHEDULE

The new schedule was discussed during three meetings held at consecutive days. It is presented in Appendix III.

During the first meeting, we discussed the draft brought by Teacher 1, which presented a sequence of topics. Teacher 2 suggested the inclusion of two topics and changes in the sequence chosen by Teacher 1.

Teacher 2 reminded us to introduce something new in this course, instead of repeating what we do at secondary school. His observation was related to a remark which I had done about the test material prepared previously by him. He also pointed out his preference for a flexible schedule. This aspect was discussed, regarding the time limitations we face during this course and the problems which could derive from an excessive flexibility. In fact, the non-observance of the schedule caused problems to both teachers.

In relation to the topics, Teacher 2 stressed the problem with the acceleration, which was detected during his pilot lesson. At this point, while I tried to
emphasize the necessity of developing materials which could be used by the students, Teacher 2 concentrated on his idea of working with a specific equation (on the blackboard).

During our discussions about the best way to present a topic, it became clear that Teacher 2 had a very limited view of the use of a reference frame. This aspect was important for the development of the course, and could be linked to the difficulties presented by the students in using reference frames.

Specific details about the way to present the topics were discussed during the second meeting. Teacher 2 presented some of his strategies. At that occasion, I repeated my remark about the importance of giving written materials to the students. Both teachers, however, declared that they had no time availability for preparing these materials.

During the third meeting, Teacher 2 was interested in discussing the teaching methods. The evaluation was another aspect emphasized by the group members, who realized that the schedule was not enough to guarantee the success of their work during the course.

A copy of the schedule was given to the participants. It was not followed by Teacher 2, who declared during our final meeting, held on 28/06/88, that he had looked at it only once during the course. His reason for the non-use of the schedule was his experience in giving this course. Despite his remark, he considered the schedule very important, because it could guide his work. In addition, we checked the development of the course during our meetings, held once a week, based on the schedule. For him, he did not have to be dependent of the schedule.

It is interesting to observe the implication of a personal characteristic of Teacher 2 for his teaching practice. Although he had recognized the importance of the schedule, he did not want to be dependent of it. He preferred to rely on his past experience in giving this course, and to consider the schedule only in general terms. Thus, the sense of independence of Teacher 2 appeared as an important aspect inhibiting change.
8.4.3 - MEETING TO PRESENT THE TEACHING MATERIAL

This meeting was held at the Physics Department after the beginning of the Physics 1 course. Its objective was to present the changes introduced by Teacher 2 in his teaching sequence, after the pilot lesson. The meeting was attended by the participants in this study.

Teacher 2 intended to use the material he was presenting, in two lessons of ninety minutes each. He started the meeting by reading the material, which included the necessary prerequisites for these lessons. It also contained the objectives of the lessons: to show the vertical, horizontal and oblique launchings; to represent graphically their motion and to determine the equation of their trajectories; to observe the independence of the vertical and horizontal parts of the motion, and to use the reference frame. These objectives should be given to the students.

The first type of launching to be analysed would be the free fall. He would give a table which presented the results of an experiment, where a particle fell from different heights. The table related the height with the time interval of the fall. He would invite the students to make a diagram relating these variables. The shape of this diagram would be considered by the students to determine the type of equation which represented this motion.

During Teacher 2 presentation, the participants pointed out some aspects which were related to students' doubts. It became clear that Teacher 2 had already thought about a specific way to present the topic, and that he did not intend to explore students' ideas about it.

Teacher 1 asked Teacher 2 about his intention of using any group activity. He answered that he was applying a strategy which enabled more student participation - instead of telling the conclusions to the students, he was inviting them to tell by themselves.

Teacher 2 stressed the importance of two previous lessons for students' understanding and participation in this lesson. At this point, by his explanation, it became clear that he considered the students as able to understand, because they had had a previous contact with all aspects which he considered as necessary, and they had used this content in solving exercises and in making
diagrams too. Since he had organized the content on the blackboard, he expected that the students had done the same in their minds. Despite our discussions during one semester and his personal experience in activities designed to emphasize the fragility of this idea, Teacher 2 still kept it in his conceptual framework.

The material presented by Teacher 2 also included three questions to be used as an evaluation. I asked him about the way he intended to use these questions and it was not clear for him. It seemed that Teacher 2 concentrated on the content he wanted to transmit and did not think about the teaching methodology, when he prepared this material.

The second part of the material included an experiment to be carried out on teacher's desk, to discuss the horizontal launching and the independence of the horizontal and vertical parts of the motion. Teacher 2 intended to use two coins and a ruler to throw one of the coins horizontally, while the other would fall vertically. The experiment was very simple and interesting, and its objective, according to Teacher 2, was to enable the students to answer the following question: If the velocity increases, the time interval of the fall will also increase? By answering this question, the students should come to the conclusion that the horizontal and vertical parts of the motion were independent.

Teacher 2's idea that the experiment was evident by itself was questioned by the participants, who discussed several aspects which could not be clear for the students. It was interesting, however, because it revealed an aspect of Teacher 2's perspective which is very relevant for his teaching practice.

In general, the material prepared by Teacher 2, in opposition to the one prepared by Teacher 1, emphasized the mathematical aspects of the topic and its transmission. It was organized according to Teacher 2's ideas about the teaching-learning process, although it included small details which could be linked directly to the aspects discussed during our study.

Similarly to Teacher 1, Teacher 2 kept his central ideas and included new ones in his conceptual framework. Any inconsistency between these ideas was not noticed by Teacher 2, who perceived the new ideas through his own goggles.
Teacher 2 was observed during a total of fourteen hours, while he was using both traditional and innovative methods. Out of these, ten hours were recorded.

I was introduced to the class at the end of the first lesson, as a member of a group, which included himself, who was conducting a research. He asked the students to help me with my work, participating in interviews. Few students were interested and only two could participate.

During my observations I had to sit at the right corner of the classroom, to plug in my tape recorder. The students usually sat at the left side to look at the blackboard from a more appropriate angle (due to the illumination). This physical separation together with lack of student interest, constituted an obstacle to my communication with the students. They were not relaxed in my presence, and avoided making more questions in order to hide their misunderstandings.

While the students changed their behaviour during the observations, Teacher 2 did not pay much attention to my presence, concentrating his attention on students' reactions.

The group had students in different undergraduate courses and several were repeating the Physics 1 course for the second or the third times. The constant delays and parallel talks between the students revealed their lack of interest in this course.

During the first lesson, held on 3/2/88, Teacher 2 adopted the same methodology which he used in his pilot lesson. He conducted the lesson, making questions and leading the students to the conclusions he wanted. The majority of students did not answer his questions, but stayed listening.

Although the lesson plan was not prepared by himself, Teacher 2 was at ease with the material, giving details and acting as though the material were familiar to him. He followed the instructions, but adapted the material to his teaching style.
At the second observation, which occurred on 1/3/88, the course was delayed in relation to the schedule prepared by the teachers. Some students arrived thirty minutes after the beginning of the lesson. The parallel talks were very disruptive, and only a few students were participating actively in the lesson.

Teacher 2 adopted the same methodology, guiding the students towards the conclusions which he had chosen, using questions and waiting for the answers or, sometimes, answering himself. He concentrated his attention on the students who sat close to him, in the first few rows nearest the blackboard.

The next lesson to be observed was the second one in the teaching sequence about projectiles. Teacher 2 emphasized the mathematical aspects of the content and, in opposition to Teacher 1, he used the blackboard as his main support. He continued to ask questions to the students, without discussing alternative ideas, and answering when the students did not. Teacher 2 did not perceive that the students were not following his mathematical explanations and that they were only answering those questions concerning the situations he was exploring in the experiments.

At the next observation, Teacher 2 used the material developed by Teacher 1, introducing extra information and changing the approach. Instead of presenting the situation and asking the question chosen by Teacher 1, Teacher 2 tried to guide the students towards the relationship involving force and velocity. He showed a box at rest and started to ask questions. T2 represents Teacher 2's utterances and Ss students'.

T2: What should I do to move this box?

Ss: A force (in choir).

T2: I should apply a force. Can you agree that what I am doing is a force?

Ss: Yes (in choir).

T2: And now, as soon as I applied the force, what happened to the box?

Ss: It moved (in choir).
T2: What happens if I apply a stronger force?

Ss: It moves quicker (in choir).

T2: It increases the velocity. And what happens if I stop the force?

Ss: It stops (in choir).

T2: If this force is very weak, the velocity must be...

Ss: Low (few students).

T2: If I increase this force, as long as I increase the force, the velocity will...

Ss: Increase (few students).

T2: But even if I increase the force and then I stop it, the motion will... cease, isn't? So, I am relating the force with...

Ss: The velocity (few students).

T2: Without this force, there wouldn't be... velocity.

At this point, a student said that the box stopped due to a disacceleration. Teacher 2 said that there was an acceleration while the force was applied, and asked the students to define acceleration.

T2: How is the acceleration involved in this situation? The box was at rest, I applied a force and now, what happened? What are you relating now? Are you relating the force with the velocity? What happens when I stop the force?

Ss: The velocity decreases (few students).

With the inclusion of the acceleration in the discussion, Teacher 2 intended to give a hint to the students towards the right relationship - force and acceleration.
After this discussion, Teacher 2 followed the instructions contained in the teaching material, but he was not able to keep an open discussion involving students' answers to a specific question proposed in the material. He tried to guide the students towards the right answer, stopped, gave hints, etc. He was controlling himself to try to follow a methodology which was different from his own.

The next observation occurred more than one month later. At this occasion, Teacher 2 was using the material prepared by myself. He had to elicit students' ideas about the concept of work, using pictures given to small groups, and discussing these ideas afterwards.

The opinions given by the students were written on the blackboard and then Teacher 2 started to read each one and to make comments about them. These comments, differently from the previous lessons, were not leading the students towards a specific conclusion, but were used to elicit more information from the students, who were involved in the discussion.

It was possible to notice that Teacher 2 was adopting a different methodology. Instead of leading the students, he was questioning their opinions without giving a definite answer. He was considering students' opinions to construct, with the students, a plausible answer.

During the first part of this lesson, the students participated more actively, making questions and answering Teacher 2's questions. At the second part, however, Teacher 2 adopted a more traditional methodology, emphasizing the transmission of knowledge, and the students started a parallel talk which lasted the rest of the lesson.

During the final meeting to discuss our study, Teacher 2 acknowledged the difficulty he felt when he was giving this lesson, because the teaching material required a methodology which was very different from his own. It is interesting to notice that the teaching material developed by Teacher 1 also required a similar methodology. In that case, however, Teacher 2 was not able to apply the material with the methodology chosen by Teacher 1. Therefore, although Teacher 2 felt some difficulty, this time he was able to follow the instructions and to present a different teaching practice.
In brief, Teacher 2 revealed the ability to change his teaching methodology, even though this change was guided by some material prepared by others. To reach this stage, Teacher 2 had to include new ideas in his conceptual framework, reflect about them, adopt new strategies in his practice, and discuss these strategies. Initially, his practice was not consistent with his ideas, although he did not perceive it. At a second moment, his teaching practice was a mixture of his previous style with some strategies inconsistent with this style. Again, the incoherence of his practice was not perceived by Teacher 2. Finally, he presented a different teaching style, which included elements of his previous teaching practice and other elements required by the teaching material, integrated in a coherent practice.

After his experience with the teaching material developed by Teacher 1, Teacher 2 received the feedback given by me, during our discussion after the lesson, and by the cassette in which I recorded the lesson. This feedback together with Teacher 2's interest and dispossibility for analysing and restructuring my teaching material before using it, led to his understanding of the theoretical and practical aspects of this material. This understanding was demonstrated by his coherent practice.

8.5 - CHANGES IN PERSONAL THEORIES OF TEACHING AND LEARNING

The influence of this study on Teacher 2's ideas about teaching and learning was analysed more specifically through four repertory grids (see Chapters 4 and 5) completed at the end of the study.

As was emphasized before, the analysis of these grids cannot give an absolute measure of the changes which occurred in Teacher 2's conceptual system, but an idea about these changes.

SECOND REPERTORY GRID ABOUT TEACHING-LEARNING PROCESS AND NATURE OF KNOWLEDGE (TLP2)

This grid was completed after Teacher 2 finished the Physics 1 course. The elements were elicited quite easily, whereas the constructs were not.
The majority of elements was related to the teacher, who was at the centre of the process, transmitting knowledge to the students. Thus, the central ideas of Teacher 2 did not change.

The first element was teacher's knowledge about content. This element revealed the importance given by Teacher 2 to the knowledge which should be transmitted during the teaching-learning process.

The reception of the knowledge, understood as learning, was also an important aspect of this process. The students should be involved through their interest and the importance of the course for their professional lives. The knowledge would be constructed in students' minds in the following way:

...through the methods which will be used by the teacher, since he knows the teaching methods and he had time to prepare the lessons and to probe students' level of knowledge.

(Teacher 2, TLP2)

Another way of facilitating student participation would be through the reading of books, which should be encouraged by the teacher.

Several elements were similar to the ones which appeared in the first grid about the teaching-learning process. It is interesting to notice that the element student's curiosity, which appeared in the first grid, was substituted by student assiduity in the second. Thus, instead of assuming an active role, where their curiosity was perceived as an important factor related to their learning, the students were now assuming a passive role, with their presence, to receive information, being perceived as the important factor.

Other elements related to the student, which appeared in the first grid, were substituted by elements related to the teacher. This emphasis given to the teacher may be linked to Teacher 2's reaction to our reality, where the students prefer to assume a passive role in the teaching-learning process, due to lack of conditions to study (the majority of students has to work to pay the university) and lack of interest in a course whose content seems to be completely apart from their everyday lives.
The element tree presents two large clusters. In the first, the elements identify the necessary conditions and prerequisites, together with a teaching strategy to enhance the process. This cluster is organized around the teacher. The second cluster is more related to the student, and includes elements of several types (related to conditions, evaluation, curriculum and affective factors).

The constructs in the construct tree are not closely linked. The closest ideas are the activity developed in the classroom, the involvement of the institution and the participation of the teacher and students. There are no constructs which indicate the type of activity developed in the classroom. This lack of attention to the teaching methods and emphasis given to the conditions, seem to reflect Teacher 2's belief in the lack of conditions as the main difficulty for learning to occur.

The evaluation was perceived as a source of information for the teacher:

*When I verify periodically the learning, I am verifying whether the method which I have used, my method, has worked or not.*

(Teacher 2, TLP2)

In brief, the ideas presented by Teacher 2 were not very different from the ones he presented in the first grid. The teacher was again conducting the process and the preoccupations included in this perspective, such as those with curriculum and evaluation, were subordinated to the central ideas. Hence, the changes introduced in Teacher 2's view were perceived as an extra support for the teacher.

**SECOND REPERTORY GRID ABOUT CURRICULUM MATERIALS (CM2)**

The elements present in this second grid are similar to those present in the first. The organization, however, is different. The elements *textbook* and *laboratory*, for instance, which appear in the same cluster in this last grid, were in different clusters in the former.

The element tree has three clusters. The first includes the elements related to the development of the course. These elements, excepting the element *regular university tests*, which is related to the evaluation, may be classified in the
category conditions, since they constitute the sources of information which give support to Teacher 2's teaching practice.

The second cluster includes the elements *evaluation after each chapter* and *students extra-class activities*. The relationship between these elements was considered by Teacher 2 as follows:

When I make an evaluation using questions or exercises after each chapter, I am evaluating at each step. These questions and exercises may be about the extra-class activities which I have defined.

(Teacher 2, CM2)

Therefore, this evaluation constitutes an extra activity, which is linked to the activities developed by the students outside the classroom. The intention of Teacher 2 was to use this evaluation to control these activities.

The third cluster includes two elements related to activities developed at the beginning of the course.

The control exerted by the teacher appears in the only cluster present in the construct tree. Teacher 2 seems to be convinced of the importance of this control for the efficacy of the teaching-learning process, and applies this idea in his teaching practice.

In general, this second grid included elements which may be related to our study. First, the element *course plan*, whose practical importance was acknowledged by Teacher 2 after his experience in preparing the course schedule and giving a course guided by this instrument. Second, the elements *initial evaluation* and *evaluation after each chapter*, which revealed Teacher 2's preoccupation with the evaluation.

Despite the inclusion of new elements and the reorganization of the old ones, the grid did not show great changes in Teacher 2's perspective.

SECOND REPERTORY GRID ABOUT TEACHER'S ROLES (TR2)

The first element chosen by Teacher 2 in this grid was *the one who gives*
classes frequently. This element, together with the others chosen by Teacher 2, revealed his preoccupation with the practical aspects involved in the teaching-learning process. He also included elements related to affective factors, and excluded elements related to the teaching methods. Furthermore, the elements related to the teaching methods concentrated on activities developed by the students outside the classroom.

Teacher 2 was convinced that the students needed more time to study, otherwise that would constitute an important reason for their failure. He emphasized the importance of the learning occurring outside the classroom. On the other hand, the learning occurring inside the classroom depended mainly on teacher's performance, which included the affective relationship with the students. This relationship was important enough to compromise student learning.

The constructs were very loosely connected and included ideas related to various aspects such as the quantity of information/quality of the course, evaluation after/before the course, affective/cognitive aspects and directed/non-directed learning. These constructs were very general and did not give more information about Teacher 2's ideas.

In general, the major change in relation to the first grid about teacher's roles was the inclusion of elements related to affective factors. The consideration of this aspect enlarged Teacher 2's perspective about the teaching-learning process.

SECOND GRID ABOUT STUDENT'S ROLES (SR2)

Teacher 2 expected that the students assumed an active role in the process, looking for information, criticizing, relating the course’s content with their previous knowledge, making an auto-evaluation and attending classes. He also expected that the students applied the course’s content to their everyday lives.

According to Teacher 2, learning is the same as assimilating information. Furthermore, if learning occurred, the student should be able to apply this knowledge to his life. Therefore, during the course, the student should have access to information, dedicate some time to study this information and finally apply this information.
The element tree has two clusters. The largest cluster includes the elements perceived as essential for learning to occur. These elements may be classified in the categories conditions, evaluation and teaching methods. It is interesting to observe that the majority of elements are related to the conditions (see Chapter 5).

The other cluster includes the elements the one who makes an auto-evaluation and the one who relates the content with his previous knowledge. These elements were perceived as desired activities which could be complementary to the process.

The construct tree presents a large cluster which associates the ideas of learning and knowledge assimilation with the ideas of evaluation in group and permission to discuss the teaching methodology. Although the learning was enhanced by the group activity, the application of this knowledge was perceived as an activity of the individual, which would allow him to know if he had learned.

The relationship between group activity and learning may be linked to the discussions during our study. Therefore, as happened with the other grids, it is possible to notice that our study contributed for the inclusion of some elements and for the reorganization of Teacher 2's ideas. There were no major changes in Teacher 2's perspective about the teaching-learning process, but the changes already introduced into his perspective may lead to more restructuring which may affect the central ideas.

8.6 - EVALUATING THE RESULTS

Students in Teacher 2's class were interviewed, to detect possible influences of his teaching methods on their ideas. The main results of these interviews are shown in Chapter 6.

Some aspects, which seem to be related to Teacher 2's way of teaching, are discussed below:

- The students present difficulty in locating the origin of the reference frame. Although Teacher 2 emphasized the use of a reference frame in the analysis
of motions, during these occasions he gave no attention to the precise location of the frame. He was more interested in determining the orientation of the axes.

- Time interval and instant are mixed up. The difference between these concepts was not explored. Moreover, the average and instantaneous values of velocity and acceleration were not discriminated.

- There is a relation between the direction of the velocity and the trajectory only for circular motion. This relation was stressed by Teacher 2 while he studied this motion. On the other hand, he paid no attention to this relation when discussing other motions.

- The sign of the acceleration is linked to the sign of the velocity. This alternative conception was detected amongst Teacher 2's students, despite his emphasis on the relationship between the acceleration and the variation of velocity.

- The students presented several doubts concerning the angle in work's formula. The definition of this angle was given to students but was not explored using exercises.

In general, the changes detected in student's conceptions, similarly to what happened with Teacher 1's students, were limited to specific aspects treated during the course. On the other hand, some alternative conceptions remained unchanged even after being discussed during the instruction.

In the evaluation meeting, held at the end of this study, Teacher 2 emphasized the importance of our study for his teaching practice. He had started a post-graduation course about teaching methodology and was convinced that this type of activity is very useful for teachers, because enables the reflection about their teaching practice. This type of reflection was also carried out during our study. Therefore, although the changes in the practice of Teacher 2 were not very noticeable, the changes in his ideas and especially in his self-esteem were acknowledged by himself.

The observations carried out during the lessons were also positively perceived by Teacher 2. Although he admitted to be slightly disturbed by my presence, he
welcomed my comments and suggestions, which helped him in enhancing his understanding of the subtleties of the teaching-learning process.

The answers given by Teacher 2 and some of his students to a questionnaire applied at the end of the Physics 1 course (see Chapter 6 and Appendix II), will be considered below, to point out possible sources of conflict.

Amongst the students who answered the questionnaire, 47% were repeating the course. These students perceived a positive difference between this and the previous time.

In relation to teacher's attitudes and activities, Teacher 2 and his students agreed in the three most preferred alternatives. It is interesting to notice that the fourth most preferred alternative was not chosen by Teacher 2, although he had emphasized the importance of giving texts to the students, when answering the grids. He did not emphasize, however, the importance of giving lists of exercises.

The students' interest in lists of exercises may be due to the use of exercises in Teacher 2's evaluation. Despite his emphasis on concepts, he generally used exercises in his tests.

In relation to students' attitudes and activities, Teacher 2 and the majority of students agreed in only one alternative. The alternatives selected by Teacher 2 confirmed his perspective about the roles assumed by the students. He expected an active participation during the lessons and outside the classroom. The students, however, although recognizing the importance of studying alone, concentrated their preferences on their activities inside the classroom.

The majority of students and Teacher 2 agreed that the use of the blackboard is essential to the teaching-learning process and facilitates content presentation. On the other hand, while the majority of students considered that it is not useful to introduce new concepts, although it is useful to learn concepts, Teacher 2 was neutral in relation to these two aspects. These answers were controversial, especially concerning Teacher 2's opinion, since he always emphasized the importance of learning concepts.
The major disagreement in relation to the use of the blackboard, however, concerned the development of critical sense. While Teacher 2 was in favour, the majority of students was against. Therefore, if Teacher 2 expected that the students assumed a critical role in the process, he was not attaining this objective by using the blackboard.

Another important aspect considered in the questionnaire was the role of the written tests. In this case, Teacher 2 and the major number of students agreed in only two out of ten alternatives. Furthermore, Teacher 2 was neutral in eight alternatives. It is also interesting to notice that, although the majority of students considered these tests as useful to evaluate them, the students' opinions were divided in relation to their capacity of enhancing learning fixation and testing learning.

In relation to students' performance, it became clear that they have not studied enough. Lack of time was a constant problem for students and teachers and constituted a major constraint for their improvement in general. Therefore, it was not a surprise to receive the suggestion of reserving more time for the Physics 1 course.

The students and Teacher 2 also disagreed in relation to the teacher's performance. While the majority of students considered his performance as good, Teacher 2 perceived it as regular. This disagreement may be related to their different expectations in relation to teacher's and student's roles.

8.7 - SUMMARY

There were no major changes in Teacher 2's ideas, but an enlargement of his perspective about the teaching-learning process, with the inclusion of elements of different types. His central ideas, however, were kept undisturbed.

The most important aspects for the development process undergone by Teacher 2, were:

- The opportunity of experiencing, by himself, the advantages and limitations of teaching strategies based on perspectives about the teaching-learning process, which were different from his own, enabled Teacher 2 to include
new ideas in his conceptual framework. It also facilitated the questioning and reorganization of his previous ideas;

- The process was very open and as Teacher 2 is a rather uncompromising character, he felt free to participate and get more involved. Thus, the harmony between the personal characteristics of the participants and the characteristics of the process were highly relevant;

- The support and pressure provided by the group seemed to be extremely important for the continuation of the process, because Teacher 2's other activities created demands which tended to involve him completely. The links developed by the group work acted as opposite forces, helping him to keep going.
CHAPTER 9
CONCLUSIONS

9.0 - INTRODUCTION

This study was developed with the objective of answering the following research questions:

- How does teacher's awareness of his/her own implicit theories of teaching and learning enable him/her to evaluate/change his/her teaching practice?

- How does teacher's construct system in relation to curriculum materials interfere in his/her adoption of new teaching methods?

- What aspects of PCT could be used in respect of what aspects of a physics course?

In this chapter I shall answer these questions based on the results of this research. I shall also present a model of learning which considers aspects of the Personal Construct Theory (Kelly, 1955).

Suggestions for future researches will be given at the end of this chapter.

9.1 - ANSWERS TO THE RESEARCH QUESTIONS

The first research question is related to the personal theories of teaching and learning, which are developed by persons in general, and teachers in particular. These theories result from years of experience in classrooms, first as students and finally as teachers. Consequently, they are highly complex, involving cognitive and affective aspects.

On the other hand, the common occurrence of the teaching-learning process in our lives, favour the idea that this is a simple process, which does not require any theoretical preparation but practice.
Time constraints (see Chapter 2, p. 58) were perceived, for example, in the case of Teacher 1, when he was giving lectures with materials prepared by others. He did not have enough time to study the materials and to adapt them to his own teaching style. As a result, he just ignored important parts of them. It was also linked with the problem of ascribing meaning. Since those parts were not meaningful for him, he just ignored them.

The problem of social constraint (see Chapter 2, p. 58) was felt, for example, when Teacher 1 decided to solve problems in the way students were used to. Thus, tradition combined with time constraints proved to be stronger forces than the will to change teaching procedures.

Although the participants intended to change their teaching practice into a constructivist one, they were only able to introduce some aspects of it, concentrating their strategies on traditional procedures. This was similar to what happened to student teachers working with the material developed by Gilbert and Osborne (1981) (see Chapter 2, pp. 47-48).
These two aspects together lead to lack of questioning of these theories.

During this study, I tried to elicit the personal theories of the participants, using repertory grids, workshops and group discussions. We also discussed other perspectives, and reflected on their advantages and limitations.

It was noticeable that the process of elicitation was long and difficult, and required more time than expected. The instruments used during this process acted upon different parts of participants' theories, revealing different aspects of them. Thus, the repertory grids were more useful to elicit the theoretical aspects, whereas the workshops enabled the elicitation of practical aspects.

After starting the process of elicitation, it became clear to the participants in this study that the reflection on their ideas was an endless process. The difficulties in keeping this reflection without support, however, was also acknowledged by the participants.

* The distance between theory and practice was another aspect which became clear to the teachers who decided to change their teaching practice. Despite their awareness of their implicit theories of teaching and learning and their willingness to change, they had to identify several automatic procedures included in their teaching practice before being able to consciously act upon their practice. This identification was performed with the support of observations carried out inside their classrooms.

The awareness of their implicit theories also facilitated the teacher auto-evaluation because it identified the points to be evaluated.

** In summary, although the awareness of their implicit theories was a very important step towards evaluating/changing teachers' practice, it became clear that it is a necessary but not sufficient condition. The awareness of the elements which constitute their teaching practice was identified as another necessary condition.

The second research question is related to the influence of the ideas in the construct system concerning curriculum materials on the adoption of new teaching methods.
As discussed before, there is a distance between theory and practice. Furthermore, in the repertory grids about curriculum materials completed by the participants, very few elements were related to teaching methods. The majority of the elements were related to conditions necessary to the process. Therefore, there was no direct link between the ideas in the construct system related to curriculum materials and the teaching practice.

An important aspect related to this question was the awareness of the theories supporting a teaching method. Thus, in order to adopt a different teaching method, the teacher has to analyse the method carefully, identifying the theoretical assumptions included in it. He also has to be aware of the inconsistencies between these assumptions and his own to make the necessary adaptations in the material or in his teaching style. More reflection upon the possible uses of curriculum materials, as well as upon the relationships between these uses and the theoretical assumptions included in the teaching methods is required.

All this care is necessary if the teacher intends to test a new teaching method. Otherwise, it is possible that the use of the method disregards fundamental aspects, which may compromise its efficacy.

The third research question will be answered in two ways. In general, some aspects of PCT may be used to construct a model of learning, which may guide teachers' practice in a physics course. This model will be presented in the next section. In particular, the fundamental postulate of PCT is especially relevant for the experiments used in physics courses. Although physics teachers base their teaching methodology (for the theoretical lessons) on different assumptions, there is a general agreement about the role assumed by demonstrations and other experiments conducted in the laboratories. The use of these materials is perceived as an opportunity, for the students, of seeing physical phenomena. Therefore, especially in these occasions, the physics teachers expect that the students approach this event in the same way.

The acknowledgement of the possibility of existing different ways of approaching the same event, would improve the efficacy of laboratory sessions in the physics courses, through the consideration and exploration of these different perspectives.
The importance of the context in relation to concepts became clear during the workshops. The use of specific contexts to introduce aspects of the teaching-learning process were very useful to the participants, who constantly referred back to those contexts during subsequent group discussions.
In relation to staff development, the use of repertory grids and workshops seemed to be a valuable tool for facilitating reflection and elicitation of personal theories of teaching, two necessary conditions for improving teaching practice.

9.2 - A CONSTRUCTIVIST MODEL OF LEARNING

Personal Construct Theory (Kelly, 1955) may be used as a basis for a model of learning. It emphasizes the different ways knowledge is constructed in individuals' minds and that this construction is related to specific contexts.

Based on this view, learning may be thought of as a process of ascribing meaning. Therefore, when persons learn something, it does not mean that they are relating what they have encountered to their current ideas, but that their current ideas may be used to give meaning to what they have encountered.

If the current ideas, or conceptions, of a person cannot give meaning to a specific situation, two alternatives are possible: either the situation is ignored or the person changes his conceptions. The decision in favour of one of these possibilities is not only a rational affair but also an affective one.

When I talk about conception, I mean a system formed by a group of constructs, which is applied to explain events in a specific context. Thus, conception may be thought of as an internal representation of a concept. Although concepts may be considered as abstract entities with universal application, they can only be meaningful to a person if they are internally construed. Since all construction is context-related, it is not possible to construe a concept in a general way, independent of context.

* This aspect is fundamental for teacher staff development since it emphasizes the necessity to consider their classrooms with their specific environments. For students, it is important to analyse different situations related to their reality. Thus, the learning of a concept should start from specific situations where the conceptions could be construed.

... It is well known now from many of the studies of alternative frameworks that children quite readily accept exceptions to the
views or explanations they hold that could not be tolerated in science itself. The universality of scientific laws and concepts and the deductive nature of science are not a priori parts of most school science learners' understanding.

(Fensham and Kass, 1988, p.4, my emphasis)

The capacity of the construct system to hold conceptions inconsistent with each other is acknowledged by PCT's Fragmentation Corollary. Therefore, it is perfectly possible for students to give different explanations to what seems to the teacher as examples of the same concept. This was observed during the interviews with students.

In order to develop their conceptions, the students should try to enlarge their context of application, or range of convenience, that is, they should test their conceptions in other contexts. If they have already construed conceptions to deal with these contexts, and if they are satisfied with them, they have no special reason to change them. However, if they decide to consider a larger context, they will have to adapt their construct systems in order to solve the inconsistencies which may then arise.

In relation to teacher staff development, it is necessary to consider different contexts in order to develop their conceptions. In this case, the test of new teaching sequences with different groups of students may give this opportunity.

The construct system is seen as a hierarchical structure with higher order constructs being linked to an increasing number of other constructs, and being indirectly applied to a larger range of convenience through different sub-systems. Thus, these higher order constructs are responsible for the more inclusive conceptions, that is, for our more general ideas.

Situations may be analysed at different levels. If we apply our more general ideas to perceive the situation, we will be using higher order constructs. It happens, for example, when an expert uses the principle of conservation of energy to solve a set of problems. On the other hand, a novice who has not developed a more inclusive conception, would analyse the problems according to the explicit characteristics which he considered as defining the situations.
An example of keeping higher order constructs intact and changing lower levels ones may be found with Teacher 1, who acknowledged the importance of the dialogue, even with a bad experience:

...we think that there is dialogue happening... but, truly, it is not happening the way I would expect it in the classroom...

and introduced minor changes in his construct system by introducing elements related to our discussions (e.g. course planning and evaluation of teacher and students).
Therefore, the idea of different levels of learning (Bloom, 1972) may be seen as equivalent to the development of conceptions at different levels in the construct system. Since higher conceptions are linked to several lower conceptions, the person may use them to relate different situations and to analyse the relationships between them. These more general conceptions, developed after the lower ones, enable the person to attain higher levels of learning as analysis, synthesis and evaluation.

On the other hand, due to their position within the construct system, higher order constructs are more difficult to change and their change affects more parts of the system. Furthermore, since these constructs are only indirectly linked to different contexts, empirical evidence is less powerful to change them - the changes may occur at a lower level, leaving the rest of the system intact. One example of this case is the use of *ad hoc* hypotheses to save a theory. The higher order constructs, responsible for the central ideas, are kept intact by the introduction of minor adjustments into the system.

Then, how would these higher order constructs be changed?

An important point concerning change in the construct system is the acknowledgement that persons are informed by reason and affection. Thus, even when we are talking about learning of science, it is not possible to thoroughly explain the process of change only in rational terms.

In my opinion, the basic variable involved in the change process is the range of convenience. Changes start to occur when we try to enlarge the range of convenience of the lower order constructs to include new experiences. Once we have a set of sub-systems working satisfactorily within defined ranges of convenience, the next step is to develop higher order constructs to link these sub-systems. If new experiences lead to changes in the sub-systems in a way that it is no longer possible to apply the higher order constructs to link all of them, three situations may occur: either there is a split in the system, with new links being established between some sub-systems and other higher order constructs, or there is a change in the higher order constructs to keep the sub-systems together, or even there is the construction of new higher order constructs to link some of the sub-systems.
It is important to notice that, while fragmentation is used to maintain possible inconsistencies within the construct system by reduction of the range of convenience, major changes occur by integration, when we try to enlarge the range of convenience of conceptions. Therefore, the most important variable in the development of the construct system is the range of convenience.

Considering the complexity of somebody's construct system, it is highly improbable to find two persons with the same construct system. On the other hand, it is not so difficult to discover common aspects between them. Therefore, if learning is associated to ascribing meaning through the use of constructs, the transference of knowledge may not be considered as an efficient process.

The changes in a person's construct system may, therefore, be explained in terms of two processes: fragmentation and integration.

Changes in central ideas, or higher order conceptions, are a result of integration, whereas development of new knowledge is obtained through fragmentation. The combination of both processes leads to the development of the person's construct system.

... Fensham (1980) and Freyberg and Osborne (1985) have argued for conceptual addition rather than conceptual change as a more appropriate cognitive goal of school science education. The work of Marton (1981) and the other Swedish phenomenographers also argues for learning being the addition of conceptions.

(Fensham and Kass, 1988, p.4)

I consider this statement as a requirement for fragmentation instead of integration. It may also be considered as an acknowledgement of the difficulty to obtain integration within the very limited range of experiences available to students in schools.

It is unrealistic to deny that the objective of school curricula is the acquisition of some scientific knowledge by students. This objective, however, is not easily attained because students do not acquire concepts, especially when these concepts are already represented in their minds. The existence of alternative
conceptions, or, as I would prefer to say, personal conceptions, is seen as an obstacle to the acquisition of these conceptions.

I would like to present this situation from a different perspective, and then try to solve its implicit inconsistency. I would prefer to establish the objective of school science education as the construction by the student of conceptions with some characteristics in common with the scientific ones. This construction would occur within a specified range of convenience, limited by the time restrictions faced by students in school. The use of the conception thus constructed would be evaluated, and therefore expected to occur within the same range of convenience. In this case, the main process involved in the change of students' construct systems would be fragmentation.

In the case of existence of a previous personal conception applied to the same range of convenience, however, it would be necessary to change the construct sub-system in order to include the desired characteristics. The degree of difficulty to occur such change would depend on the structure of the rest of the system, and on the student's willingness to change. In this case, what is relevant is the organization of student's construct system and not the structure given to the content by the teacher.

Although the short-term objective of school science education is the development of conceptions within a specific range of convenience, its long-term objective always involves the idea of transfer of learning. The use of principles as a basis to transfer has been acknowledged for a long time (Bruner, 1962). Reviewing the discussion about transfer, Doran and Ngol (1979) decided to conduct an investigation concerning the relationship between retention and transfer. They came to the following conclusion:

*It appears that understanding of concepts can be retained and positive transfer to very similar domains can occur if the instructional experiences are designed with these specific purposes in mind. Review of basic concepts and overt connection between the original and the new domains appear to be supportive of retention and transfer.*

(pp.214-215, my emphasis)
This conclusion is in agreement with my emphasis on the role played by the range of convenience for the development of the construct system. The traditional view of retention of a concept may be translated to construction of a conception which explains experiences within a specific context. The same conception may be used to explain other experiences in different contexts, as long as they can be constructed in a similar way. Thus, the problem of transfer is entirely dependent on the type of system developed by the person. It occurs when new situations may be seen as similar to others previously encountered.

The importance of the context, which I emphasized on several occasions, does not imply that this context must be identified in the real world. The use of abstract contexts and "gedanken" experiments for the development of ideas in situations where it is not easy to obtain empirical data, has shown its utility since the time of Galileo. What seems to be important is to define the characteristics of this context.

Considering that construct systems develop through fragmentation and integration, it is necessary to discuss the role played by higher order and lower order constructs in this development.

Feyerabend (1978) in his analysis of the work of Galileo, shows that when some paradigms are used without problems in different domains, there is no motive, at least from the available results, to change them. Thus, the motive must come from another source. For him, two possible sources would be the metaphysical urge for unity of understanding and conceptual presentation, and Galileo's basic idea about the motion of the earth.

In this case, Galileo is presented as developing his theory starting from his basic assumption and not from the empirical evidence or from the existing theories which were able to explain these empirical results.

Feyerabend used this example to propose that theories are not judged by experience. Kuhn stresses that knowledge grows through challenge to observations and adjustment of theories. This adjustment, according to Watkins (1970), may have a theoretical rather than an empirical cause.

It is important to realize that for these philosophers what is being discussed is the power of empirical evidence per se. If we adopt a constructivist view, the
same empirical evidence is considered in different ways, depending on the person's constructs. Moreover, since these constructs are developed in order to explain situations, abstract or concrete, it is possible for a person to develop higher order constructs linked to abstract situations while keeping the constructs used to explain concrete situations at a lower level within his construct system.

This mechanism would allow the articulation of somebody's ideas being more independent from external influence. It would also explain some examples found in history of science, when the study of the dominant paradigm was important as a way to articulate the scientist's own ideas and to develop them, creating a new theory.

In order to choose between different theories, the person must compare them at the same level. It is equivalent to what Feyerabend (1978) stated:

... we must emphasize that a comparative judgement of observation languages ... can start only when all of them are spoken equally fluently.

(p.80, original emphasis)

This statement has important consequences for teaching. Since new ideas are introduced by the teacher in a rather restricted way, due to limitations in time or to the objectives of the course, the students will not be able to develop new conceptions at a high level. It means that these new conceptions, developed through fragmentation, will not be compared with the basic ideas developed by the students throughout their lives, because they will be at a lower level.

Therefore, it may lead to an apparent conceptual change, because the students may adopt the new conceptions, which are supported by the teacher, immediately after the instruction, and afterwards they may restructure their old conceptions at a higher level in order to include this new information. This restructuring may lead to the abandonment of the conception previously adopted. In this case, what seemed to be an acquisition of a new concept was just the development of a lower order conception unable to take the place of a previous conception.
This type of situation was identified by Gauld (1988) when he investigated the changes in school pupils' ideas as a result of a first course about electric circuits, organized according to a model developed by Cosgrove and Osborne (1983, 1985). This model intended to elicit pupils' conceptions, challenge them, and afterwards give pupils the opportunity to use their new conceptions. It was based on the idea of conceptual change promoted by a situation of conflict.

Gauld conducted a set of interviews with fourteen students from the class, about three months after the course. His results revealed that the great majority of pupils, twenty-five out of twenty-nine, changed their views towards the model which was supported by empirical evidence, immediately after the lesson during which this evidence was provided by the teacher. The apparent reason for this change was the perception of the empirical evidence.

At the time of the interviews, however, just one out of fourteen pupils still adopted this model. The others used the information available to develop their own theories.

Even when beliefs appeared to be unaffected by the lessons, there was widespread modification to the mental context in which those beliefs were embedded. The beliefs were adopted in the face of a wider range of alternatives and by appealing to a richer domain of evidence and reasons.

(p.273)

Even the empirical evidence was transformed by the pupils to give support to their new views:

Students who adopted models other than model D sometimes supported their beliefs by appealing to 'memories' which appeared to be derived from their currently held model.

(pp.272-273)

The limitation of the conceptions developed by students during instruction is also acknowledged by West et al. (1985):

The pupils will develop their own private understanding which will be poorer than the teacher's, partly because they will not
This was recognised with the teachers in this study, whose ideas changed according to the degree of perceived importance of the aspects under discussion. Thus, for example, aspects like 'objectives' (see Activity no. 14), which were not considered as relevant for their practice, were not incorporated in their construct systems.

The use of ad hoc hypotheses to preserve their personal theories, or the existence of 'hostility', in Kellyan terms, was also detected, for instance, when Teacher 2 tried to explain the results observed during the workshops in terms of aspects which could corroborate his personal theories.

In general, I would say that now the teachers acknowledge the aspects described in Tamir's quote (see p. 18) as very relevant for their practice. This change in their perspectives resulted in part from their participation in the activities used during this study, especially the workshops and group discussions, which provided specific contexts where they could apply their ideas. This constructivist approach to staff development highlighted the non-existence of 'instant learning', as described by Lakatos (see pp. 26-27) and the time required for a 'scientific revolution' to occur.

After this study, Teacher 1 moved to another job, at a technical college, where he has more time to study and analyse his teaching practice. He is preparing himself to continue his studies in science education. Teacher 2 now is the Deputy Principal of a faculty which prepares teachers for primary and secondary schools.
internalize all of the bits of information, partly because the inter-relational links will be less extensive, and partly because there will be fewer other experiences, knowledge, and other skills to add meaning to each new bit of information. Any individual pupil's private understanding will, of course, also have some idiosyncratic features.

(p. 33, my emphasis)

Therefore, the situation experienced by students during their courses is that of developing a construct sub-system with a more or less defined range of convenience. If teachers intend to change their existing views, they have to provide opportunities for students to develop new conceptions at the same level of their current ones. It means that they need to construe in the same range of convenience where they apply their present conceptions.

A similar situation is faced by teachers during a staff development process. If the objective of the process is to change their practice, which involves central conceptions, they have to construe in the same range of convenience, that is, they require the opportunity of applying new ideas in their classrooms, otherwise they will only undergo a process of fragmentation.

What is very important to notice is that the development of these new conceptions, as well as the new links generated with existing ideas, will depend directly on the student and can only be influenced by the teacher.*

9.3 - SUGGESTIONS FOR FUTURE RESEARCH

According to the answers to the research questions and to the model of learning presented in the last section, it is necessary to further the analysis of some questions:

- Despite being aware of the objectives of the teaching material, is it possible for the teacher to use it adequately, that is, observing the original intention of the producer, if his own theories about teaching and learning are different?

- What are the contexts in which students' ideas are applied?
- How some contexts considered similar by the teacher are constructed by the students?

- What are the similarities and differences between some contexts and how students' ideas are applied to them?

The answer to the first question will give more information about the support required by teachers when adopting teaching materials developed by others.

The answers to the other questions may clarify the importance of the context for the learning, as suggested in the model presented in the last section.
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In this appendix I shall present the elements and constructs elicited from the participants during the completion of four repertory grids about: teaching-learning process and nature of knowledge (TLP), curriculum materials (CM), teacher's roles (TR) and student's roles (SR).

I shall also present the matrices which relate these elements and constructs as well as the element and construct trees.

Each grid was completed twice, thus there are two grids of each type for each participant.

Teacher 1's first grid about teaching-learning process and nature of knowledge is shown in Chapter 5.

GRIDS ABOUT TEACHING-LEARNING PROCESS AND NATURE OF KNOWLEDGE (TLP)

TEACHER1/2ND GRID (TLP2)

ELEMENTS:
1- Dialogue
2- Student's time to reflect
3- Teacher's time to prepare didactic materials
4- Course planning
5- Course and students evaluation
6- Students' alternative conceptions

7- Teacher's conduct
8- Student's interest
9- Teacher-student relationship
10- Content-everyday life relationship
11- Teacher's working conditions
12- Student's working conditions
CONSTRUCTS:
01- Inside classroom/Outside classroom
02- Connected to affective question/Connected to material question
03- Helps content preparation/Does not help
04- Depends on teaching method/Independent of teaching method
05- Teacher leading the process/Student leading the process
06- Fundamental to learning/Not fundamental to learning
07- Student preparation in content/Student preparation as person

<table>
<thead>
<tr>
<th>Inside classroom</th>
<th>1</th>
<th>4</th>
<th>5</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>3</th>
<th>2</th>
<th>5</th>
<th>outside classroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>connected to affective question</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>helps content preparation</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>depends on teaching method</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>teacher leading the process</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>fundamental to learning</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>student preparation in content</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

- element used to define the construct

**Figure A1-1** Matrix of the second grid elicited from Teacher 1 about teaching-learning process and nature of knowledge (TLP2)
depends on teaching independent of teaching method
connected to affective connected to material question
inside classroom outside classroom
student preparation student preparation as person in content
does not help content helps content preparation preparation
student leading the teacher leading process the process
fundamental to not fundamental learning to learning

- construct with reversed poles

FIGURE A1 - 2 Construct and element trees Teacher 1/TLP2
TEACHER 2/1ST GRID (TLP1)

ELEMENTS:
1- Student's curiosity
2- Interest on subject to be taught
3- Teacher's dedication
4- Time availability
5- Student's socio-economic environment
6- School's infrastructure
7- Work market
8- Teacher's didactic
9- Teacher's knowledge about content
10- Teacher's autonomy
11- Uses of content in everyday life
12- Evaluation methods

CONSTRUCTS:
01- Depends on student/Depends on teacher
02- Depends on economic factors/Does not depend
03- Knowledge transmission/Knowledge acquisition
04- Connected to pre-requisites to teaching-learning process/Connected to results of teaching-learning process
05- Connected to student's interest/Not connected
06- Connected to innovations in the process/Not connected
07- Connected to valuation of process/Connected to mechanical reproduction of process
08- Improves learning/Does not influence on learning
09- Leads to a questioning/Does not lead
10- Connected to teacher's formation/Not connected
Figure A1-3 Matrix of the first grid elicited from Teacher 2 about teaching-learning process and nature of knowledge (TLP1)
Knowledge transmission depends on teacher, connected to reproduction of process. Results of TI process connected to prerequisites of TL process. Knowledge acquisition depends on student, connected to valuation of process. Results of TI process connected to prerequisites of TL process. Knowledge transmission does not depend on economic factors, connected to teacher's formation. Improves learning depends on student's interest, connected to process reproduction of process. Results of TI process connected to prerequisites of TL process. Knowledge transmission leads to questioning, connected to innovations in process. Knowledge transmission connected to teacher's formation. Knowledge transmission connected to teacher's formation.

- construct with reversed poles

Figure A1 - 4 Construct and element trees Teacher 2/TLP1
### TEACHER 2/2ND GRID (TLP2)

#### ELEMENTS:

<table>
<thead>
<tr>
<th>No.</th>
<th>Element</th>
<th>No.</th>
<th>Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Teacher's knowledge about content</td>
<td>7</td>
<td>Time to discuss students' doubts</td>
</tr>
<tr>
<td>2</td>
<td>Student assiduity</td>
<td>8</td>
<td>Uses of content in everyday life</td>
</tr>
<tr>
<td>3</td>
<td>Time availability to prepare lessons</td>
<td>9</td>
<td>Periodical verification of learning</td>
</tr>
<tr>
<td>4</td>
<td>Students' knowledge of course importance</td>
<td>10</td>
<td>School's infrastructure</td>
</tr>
<tr>
<td>5</td>
<td>Assessment of students' knowledge level</td>
<td>11</td>
<td>Incentive to utilization of books</td>
</tr>
<tr>
<td>6</td>
<td>Teacher's theoretical knowledge about teaching methods</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### CONSTRUCTS:

| No. | Construct                                                                 |
|-----|                                                                          |
| 01  | Related to teacher/Related to student                                   |
| 02  | Extraclassroom activity/Classroom activity                              |
| 03  | Activity involving teacher and students/Teacher activity                 |
| 04  | Involves the institution/Does not involve                               |
| 05  | Related to knowledge application/Not related                            |
| 06  | Is made at the beginning of the process/Is made during the process       |
| 07  | Requires usual remuneration/Requires specific remuneration               |
**Figure A1 - 5** Matrix of the second grid elicited from Teacher 2 about teaching-learning process and nature of knowledge (TLP2)

<table>
<thead>
<tr>
<th>Related to Teacher</th>
<th>1</th>
<th>3</th>
<th>1</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>4</th>
<th>2</th>
<th>1</th>
<th>3</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraclassroom activity</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Activity involving teacher + students</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Involves the institution</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Related to knowledge application</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Made at the beginning of the process</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Requires usual remuneration</td>
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<td>3</td>
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<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

○ - element used to define the construct

**Figure A1 - 6** Construct tree Teacher 2/TLP2

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Figure AI - 6' Element tree Teacher 2/TLP2

STUDENT 1/1ST GRID (TLP1)

ELEMENTS:
1- Student's previous knowledge
2- Student's social environment
3- Student's life aspirations
4- Teaching method
5- Didactic resources
6- Student's effort
7- Teacher-student communication
8- Preparation of lectures' content
9- Visualization of the real world in the symbols
10- Affective relation between student and teacher
11- Evaluation
12- Curriculum

CONSTRUCTS:
01- Product of social environment/Not product of social environment
02- Depends on the teacher/Does not depend
03- Depends on the student/Does not depend
04- Systematic/Not systematic
05- May vary during the process/Does not vary

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Figure A1 - 7 Matrix of the first grid elicited from Student 1 about teaching-learning process and nature of knowledge (TLP1)
FIGURE A1 - 8 Construct and element trees Student 1/TLP1

STUDENT 1/2ND GRID (TLP2)

ELEMENTS:

1- Language
2- Didactic material
3- Student's interest
4- Teacher's knowledge
5- 
6- 
7- Evaluation
8- School's physical infrastructure
9- Number of students in the classroom
10- Student's mathematical background

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<table>
<thead>
<tr>
<th>5- Teacher's organization</th>
<th>11- Critical reading</th>
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<tbody>
<tr>
<td>6- Student's organization</td>
<td>12- Teacher-student affective relation</td>
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**CONSTRUCTS:**

01- Depends on the teacher/Depends on the student
02- Utilizes the emotions/Utilizes reason
03- Influences on the conditions to occur attentiveness/Does not influence
04- Facilitates concept formation/Does not facilitate
05- Facilitates content organization/Does not facilitate
06- Unchanging presentation of content/Varied presentation of content
07- Regards student's idea/Does not regard
08- Influences directly on the teaching method adopted/Does not influence

**Figure A1 - 9** Matrix of the second grid elicited from Student 1 about teaching-learning process and nature of knowledge (TLP2)
FIGURE A1 - 10 Construct and element trees Student 1/TLP2

STUDENT 2/1ST GRID (TLP1)

ELEMENTS:
1- Content
2- Objectives
3- Teacher's didactic
4- Teacher's language
7- Didactic materials
8- Student's interest
9- School's infrastructure
10- Teacher's interest
5- Student's prerequisites 11- Teacher's salary
6- Content's utility for the student 12- Evaluation

CONSTRUCTS:
01- Carried out by the teacher/Not carried out
02- May facilitate student's learning/May difficult student's learning
03- Depends on economic factors/Independent of economic factors
04- Depends on teacher's character/Independent of teacher's character
05- Prepares the student for life/Does not prepare
06- Necessary for learning to occur/Not necessary
07- Necessary for planning/Not necessary
08- Depends on teacher's interest/Independent of teacher's interest
09- Necessary for a good teaching/Not necessary
10- May influence on the student's moral formation/Does not influence
11- Depends on teacher's ability to present the content/Does not depend

Figure A1 - 11 Matrix of the first grid elicited from Student 2 about teaching-learning process and nature of knowledge (TLP1)
STUDENT 2/2ND.GRID (TLP2)

ELEMENTS:

1- Audiovisual resources
2- Course's program
3- Teacher's time availability
4- Teacher's working conditions
5- Extra-class work
6- Questions and exercises
7- Student's time availability
8- Student's prerequisites
5- Teacher's general knowledge 11- Student's interest
6- Planning

CONSTRUCTS:
01- Facilitates teacher's work in the classroom/Difficults teacher's work
02- Develops student's interest/Develops student's uninterest
03- Raises the level of knowledge/Does not raise
04- Facilitates reinforcement/Does not facilitate
05- Is not gratifying for the teacher/Is gratifying
06- Influences teaching positively/Influences learning positively
07- Gives conditions to innovate the process/Does not give conditions
08- Is fundamental for evaluation/Is not fundamental

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*Figure A1 - 13* Matrix of the second grid elicited from Student 2 about teaching-learning process and nature of knowledge (TLP2)
FIGURE A1 - 14 Construct and element trees Student 2/TLP2

TEACHER 1/1ST GRID (CM1)

ELEMENTS:

1- Blackboard
2- Written test
3- Oral test
4- Transparencies
5- Lesson plan
6- Laboratory
7- Probe test
8- Slides
9- Textbook
10- List of exercises
11- Auxiliary bibliography
12- Report of activities
CONSTRUCTS:
01- Used to evaluate the student/Not used to evaluate
02- Concrete/Abstract
03- Useful to identify student's initial conditions/Not useful
04- Essential to process/Complementary to process
05- Develops skills/Unrelated to skills
06- Facilitates content presentation/Not useful
07- Teacher's support material/Student's support material
08- Determines methodology/Unrelated to methodology
09- Useful to evaluate the process as a whole/Useless
10- Useful to concept learning/Useful to concept demonstration
11- Useful to lesson preparation/Useful to lesson evaluation

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<th>Written Text</th>
<th>Oral Test</th>
<th>Transparencies</th>
<th>Lesson Plan</th>
<th>Labor Story</th>
<th>Probe Test</th>
<th>Slides</th>
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O - element used to define the construct

Figure A1 - 15 Matrix of the first grid elicited from Teacher 1 about curriculum materials (CM1)
useful to concept learning concrete
useful to concept demonstration abstract
unrelated to methodology not useful
determines methodology useful to identify
not useful student's initial condition
useless useful to evaluate the process as a whole
not used to evaluate student
unrelated to skills develops skills
useful to lesson preparation facilitates content not useful
presentation evaluation
teacher's support student's support material material
essential to complementary to process

- construct with reversed poles

Figure A1 - 16 Construct and element trees Teacher 1/CM1
TEACHER 1/2ND GRID (CM2)

ELEMENTS:
1- Blackboard
2- Lesson plan
3- Laboratory
4- List of exercises
5- Text reading and interpretation
6- Overhead projector
7- Textbook
8- Written test
9- Oral test
10- Seminars
11- Activities timetable
12- Tape recorder

CONSTRUCTS:
01- Develops skills/Unrelated to skills
02- Organizes content externally/Organizes content internally
03- Content development/Content presentation
04- Develops creativity/Does not develop
05- Facilitates communication in the classroom/Does not facilitate
06- Uses student's reasoning/Uses teacher's reasoning
07- Develops student's oral communication/Does not develop
08- Organizes work in the classroom/Evaluates work in the classroom
09- Student active/Student passive
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</table>

- element used to define the construct

**Figure AI - 17** Matrix of the second grid elicited from Teacher 1 about curriculum materials (CM2)

**Figure AI - 18** Construct tree Teacher 1/CM2
Figure A1 - 18' Element tree Teacher 1/CM2

TEACHER 2/1ST GRID (CM1)

ELEMENTS:
1- Textbook media
2- Student's notes during lesson
3- Scientific publications
4- Blackboard
5- Everyday life objects
6- Audiovisual resources
7- Reports from communication
8- Voice
9- Laboratory
10- Nature's phenomena
11- Discussions with colleagues
12- Evaluation materials

CONSTRUCTS:
01- Direct result from teacher's work/It is not a result
02- Connected to school's precinct/Not connected
03- Connected to information/Connected to application
04- Useful to motivate the process/Useful to evaluate the process
05- Varies during the process/Does not vary
06- Involves the student in an active way/Involves in a passive way
07- Part of research elaboration/Contains the research results
08- Product of person's work/Not product
09- Useful to acquire knowledge/Useful to test the correctness of acquired knowledge
10- Depends on teacher/Does not depend

<table>
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<tr>
<th>1</th>
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- element used to define the construct

**Figure Al - 19** Matrix of the first grid elicited from Teacher 2 about curriculum materials (CM1)
Figure A1 - 20 Construct and element trees Teacher 2/CM1

TEACHER 2/2ND GRID (CM2)
ELEMENTS:
1- Blackboard
2- Laboratory
7- Extra-class activities
8- Regular University tests
3- Textbook
4- Books
5- Magazines and reports
6- Course plan
9- Evaluation as questions or exercises after each chapter
10- Initial evaluation

CONSTRUCTS:
01- Can only be used at University/Can be used outside University
02- Establishes a connection with everyday life/Does not
03- Forces student to follow the course/Does not force
04- Indicates student's conditions/Gives support to student to improve his conditions
05- Controlled by teacher/Controlled by student
06- Activity at course's beginning/Activity during the course
07- Takes part in learning process/Checks learning
08- Changes during the course/Does not change

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**Figure A1 - 21** Matrix of the second grid elicited from Teacher 2 about curriculum materials (CM2)
- construct with reversed poles
STUDENT 1/1ST GRID (CM1)

ELEMENTS:
1- Blackboard
2- Drawing materials to be used on the blackboard
3- Existing materials in the classroom
4- Didactic books
5- Demonstrations conducted by the students

6- Classnotes
7- Demonstrations conducted by the teacher
8- Demonstrations conducted together
9- Written tests
10- Reports
11- Oral tests
12- Problem solving in the classroom

CONSTRUCTS:
01- Depends on teacher’s skills/Depends on student’s skills
02- Students’ exclusive work/Teacher’s exclusive work
03- Introduces a new concept/Tests learning
04- Abstract/Concrete
05- Practical teaching/Theoretical teaching
06- Develops student’s critical sense/Does not develop
07- Develops student’s creativity/Does not develop
08- Requires an adequate environment/Does not require
09- Develops motor skills/Develops cognitive skills
10- Retains more information/Retains less information

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*Figure A1 - 23 Matrix of the first grid elicited from Student 1 about curriculum materials (CM1)*
**Figure Al - 24 Construct and element trees Student 1/CM1**

**STUDENT 1/2ND GRID (CM2)**

**ELEMENTS:**

1- Drawing materials to be used on the blackboard
2- Blackboard
3- Blackboard Pointer
4- Audiovisual resources
8- Stationery
9- Classroom
10- Laboratory
11- Reports
12- Evaluation checklist
| 5- Demonstrations | 13- Lesson plan |
| 6- Demonstrations conducted by the students | 14- Course plan |
| 7- Didactic books | 15- School register |
| | 16- Written and oral tests |

**CONSTRUCTS:**

01- Helps in visualizing the real world/Does not help
02- Stimulates student participation/Does not stimulate
03- Facilitates the organization of students' ideas/Does not facilitate
04- Puts the student under stress/Does not put
05- Improves student's speech/Does not improve
06- Develops student's psychomotor skills/Does not develop
07- Collects data/Uses data

---

**Figure A1 - 25 Matrix of the second grid elicited from Student 1 about curriculum materials (CM2)**
Figure A1 - 26 Construct and element trees Student 1/CM2

STUDENT 2/1ST GRID (CM1)

ELEMENTS:
1- Blackboard
2- Books
3- Laboratory
4- Visits
5- 
6- Audiovisual resources
7- Written test
8- Demonstrations prepared by the students

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CONSTRUCTS:
01- Used in a lecture/Not used
02- Increases student's interest/Does not increase
03- Are useful for student evaluation/ Are not useful
04- Facilitates student's learning/Does not facilitate
05- Requires more student participation/Does not require
06- Facilitates teaching/Does not facilitate
07- Gives knowledge to student/Does not give
08- Used by the teacher during the planning phase/Not used
09- Materials under teacher responsibility/Materials under school responsibility
10- Stimulates teacher to show his knowledge/Does not stimulate
11- Enhances practical lessons/Enhances theoretical lessons

Figure A1 - 27 Matrix of the first grid elicited from Student 2 about curriculum materials (CM1)
Figure A1 - 28 Construct and element trees Student 2/CM1

STUDENT 2/2ND GRID (CM2)

ELEMENTS:
1- Laboratory experiments
2- Posters
3- Books
4- Blackboard
6- Monitors
7- Apostiles
8- Tests
9- Demonstrations prepared by the
5- School trips
10- Homework.

CONSTRUCTS:
01- Better for group work/Better to work alone
02- More important in the classroom/Not important in the classroom
03- Based on the planning/Not based
04- Useful to reinforce content in the classroom/Useful to widen student's knowledge
05- Stimulates student's reasoning/Does not stimulate
06- Essential to the process/Not essential
07- Requires more knowledge from the teacher/Does not require

Figure A1 - 29 Matrix of the second grid elicited from Student 2 about curriculum materials (CM2)
GRID ABOUT TEACHER’S ROLES

TEACHER 1/1ST GRID (TR1)

ELEMENTS:
1- Guide
2- The one who respects students’ individual characteristics
3- The one who keeps the dialogue
4- The one who produces knowledge
5- The one who transmits knowledge
6- The one who organizes activities
7- The one who shows exemplary attitudes
8- The one who modifies attitudes
9- The one who rationalizes science
10- The one who receives knowledge
11- The one who gives encouragement
12- The one who links Physics and Basic Departments
CONSTRUCTS:
01- Collects information about students/Suggests possible solutions
02- Creates ideas/Reproduces ideas
03- Constructs a model/Transforms a model
04- Gives/Receives
05- Contributes to content learning/Adds to student's moral formation
06- Bilateral relationship/Unilateral relationship
07- Works with students' ideology/Works with students' techniques
08- Integrates the student in this course/Integrates the student in the undergraduate course
09- Related to process development/Related to process results

<table>
<thead>
<tr>
<th></th>
<th>t.o.v. respects student's individual characteristics</th>
<th>t.o.v. keeps the dialogue</th>
<th>t.o.v. produces knowledge</th>
<th>t.o.v. transmits knowledge</th>
<th>t.o.v. organizes activities</th>
<th>t.o.v. shows exemplary attitudes</th>
<th>t.o.v. modifies attitudes</th>
<th>t.o.v. rationalizes science</th>
<th>t.o.v. receives knowledge</th>
<th>t.o.v. makes the connection between Phis. and Basic dept</th>
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</table>

- element used to define the construct

**Figure A1 - 31** Matrix of the first grid elicited from Teacher 1 about teacher roles (TR1)
- construct with reversed poles

Figure A1 - 32 Construct and element trees Teacher 1/TR1
TEACHER 1/2ND GRID (TR2)

ELEMENTS:
1- Guide
2- Evaluator
3- The one who produces didactic materials
4- The one who links the Physics Dept. to the students
5- The one who influences on content selection
6- Course planner
7- The one who influences attitudes
8- The one who links university to the profession

CONSTRUCTS:
01- Work developed with students/Work developed by the teacher alone
02- Depends on course's content/Does not depend
03- Organizes the content/Does not organize
04- Influences students ideologically/Does not influence
05- Plans the activities/Applies the activities
06- Develops student's critical sense/Does not develop
07- Gives student opportunity to produce knowledge/Does not give

<table>
<thead>
<tr>
<th></th>
<th>Guide</th>
<th>Evaluator</th>
<th>t.o.w. produces didactic materials</th>
<th>t.o.w. makes the connection between Phys. Dept. and student</th>
<th>t.o.w. influences content</th>
<th>t.o.w. influences attitudes</th>
<th>t.o.w. makes the connection between uni. and profession</th>
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<td>Work developed with the student</td>
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<td>Influences students ideologically</td>
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<td>Plans the activities</td>
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<td>Develops student's critical sense</td>
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<tr>
<td>Gives student opportunity to produce knowledge</td>
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Figure A1 - 33 Matrix of the second grid elicited from Teacher 1 about teacher's roles (TR2)
work developed with the student applies the activities does not influence develops student's critical sense depends on course's content does not organize does not ... produce knowledge
work developed by the teacher alone plans the activities influences students ideologically does not develop does not depend does not organize gives student opportunity to...

- construct with reversed poles

Figure A1 - 34 Construct and element trees Teacher 1/TR2
TEACHER 2/1ST GRID (TR1)

ELEMENTS:
1- The one who probes students' level of knowledge
2- The one who knows the course followed by the student
3- The one who provides the objectives and the course planning
4- The one who discusses and communicates the evaluation process
5- The one who encourages student participation
6- The one who provides texts and exercises
7- The one who relates course's content with everyday life
8- The one who encourages student participation in the laboratory
9- The one who evaluates learning at each stage

CONSTRUCTS:
01- Limited to the beginning of the course/During the whole course
02- Connected to evaluation process/Not connected
03- Already prepared/Constructed
04- Related to practice/Related to concepts
05- Guides methodology/Gives attention to the uses
06- Gives feedback about teacher efficiency/Does not give
07- Discovers information possessed by the student/Gives student opportunity to think
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<th>Connected to evaluation process</th>
<th>Already prepared</th>
<th>Related to practice</th>
<th>Guides methodology</th>
<th>Gives feedback about teacher efficiency</th>
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Figure A1 - 35 Matrix of the first grid elicited from Teacher 2 about teacher's roles (TR1)

**Figure A1 - 36** Construct tree Teacher 2/TR1
TEACHER 2/2ND GRID (TR2)

ELEMENTS:
1- The one who gives classes frequently
2- The one who is confident on his knowledge of course's content
3- The one who is flexible
4- The one who knows students' level of knowledge
5- The one who gives students works to be done outside classroom
   doubts
6- The one who evaluates students regularly
7- The one who has a natural way with students
8- The one who leads students towards consulting books
9- The one who is available outside classroom to discuss students'
   doubts

CONSTRUCTS:
01- Influences on quality/Influences on quantity of information
02- Evaluates learning after the course/Evaluates learning before
03- Linked to affective aspect/Linked to cognitive aspect
04- Leads to directed learning/Leads to non-directed learning
Figure Al - 37 Matrix of the second grid elicited from Teacher 2 about teacher's roles (TR2)

Figure Al - 38 Construct tree Teacher 2/TR2
Figure AI - 38' Element tree Teacher 2/TR2

STUDENT 1/1ST GRID (TR1)  

ELEMENTS:
1- The one who transmits knowledge  
2- The one who prepares didactic materials  
3- The one who keeps students quiet  
4- The one who organizes students' ideas  
5- Affective guide  
6- The one who gives encouragement  
7- The one who talks with the students  
8- The one who creates analogies  
9- Inquirer  
10- Judge  
11- Instructor  
12- Technician  

CONSTRUCTS:
01- Stimulates student's interest/Does not stimulate  
02- Requires emotional control/Does not require  
03- Stimulates student towards scientific research/Does not stimulate  
04- Depends on teacher-student communication/Does not depend  
05- Depends on a previous organization/Does not depend  
06- Holds student's attention/Does not hold
Figure A1 - 39 Matrix of the first grid elicited from Student 1 about teacher's roles (TR1)

Figure A1 - 40 Construct and element trees Student 1/TR1
STUDENT 1/2ND GRID (TR2)

ELEMENTS:
1- The one who transmits knowledge
2- Interpreter
3- Technician
4- Friend
5- The one who gives encouragement
6- Leader
7- Guide
8- Organizer
9- The one who prepares didactic materials
10- Judge
11- The one who keeps students quiet

CONSTRUCTS:
01- Helps student to think fast/Does not help
02- Requires method/Does not require
03- Aroused student's pride/Does not arouse
04- Detects student's and process deficiencies/Does not detect
05- Facilitates verbal communication/Does not facilitate
06- Requires a formal treatment with the student/Does not require
07- Leads to a more consistent learning/Does not lead

Figure Al - 41 Matrix of the second grid elicited from Student 1 about teacher's roles (TR2)
Figure A1 - 42 Construct and element trees Student 1/TR2

STUDENT 2/1ST GRID (TR1)

ELEMENTS:

1- The one who transmits course's content
2- The one who gives encouragement
3- Adviser
4- The one who makes innovations
5- 6- 7- 8- The one who gives examples related to everyday life
9- The one who gives a conceptual perspective about the content
10- Instructor of studying methods
5- The one who gives grades
6- The one who evaluates learning
7- The one who tries to put all students at the same level of knowledge

CONSTRUCTS:
01- Provokes student's interest/Does not provoke
02- Induces changes on student's method of studying/Does not induce
03- Leads students to the same proficiency/Enables student development
04- Causes student to care about learning/Causes student to care about evaluation
05- Demonstrates more preoccupation with teaching/Demonstrates more preoccupation with learning
06- Leads students to reproduce what was given/Leads students to transform what was given
07- Enables the teacher to know better students' difficulties/Hinders the teacher in discovering students' difficulties
08- The student reaches higher levels of learning/The student learns more superficially

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Figure A1 - 43 Matrix of the first grid elicited from Student 2 about teacher's roles (TR1)
Figure A1 - 44 Construct and element trees Student 2/TR1

STUDENT 2/2ND GRID (TR2)

ELEMENTS:
1- Guide
2- Friend
3- The one who knows the content
4- The one who is fair in giving grades
7- Expert in teaching
8- Well-informed
9- The one who is fair in giving grades
4- Fighter  
5- The one who follows a method  
6- The one who shows patience  

10- The one who works together with the institution to improve the course

CONSTRUCTS:
01- Gratifies the student/Does not gratify  
02- Creates better teaching conditions/Does not create  
03- Influences on evaluation/Does not influence  
04- Improves student's performance/Does not improve  
05- Facilitates student's work/Facilitates teacher's work  
06- Fundamental to learning/Not fundamental  
07- Emphasizes content learning/Emphasizes content presentation  
08- Influences on student's behaviour/Influences on system's changes

---

Figure A1 - 45 Matrix of the second grid elicited from Student 2 about teacher's roles (TR2)
Figure AI - 46 Construct and element trees Student 2/TR2

GRIDS ABOUT STUDENT'S ROLES

TEACHER 1/1ST GRID (SR1)

ELEMENTS:
1- The one who produces knowledge
2- The one who receives information
3- The one who participates in the dialogue
6- The one who develops study habits
7- The one who contributes for teaching methodology
8- The one who is considerate to
4- The one who seeks for solution of his difficulties
5- The one who seeks for integration with classmates
9- The one who observes his duties
10- The one who is considerate to classmates

CONSTRUCTS:
01- Makes the lesson more dynamic/Does not influence on lesson's dynamics
02- Develops alone/Develops in group
03- Provokes changes on teaching process/Does not change the process
04- Requires expression of thoughts/Does not require
05- Increases interest/Does not increase
06- Leads to organization of thoughts/Leads to organization of attitudes
07- Develops the critical sense/Does not develop
08- Stimulates analysis of alternative conceptions/Does not stimulate

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<tr>
<th>makes the lesson more dynamic</th>
<th>t.o.w. produces knowledge</th>
<th>t.o.w. receives information</th>
<th>t.o.w. participates in the dialogue</th>
<th>t.o.w. seeks for solution of his difficulties</th>
<th>t.o.w. seeks for integration with classmates</th>
<th>t.o.w. develops study habits</th>
<th>t.o.w. contributes to teaching methods</th>
<th>t.o.w. is considerate to teacher</th>
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<td>1</td>
<td>2</td>
<td>leaves process undisturbed</td>
</tr>
<tr>
<td>requires expression of thoughts</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>does not require</td>
</tr>
<tr>
<td>increases interest</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>does not increase</td>
</tr>
<tr>
<td>leads to organization of thoughts</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>leads to organization of attitudes</td>
</tr>
<tr>
<td>develops the critical sense</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>does not develop</td>
</tr>
<tr>
<td>stimulates analysis of altern. concep.</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>does not stimulate</td>
</tr>
</tbody>
</table>

○ - element used to define the construct

Figure AI-47 Matrix of the first grid elicited from Teacher 1 about student's roles (SR1)
Figure A1 - 48 Construct and element trees Teacher 1/SR1

TEACHER 1/2ND GRID (SR2)

ELEMENTS:
1- Inquirer
2- The one who does his homework
3- Reader
4- The one who asks the teacher
3- The one who is disciplined to solve his doubts
4- The one who is interested in course's content
5- The one who is obstinate
6- The one who does classroom exercises
9- The one who seeks for integration in the course
10- The one who plans his studies

CONSTRUCTS:
01- Develops reasoning/Does not develop
02- Develops the critical sense/Unrelated to critical sense
03- Works with the content/Does not work
04- Organizes the work/Executes the work
05- Work suggested by the teacher/Work devised by the student
06- Facilitates student's emancipation/Does not facilitate
07- Student's attitude linked to classroom/Student's attitude independent of classroom

<table>
<thead>
<tr>
<th>-develops reasoning</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>develops the critical sense</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>works with the content</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>organizes the work</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>work suggested by the teacher</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>facilitates student's emancipation</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>student's attitude linked to classroom</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

- element used to define the construct

Figure Al - 49 Matrix of the second grid elicited from Teacher 1 about student's roles (SR2)
organizes the work | executes the work
work devised by | work suggested by
the student | the teacher
facilitates student's | does not facilitate
emancipation | study
develops the | unrelated to critical
    critical sense | sense
develops | does not develop
reasoning | next
works with the content | does not work
student's att. indep. | student's attitude
of classroom | linked to classroom

- construct with reversed poles

Figure A1 - 50 Construct and element trees Teacher 1/SR2
TEACHER 2/1ST GRID (SR1)

ELEMENTS:
1- The one who knows of course's content
2- The one who has the textbook and consults other books
3- The one who knows the importance of this course for his academic course
4- The one who adopts a study scheme
5- The one who attends the classes
6- The one who emphasizes concepts before solving problems
7- The one who discusses his doubts with teachers and colleagues
8- The one who relates course's content to everyday life
9- The one who observes attentively laboratory's objectives
10- The one who tries to make laboratory's measurements precisely

CONSTRUCTS:
01- Activities developed at course's beginning/Activities developed during the course
02- Related to course planning/Related to course execution
03- Activity developed with the teacher/Activity developed without the teacher
04- Related to the laboratory/Not related
05- Related to the use of information/Related to the access to information
06- Related to student's way to study/Not related
07- Activity developed inside classroom/Activity developed outside
<table>
<thead>
<tr>
<th>Activities Developed at Course's Begin</th>
<th>1</th>
<th>5</th>
<th>1</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related to the Course Planning</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Activity Developed with the Teacher</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Related to the Laboratory</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Related to the Use of Information</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Related to the Student's Way to Study</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Activity Developed Inside Classroom</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

- Element used to define the construct

**Figure A1 - 51** Matrix of the first grid elicited from Teacher 2 about student's roles (SR1)

- Related to the use of information
- Activity developed outside inside classroom
- Not related related to the laboratory
- Related to the course planning course execution
- Activities developed acts. developed at course's begin. during the course
- Not related related to the student's way to study
- Activity developed activity developed with the teacher without the teacher

**Figure A1 - 52** Construct tree Teacher 2/SR1
TEACHER 2/2ND GRID (SR2)

ELEMENTS:
1- The one who attends the classes
2- The one who knows of course's content
3- The one who uses didactic books
4- The one who makes an auto-evaluation
5- The one who uses the special schedule to discuss his doubts
6- The one who discusses with colleagues
7- The one who is critical
8- The one who relates the content with his previous knowledge
9- The one who applies the content to everyday life
10- The one who reserves some time to study

CONSTRUCTS:
01- Activity developed at the beginning of the course/Activity developed during the course
02- Individual evaluation/Group evaluation
03- Related to knowledge assimilation/Related to knowledge application
04- Related to course planning/Related to course execution
05- Activity imposed to the student/Activity not imposed
06- Permits to discuss the teaching method/Does not permit
07- Permits to learn/Permits to know if you have learned

<table>
<thead>
<tr>
<th>Activity developed at begin. of course</th>
<th>5</th>
<th>1</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>5</th>
<th>activity developed during the course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual evaluation</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>group evaluation</td>
</tr>
<tr>
<td>Related to knowledge assimilation</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>related to knowledge application</td>
</tr>
<tr>
<td>Related to course planning</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>related to course execution</td>
</tr>
<tr>
<td>Activity imposed to the student</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>activity not imposed</td>
</tr>
<tr>
<td>Permits to discuss the teaching meth.</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>does not permit</td>
</tr>
<tr>
<td>Permits to learn</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>permits to know if you have learned</td>
<td></td>
</tr>
</tbody>
</table>

Figure A1 - 53 Matrix of the second grid elicited from Teacher 2 about student's roles (SR2)

Figure A1 - 54 Construct tree Teacher 2/SR2

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- element used to define the construct

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06- Permits to discuss the teaching method/Does not permit
07- Permits to learn/Permits to know if you have learned
STUDENT 1/1ST GRID (SR1)

ELEMENTS:
1- Listener
2- The one who participates in the teacher-student dialogue
3- The one who takes notes
4- Dissertator
5- Researcher
6- The one who follows the rules of good behaviour
7- The one who is careful
8- The one who prepares materials
9- Reader
10- The one who makes a general criticism
11- The one who transforms ideas
12- The one who fulfils his duties

CONSTRUCTS:
01- Does not use reasoning/Uses reasoning
02- Develops motor skills/Develops cognitive skills
03- Develops creativity/Develops discipline
04- Depends on student’s organization/Does not depend
05- Depends on the environment/Does not depend
06- Based on previous learnings/Not based
07- Develops emotional self-control/Does not develop
08- Developed by group work/Not developed
09- Develops the ability to memorize the content/Does not develop

Figure A1 - Matrix of the first grid elicited from Student 1 about student's roles (SR1)
Figure A1 - 56 Construct and element tree Student 1/SR1

STUDENT 1/2ND GRID (SR2)

ELEMENTS:
1- Dissertator
2- Organizer
7- Inquirer
8- The one who creates new ideas
3- The one who solves problems
4- The one who interprets what he reads
5- Friend
6- The one who prepares experiments
9- Researcher
10- Collector
11- The one who is guided by idealism

CONSTRUCTS:
01- Organizes the ideas in writing/Organizes the ideas mentally
02- Enables comprehension of scientific jargon/Does not enable
03- Stimulates creativity/Does not stimulate
04- Allows student participation in the classroom/Does not allow
05- Helps icebreaking/Increases the resistance due to stress
06- Organizes the activities/Does not organize
07- Stimulates comprehension/Does not stimulate

Figure A1 - 57 Matrix of the second grid elicited from Student 1 about student's roles (SR2)
Figure A1 - 58 Construct and element tree Student 1/SR2

STUDENT 2/1ST GRID (SR1)

ELEMENTS:
1- Listener
2- The one who transforms knowledge
3- The one who participates in the choice of course's content

7- The one who questions course's content
8- Core element in the teaching-learning process
9- The one who aims learning as
CONSTRUCTS:
01- Causes changes in the teaching-learning process/Does not cause
02- Leads to a superficial learning/Leads to a more solid learning
03- Causes a better teacher performance/Does not cause
04- Provokes more interest on social integration/Does not provoke
05- Develops more responsibility in the student/Does not develop
06- Increases student's self-confidence/Does not increase
07- Gives teacher the opportunity to evaluate learning/Does not give
08- Leads teacher to prepare himself better to give the course/Does not lead
09- Raises course's level/Does not raise
10- Uses new didactic resources/Uses only the blackboard
11- Causes changes in the teaching methodology/Does not cause

Figure A1 - 59 Matrix of the first grid elicited from Student 2 about student's roles (SR1)
Figure Al - 60 Construct and element trees Student 2/SR1

STUDENT 2/2ND GRID (SR2)
ELEMENTS:
1- Researcher
2- The one who follows a method
3- Friend
4- The one who seeks the truth
7- The one who studies
8- The one who demands
9- The one who knows his rights and obligations
5- The one who shows interest  
6- The one who participates  
10- The one who shows enthusiasm  
11- Self-evaluator.

CONSTRUCTS:
01- Facilitates teacher-student communication/Facilitates student-student communication
02- Influences on classroom work/Influences on the university as a whole
03- May change the study methodology/May change the teaching methodology
04- Essential to learning/Not essential
05- Essential to a good teaching/Not essential
06- Provokes a more active student participation/Provokes a more active teacher participation
07- Influences on teacher evaluation/Does not influence
08- Better for group activity/Better for individual activity

\[
\begin{array}{ccccccccc}
1 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 \\
1 & 1 & 2 & 4 & 2 & 1 & 1 & 2 & 1 & 1 & 3 \\
2 & 2 & 2 & 3 & 2 & 2 & 2 & 1 & 1 & 4 & 3 & 3 \\
3 & 3 & 3 & 3 & 4 & 5 & 5 & 3 & 5 & 3 & 5 & 1 \\
4 & 2 & 1 & 3 & 2 & 1 & 2 & 1 & 4 & 3 & 2 & 2 \\
5 & 2 & 2 & 3 & 2 & 1 & 2 & 2 & 1 & 3 & 2 & 3 \\
6 & 4 & 4 & 2 & 4 & 4 & 4 & 4 & 4 & 5 & 4 & 3 & 3 \\
7 & 2 & 2 & 3 & 2 & 2 & 2 & 2 & 2 & 3 & 2 & 3 \\
8 & 2 & 5 & 2 & 2 & 3 & 4 & 4 & 3 & 3 & 3 & 4 \\
\end{array}
\]

Figure A1 - 61 Matrix of the second grid elicited from Student 2 about student's roles (SR2)
Figure A1 - 62 Construct and element trees Student 2/SR2
In this appendix I shall present the questionnaire applied to the students and teachers at the end of Physics 1 course and its English version.
Dados de Identificação:

Curso -

Entrada na UNICAP (Ano/Semestre) -

Idade -

Sexo - M [ ] F [ ]

Se a 1ª vez que cursa a disciplina? Sim [ ]

Se respondeu NÃO:
Quantas vezes já repetiu, contando com esta agora? ___.

Você notou alguma diferença entre as outras vezes e esta? Sim [ ]

Se respondeu SIM, explique qual a diferença.

Marque as Cinco atitudes que você considera mais importantes num professor de Física I.

Sondar o nível de conhecimento dos alunos [ ]
Comunicar os objetivos do curso [ ]
Comunicar o planejamento do curso [ ]
Incentivar a participação dos alunos [ ]
Entregar textos e listas de exercícios [ ]
Relacionar o conteúdo com as aplicações do dia-a-dia [ ]
Discutir o processo de avaliação [ ]
Comunicar o processo de avaliação [ ]

continua na pág seguinte
Avaliar a aprendizagem a cada etapa
Ser amigo
 Transmitir conhecimento
 Manter a disciplina
 Fazer perguntas aos alunos
 Ser compreensivo
 Dialogar com os alunos
 Ser interessado nas idéias dos alunos
 Dar noções do História da Física
 Desenvolver o raciocínio do aluno
 Orientar sobre como estudar
 Tirar as dúvidas dos alunos

Marque as CINCO atividades que você considera mais importantes no aluno:
Adotar um esquema de estudo
Frequentar as aulas
Tirar dúvidas c/ professor e colegas
Estudar a teoria
Consultar livros
Relacionar o conteúdo das aulas com o dia-a-dia
Ter interesse pelo assunto
Resolver exercícios
Tomar notas durante as aulas
Ouvir com atenção
Ser curioso
Ser crítico
Ser pesquisador
Cumprir suas tarefas
Transformar o conhecimento
Ser integrante de um grupo

continua na pág seguinte
<table>
<thead>
<tr>
<th>Q5</th>
<th>Você considera que o uso do QUADRO-DE-GIZ durante as aulas:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sim</td>
<td>Não</td>
</tr>
<tr>
<td>Dependente da habilidade do professor</td>
<td>☐</td>
</tr>
<tr>
<td>Possibilita maior fixação da aprendizagem</td>
<td>☐</td>
</tr>
<tr>
<td>É essencial ao processo ensino-aprendizagem</td>
<td>☐</td>
</tr>
<tr>
<td>Facilita a apresentação do conteúdo</td>
<td>☐</td>
</tr>
<tr>
<td>Implica a aula ser expositiva</td>
<td>☐</td>
</tr>
<tr>
<td>É útil na aprendizagem de conceitos</td>
<td>☐</td>
</tr>
<tr>
<td>É útil para introduzir conceitos novos</td>
<td>☐</td>
</tr>
<tr>
<td>Desenvolve o senso crítico do aluno</td>
<td>☐</td>
</tr>
<tr>
<td>Desperta maior interesse no aluno</td>
<td>☐</td>
</tr>
<tr>
<td>Envolve o aluno de forma ativa</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q6</th>
<th>Na sua opinião, a PROVA ESCRITA é usada num curso, porque:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sim</td>
<td>Não</td>
</tr>
<tr>
<td>Serve para avaliar o aluno</td>
<td>☐</td>
</tr>
<tr>
<td>Desenvolve o senso crítico do aluno</td>
<td>☐</td>
</tr>
<tr>
<td>Envolve o aluno de forma ativa</td>
<td>☐</td>
</tr>
<tr>
<td>Serve para a aprendizagem de conceitos</td>
<td>☐</td>
</tr>
<tr>
<td>Desenvolve o raciocínio do aluno</td>
<td>☐</td>
</tr>
<tr>
<td>É essencial ao processo ensino-aprendizagem</td>
<td>☐</td>
</tr>
<tr>
<td>É um material de apoio do professor</td>
<td>☐</td>
</tr>
<tr>
<td>Questão</td>
<td>Opções</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>Q7</td>
<td>Com relação ao seu desempenho neste curso, você considera que:</td>
</tr>
<tr>
<td>Testa a aprendizagem</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Desenvolve a criatividade dos alunos</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Possibilita maior fixação da aprendizagem</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Aprendeu os assuntos apresentados</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Conseguiu resolver os exercícios</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Teve dificuldade de acompanhar as aulas</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Estudou o suficiente</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Desenvolveu o raciocínio</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Perdeu seu tempo ao fazer este curso</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Ampliou seus horizontes</td>
<td>[ ] [ ] [ ]</td>
</tr>
<tr>
<td>Q8</td>
<td>Você classificaria o desempenho do seu professor durante o curso, como:</td>
</tr>
<tr>
<td>Ótimo</td>
<td>[ ]</td>
</tr>
<tr>
<td>Bom</td>
<td>[ ]</td>
</tr>
<tr>
<td>Regular</td>
<td>[ ]</td>
</tr>
<tr>
<td>Ruim</td>
<td>[ ]</td>
</tr>
<tr>
<td>Póssimo</td>
<td>[ ]</td>
</tr>
<tr>
<td>Q9</td>
<td>Que sugestões você daria para melhorar o curso?</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Obrigado pela sua colaboração.
Q1 Identification data

Degree course - ____________________
Enterance (year/semester) - ____________
Age - ____________
Sex - M ☐ F ☐

Q2 Is this the first time you take this course?
Yes ☐ No ☐

If you have answered NO:
How many times have you repeated, including this one? ____
Have you noticed any difference between the other times and this one?
Yes ☐ No ☐

If you have answered YES, explain the difference.

Q3 Tick off against the FIVE attitudes you consider as most important in a Physics 1 teacher.

To probe students' level of knowledge ☐
To communicate course objectives ☐
To communicate course planning ☐
To encourage student participation ☐
To give texts and lists of exercises ☐
To relate content to everyday life ☐
To discuss evaluation criteria ☐
To communicate evaluation criteria ☐

to be continued
To evaluate learning at each step
To be a friend
To transmit knowledge
To keep discipline
To ask questions
To be comprehensive
To exchange opinions with students
To have interest in students' ideas
To give notions of history of physics
To develop students' reasoning skills
To guide students on how to study
To clarify students' doubts

Q4 Tick off against the FIVE activities you consider as most important in a student

To adopt a method of study
To attend lessons
To clarify his doubts with teacher and peers
To study the theory
To consult books
To relate content to everyday life
To have interest in content
To solve exercises
To take notes during classes
To listen with attention
To be curious
To be critical
To be a researcher
To fulfill his duties
To transform knowledge
To be a member of a group

to be continued
To be a receptor of information ✅
To exchange opinions with teacher ✅
To propose changes in teaching methodology ✅
To know teacher's evaluation method ✅

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Q5 You consider that the use of the CHALKBOARD during classes:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depends on teacher's ability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enhances learning fixation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is essential to teaching-learning process</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Facilitates content presentation</td>
<td></td>
<td></td>
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<tr>
<td>Leads to a lecture-type lesson</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is useful to learn concepts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is useful to introduce new concepts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develops student's critical sense</td>
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<td></td>
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<tr>
<td>Generates more student interest</td>
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<td></td>
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<tr>
<td>Involves student in an active way</td>
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<td></td>
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</tr>
</tbody>
</table>

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Q6 In your opinion, WRITTEN TESTS are used in a course because:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are useful to evaluate students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop student's critical sense</td>
<td></td>
<td></td>
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<tr>
<td>Involve student in an active way</td>
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<td></td>
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<tr>
<td>Are useful to learn concepts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop student's reasoning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are essential to teaching-learning process</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are a teacher's support material</td>
<td></td>
<td></td>
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</tbody>
</table>
Q7 In relation to your performance on this course, you consider that you:

- Have learned the content
- Could solve the exercises
- Had difficulty in following lessons
- Have studied enough
- Have developed your reasoning skills
- Have wasted your time in following this course
- Have widened your horizons

Q8 You would classify the performance of your teacher during this course as:

- Excellent
- Good
- Average
- Poor
- Very poor

Q9 What suggestions would you give to improve the course?

THANK YOU FOR YOUR COLLABORATION
# APPENDIX III
## COURSE SCHEDULE

**CRONOGRAMA DE FÍSICA I APROVADO NA REUNIÃO DE 07/01/88**

1. **Inescriffção matemática do movimento**
   - ponto material e trajetória
   - sistema de coordenadas cartesianas e polar (plano)
   - referencial
   - vetor posição e deslocamento (soma e subtração gráfica e analítica)
   - vetor unitário, componentes de um vetor  
   - **2 horas**

2. **Cinemática do movimento de translação (1 e 2 dimensões)**
   - vetor velocidade, vetor aceleração
   - lançamentos
   - análise gráfica do movimento  
   - **5 horas**

3. **Cinemática do movimento de translação**
   - princípio da inércia, Galileu versus Aristóteles
   - 2ª lei (quantidade de movimento)
   - 3ª lei  
   - **5 horas**

4. **Forças no movimento circular**  
   - **2 horas**

5. **Trabalho e energia**
   - parte histórica da energia  
   - **14 horas**

6. **Choques elásticos e inelásticos**
   - coeficiente de restituição  
   - **4 horas**

7. **Dinâmica da rotação**  
   - **10 horas**

**Total: 50 horas**
TRANSLATED COURSE SCHEDULE

PHYSICS I COURSE SCHEDULE APPROVED AT THE MEETING ON 07/01/88

1 - Mathematical description of motion
   - material point and trajectory
   - systems of cartesian and polar coordinates (plane)
     reference frame 2 hours
   - position vector and displacement (addition and subtraction -
     graphic and analytic)
   - unity vector, components of a vector 2 hours

2 - Kinematics of the translatory motion (1 and 2 dimensions)
   - velocity vector, acceleration vector
   - launchings
   - graphic analysis of motion 8 hours

3 - Kinetics of the translatory motion
   - principle of Inertia, Galileo versus Aristotle
   - 2^o law (momentum)
   - 3^o law 8 hours

4 - Forces in the motion on a circle 2 hours

5 - Work and energy
   - + historical part of energy 14 hours

6 - Elastic and inelastic collisions
   - + the coefficient of restitution 4 hours

7 - Kinetics of the rotary motion 10 hours

Total: 50 hours