AN INVESTIGATION OF A SELF-TEACHING SYSTEM IN A SIXTH-FORM PHYSICS COURSE

by

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This thesis considers the fact that, in spite of the considerable developments in educational technology in recent years, very little of the teaching of science in secondary schools in this country caters for the wide differences in ability and learning style of individual students. Even in the sixth form where more individualization could reasonably be expected, A-level syllabuses are usually covered by groups of students moving in 'lockstep' with 'chalk and talk' the predominant method of instruction.

The research described herein was an attempt to investigate how a limited amount of individualized learning might be introduced into the teaching of sixth form science. The learning system which was devised was a comparatively simple one; this was partly due to lack of available resources during a time of financial restraint, but was also a matter of choice by the researcher since it was felt to be valuable to see what could be done by a practising teacher without secondment or any special assistance.

The distinction between independent and individualized learning is first emphasised and the literature of the rationale for each of them discussed. A review of independent learning in practice then follows; evaluation methods are reviewed and reasons for adopting 'illuminative' evaluation considered.

The learning system used is explained and the two trials described. The first was largely exploratory - a feasibility trial - but the second was full-scale including analysis of data and the use of a questionnaire to explore the subjective opinions of the students. The main results to emerge were:

(a) not only is it possible to cover part of an A-level syllabus
in this way but there are also several 'spin-off' advantages, e.g. development of students' ability to learn independently;

(b) the students almost unanimously approved of the use of such a system for part of their A-level course;

(c) the changes in the teacher's role were considerable but quite acceptable.
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There are a number of reasons, pedagogic and pragmatic, for the recent increase in the interest in independent learning in schools. Before considering these, it is important to make the distinction between the terms "independent" and "individualized", since confusion between them abounds in the literature. Indeed some writers have regarded them as synonymous, e.g. Keuscher (1967), whose plea for independence is entitled "Why individualize instruction?", Taylor (1971, 1972) in all the "Resources for Learning" publications, and Green (1976) whose rationale for independent learning in science is based on the advantages of individualization.

In the following, I therefore define: (a) Independent learning as that in which the student learns with less direct control by a teacher than in the traditional lesson/lecture situation; (b) Individualized learning as that in which the instruction is tailored to the individual student's needs more than in the traditional situation. There are of course degrees of independence and individualization, but the point is that the two continua are quite distinct:

Teacher directed  Independence  Self directed
Generalised  Individualization  Fully individualized

Thus any learning system can have its learning activities at any point on each continuum e.g. a dominant personal tutor might fully individualize his instruction to his pupil without allowing him any independence in choice of modes of learning. Conversely, a student might be learning from a learning 'system' or 'package', which is hardly tailored to his individual needs, but his learning is largely self-directed i.e. independent of a teacher's influence.
The distinction between the two terms is emphasised if we think of individualization and independence as quasi-mathematical 'co-ordinates' in a two-dimensional continuum.

INDEPENCE  |  . C  . D

↑

|  . E  . A  . B |

→ INDIVIDUALIZATION

Thus: A represents a student undergoing instruction by a teacher who rigidly determines all that the student does (e.g. dictating notes) and does not vary his teaching from student to student.

B represents a student in a 'tutorial' situation where the instruction provided is geared to his personal requirements but is still fully controlled by the teacher.

C represents a student using a teaching 'package' which is not designed for him personally (e.g. a commercially-produced package). A small amount of individualization is present if the student is able to cover the course at his own pace i.e. it is self-produced individualization.

D represents a student teaching himself in a completely free situation where he is able to decide for himself which material he uses, how fast he should work, etc. Such a restraint-free situation would, of course, hardly ever occur in school education at the present time.

E is a region in the two-dimensional continuum in which individualization and independence are both involved to some extent. In this region the great majority of methods of teaching and
learning are to be found, including those learning systems to be discussed in later chapters.

The diagram also illustrates why the terms 'independence' and 'individualization' have become confused. If the teacher wishes to introduce some individualization he can only do so by allowing some independence first, i.e. the situation moves along the line A - D; thus one is rarely present without the other. The unfortunate result is that the difficulties and disadvantages associated with the introduction of independent learning (as outlined later) tend to be associated also with an increase in individualization, desirable though this certainly would be on many grounds (as it is hoped the next chapter makes clear).

It is certainly true that little progress has been made in increasing individualization in our schools; as Keuscher (1967) says, nothing is more discussed, yet has less done about it. Even in our sixth forms where the smaller classes ought to mean greater attention to the individual, the predominant method of instruction is still 'chalk and talk' with the class progressing in 'lockstep'. In Chapter 3, some of the attempts to break out of this are described, but they are really only the 'exceptions which prove the rule'; moreover, they have nearly all been achieved with considerable aid financially or in terms of secondment time.

It would therefore seem to be valuable to investigate the introduction of an individualized/independent learning system into a sixth form course, accepting the severe financial and other constraints which exist in any case at the present time. The later chapters of this thesis describe such an investigation.
2.1  INDIVIDUALIZED LEARNING

It has long been the aim of educationists 'to educate according to the age, ability and aptitude of the student' (Green, 1976). Since these personal factors are very much the concern of psychologists, we look first to educational psychology for research into the matching of instruction to the individual student.

2.11  The Psychology of Individualization

Many educational psychologists have drawn our attention to the individual differences in learning ability and style possessed by students; they have also delineated the personal factors which seem to determine the ability to learn. Some of these factors are: intelligence, maturation, anxiety, introversion, personal adjustment, motivation, interests, previous experience. De Cecco (1967) adds others of a sociological nature: family background, social class, race and culture. The resulting personal differences in learning ability are those which the teacher notices and which are most important to him e.g. learning pace, learning strategy, attention span, interest in given subject matter, preference for learning through one medium than another, etc. (Hooper 1971).

Unfortunately it is these "secondary" differences which are to a large extent disregarded in the conventional school curriculum with its standard syllabus coverage, conventional teaching method ("chalk and talk") and fixed length of lesson, and it is the view of many educational psychologists that such a lack of concern for individual learning differences usually has a greater effect on the learning achieved by a student than anything else. Gagné (1971) underlines the fact that learning is an individual matter, determined by what the individual does, and not by...
what the material does or what the teacher does. He allows that some psychologists emphasise the teacher-student interaction and the 'fit' between a teacher and a group of learners, and that much is to be gained by studying the activities of a teacher. However, he emphasises the need to begin and end with the human individual who is the learner if we wish to find out about learning, since learning actually occurs within the learner, in his central nervous system. He concludes that this 'strongly suggests that individualized instruction represents the route of efficient learning'; for efficiency, the instruction should be as learner-centred as possible, closely matched to the learner's individual characteristics. How to achieve this matching is, of course, the problem; what practical help does psychology afford us in our attempt to solve it? Unfortunately, not a great deal. Glaser (1966) writes that one of the primary obstacles in the development of educational structures which adapt to the individual learner has been the fact that the learning theories upon which educational practices need to be based have been concerned with carefully controlled experimental studies which lead to the discovery of general and simple laws of behaviour, general and simple because, for the most part, the 'nuisances' of individual differences in studies of learning have been held constant in order to understand the fundamental processes involved.

Byrne (1966) goes further and depicts a dichotomy in the science of psychology between two 'psychologies':

(1) Experimental psychology in which search is made for lawful relationships between independent variables and dependent variables ('stimuli' and 'responses'). 'Psychologists attempt to determine the relationships between responses of the organism, and the events which prompt those responses.' But individual organisms tend to differ
in the response which they make; this has led to the development of:

(2) **Correlational psychology**, which deals with individual differences.

Cronbach (1957) contrasts these two disciplines very well. He points out that individual differences have been an annoyance rather than a challenge to the 'experimental' psychologist; his goal is to control behaviour, and variation within experiments is unfortunate proof that he has not succeeded. Indeed he relegates individual variation to 'error variance'. However, the correlational psychologist is deeply concerned with just these variables which the experimenter would like to be able to ignore. He regards individual and group variations as important effects of biological and social causes, and investigates the effect of these variations on the degree of adaptation of the individual to the environment.

De Cecco (1964) argued that a rapprochement between the two psychologies was necessary, suggesting that the long-standing gulf between these two highly respected areas of psychology had worked to their mutual disadvantage. He observed that the problem came into focus when various investigators working in the programmed learning field found low correlations between post-programme criterion measures and conventional measures of general ability and aptitude. The experimental psychologists were forced to the conclusion that other independent variables present (i.e. other individual differences) were just as important as those being investigated and lack of control of these was leading to null results. For similar reasons, "no significant difference" results proliferate in the literature of research attempting to compare different instructional methods; individual characteristics of the learners being used as subjects are extremely difficult to control. Leith (1969) points out that in his research into structure of the learning task and achievement, unless differences in personality had
been taken into account in the evaluation, the different methods of presenting learning tasks would have appeared to give the same results. Geoffrey Hubbard in his address to the 1972 Annual Conference of the Association for Programmed Learning, stated that in a recent survey of over a thousand research papers in educational technology, only twelve were properly controlled and gave 'significant difference' results (Hubbard, 1972).

There has in fact been some progress towards a synthesis in the two psychologies during the last two decades. For example, in 1960, Jensen wrote that besides lacking an instructional technology for coping with individual differences we also lacked satisfactory ways of finding out what the differences were (De Cecco, 1964); however, in 1972 Suchett-Kaye indicated that all the traditional learning variables (intelligence, motivation, anxiety, extroversion, and so on) had been used as the basis for the investigation of individual differences in learning (Suchett-Kaye, 1972). Thus it appears that some progress has been made in at least isolating the important difference variables.

Nevertheless, Cronbach (1967) gave a timely warning when he wrote that even with the sort of multi-variate testing a computer could provide, adaptations would have to be built up slowly, on the basis of only a few differential variables; it would be a long time before we could take into account even half-a-dozen. He concluded that the study of instructional methods and individual differences was going to be extremely difficult and frustrating; it was even possible that research would never come up with a sufficiently solid set of conclusions to justify being adopted in educational practice.

Thus it seems that the teacher who wishes to individualize his instruction can expect little help as to the best method of doing so
from psychology. He might perhaps be reminded of William James' dictum (James, 1939): "You make a great mistake if you think that psychology, being the science of the mind's laws, is something from which you can deduce definite programmes and schemes and methods of instruction for immediate schoolroom use. Psychology is a science and teaching is an art; and sciences never generate art directly out of themselves. An intermediary inventive mind must make this application by using its originality." Silbermann (1970) asserts that it is indeed a large part of the teacher's 'artistry' to find and provide an appropriate relationship between what is to be learned, the way it is to be learned and the state the child is in - to solve what the American psychologist J. McV. Stuart calls "the problem of the match".

2.12 The Tutorial Mode of Instruction

The matching of instruction to the needs of an individual student is easiest when the student is taught in a one-to-one situation with his teacher. Jackson (1968) suggests that this tutorial mode has been regarded as an ideal for centuries, and Markle (1967) quotes as the 'ultimate paradigm' of good teaching a Mark Hopkins at one end of a log with his single questioning and questing student on the other. One of the most famous tutors of all is referred to by Suppes (1966) in an article on the future of computer-assisted programmed learning when predicting that in a 'few more years' (sic), millions of school children would have access to the personal services of a tutor as well informed and responsible to their educational needs as was Aristotle to those of the young Alexander the Great.

Undoubtedly the tutorial mode of instruction can be a highly stimulating and efficient one and although matching of instruction to the pupil is never an easy matter, at least the Socratic dialogue between teacher and pupil provides an essential ingredient - feedback from the
student which allows the teacher to proceed to the next stage in the instructional process. Unfortunately, many writers have tended to associate individualization only with the one-to-one situation; for example, Green (1971) contrasts individualization with 'working in groups' and Armstrong (in G. Taylor, 1970) condemns individualization as 'mistaken educationally' and 'morally repugnant' - but he is thinking of exclusively solitary instruction. Also, fairly generally in Sweden and America, 'not walking in step means walking alone' (Taylor 1971).

L.C. Taylor himself, in his proposals for 'Resource-based learning' (ibid.) often confused 'individualized' with 'individual' (i.e. solitary) learning. However, in a later article (Taylor 1972), he clarified his point of view, stating that 'individual' learning should be only one mode of learning employed among many; he underlines the variety in the ways in which children learn best: some alone, some in pairs, some in the company of many.

Fortunately, other writers are quite clear about the difference; they appreciate that a personal tutor might simply teach his pupil with materials designed for class teaching and which therefore take no account of the individual requirements of the pupil (Jackson 1968). On the other hand, as we shall see later, quite successful attempts at individualization can be made even though the pupils are not 'alone' but taught as a group in a classroom.

2.13 Grouping for instruction

Apart from the obvious economic difficulties (finding enough tutors to go round), there are numerous reasons why the tutorial mode is discarded in our schools in favour of instruction in groups:

(a) Sociological

One of the most important functions of a school is the 'socialisation'
of the pupils; as Vernon (1958) writes, education is not only individual
development but also the training of different individuals 'to conform
to society's patterns of intellectual and social norms'. The child's
peer group has long been recognised by sociologists as a powerful
agency for socialisation (e.g. Elkin 1960) and since a considerable
portion of childhood is spent at school there are many sociological
advantages to be gained from educating the child in peer sub-groups in
the form of school classes. The child then encounters and learns from
a 'hidden curriculum' in the group situation - achieving 'mutual
perception and acceptance' as James (1968) puts it. Even Lister (1971),
one of the advocates of de-schooling, supports the grouping of learners
and criticises 'individual' (i.e. solitary) learning as entirely the
wrong way to go for the mass of the population; he writes in support
of 'co-operative, participatory, group methods'.

(b) Pedagogic

All teachers know that pupils learn a great deal from their fellow
students in the classroom. Indeed, the good teacher can make very
effective use of the interplay between the different personal reactions
of the students to his teaching and their different levels of under-
standing as he elicits responses to his questions and comments on them.
Curr (1966) explains that in oral questioning reinforcement is only given
to the one child from whom the teacher accepts an answer; but the other,
unasked children learn something too from the way the teacher reacts to
the child whose answer is accepted. However, the good teacher also looks
for opportunities to sub-divide his class into small groups, knowing the
value of the intra-group discussion which might ensue when the more timid
members of the class are not embarrassed by the size of their audience;
interesting results have been obtained concerning the best ways in which
to group pupils for most efficient learning to be achieved (e.g. Amaria et al, 1966, 1970, Hogarth and Hartley, 1973).

The pedagogic advantages of grouping vary with the subject being taught. Glaser (1971) suggests that for mathematics, solitary learning is rather more beneficial than it is for social studies and the language arts; however, in general, teachers of history say that the last thing they want is a one-to-one situation since their lessons are considerably more effective when contributions are made by several pupils in a general forum. Gagné (1971) agrees, referring to the necessity for 'public' communication for both teachers and students; in such discussion, he suggests, 'communication of knowledge becomes refined, sharpened and clarified'. He does, however, admit that we have no theory as yet of the role of discussion in learning; he anticipates that when it comes it will not be opposed to a theory of individual learning, but will supplement it.

In science teaching, grouped instruction certainly has an important role. Practical work done individually rarely yields as much educational benefit as that done in pairs or larger groups. Many science teachers would probably agree with Taylor (1971) that as a learning unit, two has much to commend it; a pair can usually make decisions more quickly and a lot less noisily than a group, and more easily arrive at an acceptable speed of work. He points out that in a pair, a tentative suggestion is less exposed to possible ridicule; also both parties are usually actively involved whereas in a group some children quickly become passengers. However, co-operative discussion techniques have been applied in higher education in 'Seminar Experiments' (Read 1969), in which maybe fifty students do one experiment, closed circuit television allowing all the students to take measurements. Read points out that it is the
discussions which arise in such seminars which are their most valuable feature, the weaker students being able to learn by listening to the others.

Thus there are powerful arguments in favour of grouping for instruction, but it is clearly much more difficult to cater for the individual differences between the learners in a group when trying to match instruction to their learning needs. The attempts which have been made to do this can be broadly subdivided into those which deal with differences in (a) Learning Capacity (Section 2.14) and (b) Learning Style (Section 2.15).

2.14 Learning Capacity

This includes the ability of the student to learn quickly, and to learn in depth. A teacher of a group, say a year group in a secondary school, needs to realise just how great the range of individual learning capacity in the group can be. Goodlad (1966) emphasises this by noting that the slow readers of a class are often given at the end of a year the reading books used by the best readers at the beginning of the year - as if the spread in reading achievement were only that of one year. In fact, a simple rule quoted by Cook and Clymer (1962) indicates that this could be very much an under-estimate. Their research showed that the range of achievement in any school year - or rather 'grade' since Goodlad was referring to American schools - follows regular patterns and can be estimated quite easily. They stated that even if one ignores the two per cent at the extremes of the distribution, the range of ability is equal to two-thirds of the chronological age of the usual student at grade level under consideration. Thus for nine year old children (i.e. the 3rd grade), the range of ability to be expected would not be one year but six years, from 3 year to 15 year 'reading ages'.
Goodlad's own research (1966) indicates that even though less than 20% of the children in a fourth-grade class (10 year olds) are actually at fourth grade level, teachers believed the figure to be nearer 50%.

In the conventional classroom situation the good teacher appreciates that individual differences do exist (even if not the extent of them) and manages to effect a small degree of individualization, mainly by the introduction of variety into his classroom technique. Indeed, one of the hall-marks of the effective teacher is his class management - the way he provides appropriate enrichment or remedial material to cater for fast and slow students. However, such techniques have limited effect if the class has a wide range of ability; for this reason, one widely-used attempt to solve the 'problem of the match' has been that of 'streaming' the pupils in an age group in a school.

2.14.1 Individualization by streaming

It is clear that by reducing the range of ability of the students in a group, the teacher can match his instruction to more students in that group; in effect, one is trying to approximate to a single learner situation. Thus much educational thought has been devoted to standardising schools and homogenising classes and the best methods of achieving the latter have been the subject of considerable literature (e.g. MacMunn, 1921, Wilhelm, 1962, James, 1968).

Fundamentally there are two ways in which homogeneous grouping can be attempted:

(i) Vertically in which students of roughly equal ability are grouped together regardless of age. Since this would mean a wide age range in any one group, it would clearly lead to administrative and social difficulties. It was widely practised in the last century and is still to be found in a small way in English public schools and some American 'non-graded' schools.
(ii) Horizontally in which the student body of approximately the same age is subdivided into groups of roughly equal ability. If the students are then kept together for all subjects, this is streaming; if the group is selected differently for different curriculum subjects, this is 'setting'.

Streaming and setting have been widely applied but have nevertheless been the source of considerable controversy; each of the assumptions upon which streaming and setting rest have been challenged and hotly debated - particularly in the wider discussion concerning the merits of the comprehensivisation of our schools. The main argument in favour of streaming has tended to be the assertion that in an unstreamed class, bright children are not 'stretched' and therefore do less well than they should. However, James (1968) quotes the only large scale longitudinal study of streaming and selection which has been undertaken - the five year study in Stockholm in the late 1950's - as showing that the more able do just as well in unstreamed as in streamed classes, and that the less able to better when unstreamed. The evidence seems to be so conclusive that James considers it to be pointless to continue the debate and that we should be thinking instead of how to produce 'freer' situations in unstreamed classrooms and make positive use of the advantages of 'mixed-ability' grouping. However, the evidence is not quite so clear to Taylor (1971), who points out some of the statistical inadequacies of the Stockholm study; indeed, he quotes some follow-up research pointing in the opposite direction to the earlier work. He concedes nevertheless that these contrary findings can be partially reconciled; they suggest that bright children do learn as quickly in the unstreamed class as in a streamed class, but that they then have to mark time while the others catch up. One's own experience certainly
suggestions that an unstreamed class does progress at a slower pace than a streamed one because the teacher has to pitch his speed so as to carry the slowest student, i.e. near the slowest pace in the group.

Other assumptions upon which the practice of streaming is based are also unconvincing, e.g.

(i) "that the range of ability in a class is sufficiently reduced by streaming for the class to be regardable as practically homogeneous". The extent of individual differences already noted means that it is likely that wide ability-differences still exist within a streamed group, especially as, for reasons of economy, classes below the sixth form in our secondary schools are rarely below twenty-four, and are more usually at least thirty, in number.

(ii) "that present achievement is a good predictor of future achievement". Unless headteachers are prepared constantly to review the allocation of pupils to streamed classes, they have to rely on evidence of ability at, say 11+, as being applicable throughout the 11 - 16 age range. As James (1968) observes, this claim by educators to identify talent at an early age is somewhat Rubristic, and is hardly tenable now that it is widely accepted that academic ability is not fixed but is very much environment-dependent. 'Late-development' is certainly quite common in secondary schools.

(iii) "that pupils' performance is independent of the label attached to the stream they are in". On the contrary, Pidgeon (1965) indicated that in an 'elitist' (i.e. streamed) system, teachers and pupils establish 'levels of expectancy'. Children tend to perform at the level expected of them, and this level is indicated by the label attached to their stream, a thesis supported by the research of Douglas in primary schools (Douglas 1964) and Hargreaves in the secondary schools (Hargreaves 1967). Various subterfuges have been tried in order to
disguise stream levels, but of course school children soon see through these; 'high-flying' and 'sink' streams are recognised very quickly and pupils unfortunately tend to perform accordingly.

(iv) "that streaming makes no contribution to social divisiveness". 

It is well established (e.g. Douglas 1964) that social class has a profound effect on school performance. If therefore we stream using that performance as the criterion, we are very likely to be segregating children by their social class, and denying them the opportunity to 'find themselves' in relation to a wide 'diversity of persons' (James 1968). Thus "in racing we handicap the strong; in education, we handicap the weak .......... streaming takes over where (1l+) selection left off" (ibid).

The controversy over streaming continues and is likely never to be settled while different values are placed by society on the various outcomes of elitist grouping. Certainly unstreaming is spreading rapidly at the moment. In this country it is largely confined to the lower forms in secondary schools, but in countries with long experience of comprehensivisation (such as the U.S.A. and Russia), unstreaming is practised up to the end of compulsory schooling (Taylor 1971).

Of particular relevance to this present investigation is the greater range of ability likely to be found in a sixth form group studying science in an English school at the present time. The main reasons for this are:

(i) the growth of the number of 'new' sixth formers in our schools (Schools Council Working Paper 45, 1972); these students would have left school at 15+ in previous times but now they are staying on after taking O-levels and constituting a less-able addition to sixth form groups studying for A-levels.
(ii) The increasing numbers of sixth form colleges, taking in students from 'contributory' schools at 16+. Since it is difficult accurately to assess the ability of students from one contributory school vis-à-vis those from another, most sixth form colleges do not stream their A-level classes. Further, the much wider range of options in sixth form college curricula would make such streaming very difficult even if desirable.

(iii) The tendency for comprehensive schools to become smaller than when comprehensivisation first became widespread; schools of 2000 pupils, once considered an optimum size to provide a viable sixth form, are now comparatively rare. The result is that there are only enough students wishing to study, say, A-level physics to make one group in a year, and this will clearly be mixed-ability in nature.

It would appear then, that streaming is not generally regarded as a successful strategy for coping with individual differences in learning capacity; 'mixed-ability' teaching has therefore been increasingly experimented with in recent years. In fact, the knowledge that the class is indeed of mixed-ability can be a considerable stimulus to the teacher to devise pedagogic techniques to cope with the different abilities of his pupils. Wilhelms (1962) points out that streaming is often regarded as a sufficient method of individualisation by many teachers; the teacher often speaks of his 'slow' or 'fast' group as if all the members of each were identical. It is quite possible therefore for ability-grouping to reduce genuine attention to the individual (Keuscher 1967). There is no such danger with a mixed-ability class; individual differences are so apparent that the conscientious teacher has to take note of them and act accordingly. The point is that streaming only aids individualization in a negative way by reducing the nuisance of individual differences (Cronbach 1967).
2.142 Individualization by Breaking the 'Lockstep'

We are here faced with what has been regarded by many educationists as the greatest source of inefficiency in conventional school teaching. The word 'lockstep' was coined by Frederick Burk, one of the originators of the Winnetka plan for individualized learning, in an indictment of traditional class teaching (Washbourne and Marland, 1963). "In solid unbreakable phalanx the class is supposed to move through the grades, keeping in locked step". Thus Burk was indicating our 'assembly line' methods in education, whereby children are all made to progress at an average speed for the class. Clearly this is extremely frustrating for the quick, and demoralising for the slow. Just how large these effects can be is illustrated by the large variation in rates of learning which is exposed when students are allowed to learn at their own rate. Mary Ward, one of Burk's colleagues in the early days of the Winnetka scheme, produced the graph below (Washbourne and Marland, 1963), which can be said to have 'sparked off' the Winnetka plan for self-paced learning.

![Graph showing variation in days required for each child to complete High-Second Grade Arithmetic](image)

Similar startling variations in learning-rate have been found in many investigations, e.g. that of Suppes (1966), who found that when students are given the opportunity to progress at will, 'the rate at
which the brightest children advance may be five to ten times faster than that of the slowest. Jackson (1968) agrees, quoting similar evidence in computer-assisted instruction.

Clearly, the lockstep can be a severe restraint on learning efficiency; one of its corollaries is the high 'drop-out' rate in our schools of those who cannot keep up with the pace of the group. In particular, large numbers tend to drop out after public examinations such as 'O' and 'A' levels, having struggled to keep up until then. Cronbach (1967) points out that individual differences are taken into account chiefly by 'eliminating' students, the assumption being that every child should go as far in school, and only as far, as his or her abilities warrant. This assumes a point of 'diminishing returns' in education, reached early by some students and late by others, and a periodic 'weeding-out' of less responsive pupils; such a situation was aptly described by Shearer in 1899 as a 'Procrustean Bed' (quoted by Brown, 1963).

These unfortunate consequences of the lockstep arise because, as Markle (1969) puts it, 'the basic unit of accounting is time'. Thus a student in school takes a relatively fixed number of courses which meet for a relatively fixed number of hours, in which identical assignments are made to all students, and in which a standard examination is given at the end. A possible alternative, Markle says, is to work on a different accounting system: one in which the time taken to master the subject matter is the criterion by which ability is measured. Markle quotes programmed instruction as an example of where this is done: programmers to not usually standardise the time allowed for a programme (with a consequent variation in 'achievement'); rather they standardise the achievement (i.e. successful completion of the programme) and let other factors (e.g. the time taken to complete the programme) vary.
Thus each student is supposed to attain 'mastery' and assessment of performance is to be done on a basis of the rate at which mastery is achieved.

Now such a policy has never been followed in any pure form, since it would mean that some 'children' would need to stay at school until they were well into adulthood. However, as Cronbach (1967) observes, in modified form it is widely practised; indeed it was an assumption of the 'graded' school system in America, when established in the last century, that no promotions from one grade to the next were to be made until the required grade was attained. Cook and Clyner (1962) point out that in some schools the failure rate approached fifty per cent and that as a result, adolescent boys and girls were still enrolled in the primary grades. Clearly many problems were encountered in such situations of non-promotion and these are apparently still to be found; the difficulties are administrative (how to organise the teaching of children whose grade level might bear no relation to chronological age) and social (the desire of children to work with others of the same age, not grade level, and the parental pressures which are inevitably exerted when the lack of ability of their offspring is demonstrated so clearly by their lack of promotion). Oettinger (1969) writes of the stigma experienced by senior boys having to use 'fifth' grade text-books and their teacher having to provide much higher grade text-books just for them to carry around when in the corridors and cafeteria so that they should not lose face with their age peers.

It was because of problems such as these that many American schools discarded the original concept of grading, and grouped children by chronological age, giving them the same instruction (graded according to age) i.e. the complete lockstep situation with the disadvantages looked at above. However, pure grading and lockstep are two extremes.
and between their grouping by intellect and grouping by age lie the many variations which have been tried in the search for administratively and socially feasible alternatives. Examples are:

(i) **Multi-grading** in which children are permitted to work in different grades for different subjects; in England the nearest equivalent is 'setting by subjects' in which a pupil can be in a fast group for one subject and a slow group for another.

(ii) **Multiple-Track** in which the time required to complete, say, the 'elementary' school course is varied: six years for the bright, seven for the average, and eight for slow learners.

(iii) **Non-grading** in which no 'levels' of achievement are quoted; students simply move on according to their readiness to proceed, and there is no grouping by achievement at all (Goodlad, 1966). This is clearly the ideal solution as far as individualization is concerned but it involves extremely complex organisation of the resources available. As with unstreaming, most of the experimental work of this kind has been done in the 'elementary' schools (and "primary" schools in this country) but a few American 'High' schools (e.g. Melbourne High, Florida) and English Secondary Schools (e.g. Countesthorpe) are attempting continuous progress own-pace learning. The development of such innovations tends to be very slow because whole systems of learning have to be developed if wide ranges of learning speed are to be coped with; further, the implementation of the innovations only really gathers momentum if large areas of the curriculum are involved and the financial backing required for this is prohibitively large. Systems in even single subjects have only been made possible by the provision of large financial resources by bodies such as the Nuffield organisation, e.g. 'Independent learning in O-level Biology' (Reid and Booth, 1969).
It might be thought from the above discussion concerning the abolition of the lockstep that self-pacing is best for all pupils; however, the literature concerning this is far from convincing. Schramm (1964), reviewing the previous research on programmed instruction, suggested that the literature showed no significant advantage of own pace working; one result was the subsequent use of programmes for group learning so that the student had to move at the pace of the group. Leith (1966) said that his work showed that if groups were homogeneous in ability and previous knowledge, a controlled pace of responding did not lower achievement. However, the work of Oldfield (1964) and Amaria (1966, 1967, 1970), showed that even more effective learning could be achieved in heterogeneous groups, the slower students being pulled along by the faster ones while the latter benefit from having to attend to the structure of the material when explaining it to their partners; thus a rate of learning near to the optimum for all is achieved. Gropper and Kress (1965) in another review, provide a clear analysis and suggest that some students learn better when self-paced while others do better, in terms of effort and time, when the pace is set externally. Many students have 'maladaptive' natural rates, working too fast, or making too many errors, or too slow for the amount learned; thus slow but bright students might well do better if made to work faster, while fast learners often need slowing down for effective learning. Further, Apter and Murgatroyd (1975) found little correlation between error rate and imposed speed; thus greater efficiency can often be achieved by making students work faster. Green (1971) emphasises the need to differentiate between self-pacing and individual pacing, the latter being the pacing which gives the best results for the student concerned. He underlines the tendency
for self-pacing to produce procrastination in some students and how a teacher-imposed minimum pace requirement exerts pressure only on the dilatory student with a sense of freedom remaining for the majority. The best minimum pace can be determined by the teacher imposing different ones and analysing the results.

Hartley (1968) in a review of several factors affecting student performance in programmed learning, suggests that the serious limitations of self-pacing are largely due to (a) inability of the student to determine for himself what speed he should work at; and (b) lack of motivation which external pacing tends to provide. Students tend to 'withdraw' from a task which is too easy (boredom) or too difficult (frustration) and external pacing is suggested as a technique for a student achieving his optimum difficulty level. Hartley suggests that there is no evidence for moderate pacing being disadvantageous for the weak student, and that there is some evidence that students' own attitude to external pacing is favourable. Butler and Cavanagh (1969) support this view.

Two further points should be made before leaving the literature concerning self-pacing:

(a) the logistical ramifications of self-pacing in practice are considerable. Reid and Booth (1969) explain how difficult it is to provide the laboratory resources for a self-paced science group, when the students might well require as many different items as there are students in the group. Reid and Booth's second trial was, in fact, done with restricted self-pacing. Topics were started and finished together, with the faster students tackling difficult extra material at the end of each section; they found that the slowest students were only completing the introductory work for each topic with only 10% completing all the work available.
However, this approach meant that the whole group did at least keep approximately together over a period of time. (A modified form of this technique was used by the present author in the research described later).

(b) It should be realised that self-pacing is one of the simplest techniques of individualization and is one of the most commonly encountered. There is, therefore, a danger of being satisfied when only this kind of individualization is provided. Wilhelms (1962) expresses concern over this tendency and suggests that the uniformity can then actually be greater than with group instruction done by a teacher reasonably sensitive to individual needs. Wilhelm's warning was certainly necessary in the earlier days of programmed learning and should certainly not be ignored by the designers of today's learning systems.

2.143 Variation of curriculum content

The second strategy for individualization with respect to variation of learning capacity within a learning group is a rather more radical adaptation than just allowing the learning pace to vary. It recognises the need to adjust the area covered, the depth of coverage, the sequence adopted, etc. to the learner's needs.

One basic principle in adjusting curriculum content to the individual is to bear in mind the 'readiness for learning' of the student when considering the timing and sequence of instruction. Wheeler (1967) suggests that the general nature of the learning experiences offered should be determined by the major characteristics of the development 'stage' but the particular experience selected must be suitable for the individual student. This can best be expressed in the concept of 'readiness'. It is fairly clear that learning proceeds most effectively when the learner is physically, psychologically and socially ready for the experience; only then is the learning meaningful so that instruction is enhanced.
However, Wheeler contends, this does not mean that the teacher should do nothing at all until the child is 'ready'; he should provide experiences to help the child to develop the ability to attempt the new task. One interesting case-study of the practical effectiveness of matching instruction to the readiness of the student is furnished by the Rayner family of Merthyr Tydfil, the subject of a television documentary in 1971. All four children of the family were showing achievements at 'genius' level, in four different fields: mathematics, poetry, painting and piano playing. The mother spent a large part of her time teaching the children, and modestly claimed that the secret of her success was quite simply timing; by observation of each child she supplied instruction just when it was needed, i.e. at the precise moment of readiness. Of course this is by no means a rigorously investigated situation, and the children obviously have considerable basic ability, but the mother's technique certainly worked and was an excellent illustration of individualization in practice.

Curr (1966) agrees with the concept of readiness and indicates the mastery of pre-requisite skills or knowledge as its most important aspect, claiming that this mastery correlates more highly with success in subsequent topics than either chronological or mental age (i.e. psychological readiness). Gagné has done much work in this field (e.g. 1961, 1962, 1967) and has shown the importance of previous 'learning sets' for efficient learning; in fact he has shown that a curriculum topic will have a hierarchy of learning sets, and the identification of this enables the teacher to design a sequence of instruction for that topic, and also to start the student at the right point of the sequence depending on the learning sets he has previously acquired.

This concept of a hierarchy of learning skills is closely linked
with that of the intrinsic structure of a subject. Bruner (1960) emphasises the need for a student to appreciate this structure if effective learning is to be achieved; to a certain extent he suggests that little individualization is possible with respect to the content of the subject matter taught. Cronbach (1967) also argues against too much differentiation in the curriculum, even when desirable on account of ability or vocation. He quotes early examples of this in mathematics teaching, where, as a result, the 'discipline of mathematics was kept an arcane possession of a selected class, while the lower classes were drilled on formulas suitable for shopkeepers'. He contends, however, that today the theme in mathematics teaching (as in other subjects) is to give every pupil an understanding of the same basic discipline even though some pupils go further and deeper. Educational philosophers have joined in this argument against "watering-down" the curriculum for the less able; White (1969) criticises the 'soft-options' of projects for the school leaving year, and Hirst (1969) urges that one should not narrow down the curriculum too far, insisting that there are seven 'domains of knowledge' (or cognitive structures) in each of which every child should be helped towards some degree of mastery.

Of course the most obvious and potent constraint on individualized variation of the curriculum is that of the examination syllabus. Success in any career in our modern society still depends to a great extent on the previous examination results achieved by the entrants to that career, and examination success depends very much indeed on a syllabus having been covered. Scope for digression, either in depth or breadth, is thus very limited as far as the "external examination" forms in a school are concerned, i.e. in this country, the forms beyond the third year in a secondary school.
In contrast to the views of Gagne and Curr quoted above, Bruner (1960) suggests that the concept of readiness need not be too restrictive on the choice of the sequence of instruction. His hypothesis is that any subject can be taught in some intellectually honest form to any child at any stage of development; he contends that 'no evidence exists to contradict this hypothesis'. He quotes the example of fifth grade children (i.e. ten-year olds) at Woods Hole grasping the central ideas from the 'Theory of Functions' without understanding the theory itself (for which the children would have to have reached the Piagetian stage of formal operations). He later applies his hypothesis in proposing a 'spiral' curriculum, in which topics are returned to several times, each time being developed further, i.e. there is no hierarchy as such. He implies that little matching to the readiness of the learner is strictly necessary – the student will always derive something from the instruction he receives. However, Bruner concedes that the student has to be taught in a manner appropriate to his intellectual development, i.e. the methodology should certainly be varied for the individual if not the sequence.

One more viewpoint concerning sequence of instruction is worth noting. Mager (1964) has interestingly shown that the efficiency of a teacher-imposed sequence of instruction is doubtful. By allowing a group of students to take control of the sequence of the treatment of a curriculum topic, he found that the sequence most meaningful to the learner was different from that guessed by the teacher as being most meaningful to the learner. This again suggests that the teacher should adopt an empirical approach being prepared to change the sequence of his instruction if it appears that the student is finding difficulties with that presented to him.
What is there to say about the best level of difficulty at which to pitch the instruction to a given student? Here again there is some controversy. Vernon (1958) suggests that the educational environment should keep just ahead of each pupil's capacity, to stretch his mind to the utmost. However, Skinner (1967) would try to keep the level well within the capacity of the student at any time; he asserts that learning is best furthered by the 'positive reinforcement' of continual success in tackling the problems at each stage. Perhaps Lewis (1965) offers a useful summary of the position for the teacher to bear in mind; he suggests that on either side of the optimum level of difficulty there is a fairly narrow region of difficulty which suffices to hold the student's interest. Above this region, frustration is experienced; below this region, boredom is felt with the excessively simple materials. Lewis argues that there are special advantages to be gained by occasionally touching the upper boundary of difficulty because the effect of reaching it is (a) to spur the student on to greater efforts and (b) to reveal incipient weaknesses which might not otherwise have shown up.

How should the content of the curriculum be varied to cater for the individually-different rates of learning encountered in a self-pacing system, i.e. if the lockstep has been broken? We have seen the disadvantages of allowing the stages reached by students of the same age to become widely different. An alternative is to provide 'enrichment' material which the fast student can tackle while his slower class-mates cover the basic ground; the class then proceeds at approximately the same speed. Clyner and Kearney (1962) point out that enrichment can be of two kinds: (i) **Horizontal** which is the addition of new learning experiences on the level of the learner's present achievement status and (ii) **Vertical** which provides advanced work or further specialisation in the same area of learning. They go on to suggest that the known
purposes of children, as they relate both to immediate and remote goals, serve as clues in searching for the directions which enrichment should take in individual cases. They recommend various types of research library and laboratory work, and preparation of reports to cater for the different interests of children; a teacher might consider it to be more advantageous for a particular student to undertake 'horizontal' enrichment rather than to proceed with the basic curriculum more quickly.

Summing up, therefore, it is quite possible for students to travel different paths towards general curriculum objectives. Bruner (1966) argues for 'pluralism' and for 'enlightened opportunism' in the material and methods of instruction. They should involve different ways of activating children, different ways of presenting sequences, different opportunities for some children to skip some parts, while others work their way through different ways of putting things. "A curriculum, in short, should contain many tracks leading towards the same general goal" (Bruner, ibid.).

2.15 Individualisation with respect to Learning Style

Each student has his/her individual style of learning and the extent to which children differ in their method of working by themselves can be very great indeed. Glaser (1973) mentions the individual differences in 'rate, pace and rhythm' of learning, e.g. some students like to spend a concentrated amount of time on their work, complete it and then get more work to do; others like to work for shorter periods of time, enjoy their distractions and come back to it. Glaser underlined the importance of detecting such rhythm differences when designing adaptive systems of instruction and advocated an increased emphasis on 'process' and 'style', including an assessment of the differing needs of students for 'feedback' e.g. some children need more questions answered than others, some need more explanation of direction, and some need more praise than others.
Not only are there individual preferences for particular modes of working, but for particular media of instruction too. Thus poor readers learn better from the spoken or recorded word than from printed materials; so will those whose auditory memory is stronger than their visual memory. Some find human interaction motivating, others do not; the causal factors here are probably the particular student’s 'introversion' and 'anxiety' levels.

Thus each student seeks his own information, absorbs it and reproduces it in his/her own way. There is no 'Royal Road' to mastery of any one subject and as Keuscher (1967) warns us, to ignore the fact of different learning styles is both inefficient and wasteful of teacher time and student effort.

Unfortunately, we are on even more difficult ground here than in the first two types of matching instruction to the individual which we have considered, viz. variation of learning rate and curriculum content. Glaser (1971) writes that we know little about the relationships between measures of student behaviour and the learning effectiveness of the various 'means and media of instruction'. Rowntree (1974) suggests that even though the 'new' media have provided an enormously popular stamping ground for educational researchers (Coppen, 1968 etc.) very little of the published research is of any help at all in deciding which media to use. Research into 'older' media, is even less productive of insights, the main reasons for this being weak experimental design, insufficient detail in published reports, or simply failure to ask research questions relating media effectiveness to characteristics of the learner's situation and objectives. Certainly, very few generalizations can be drawn; researchers have looked in vain for differences in preference for media between students of different age, ability, anxiety,
introversion, previous education, sex, dependence, impulsiveness etc.,
without establishing any general guidelines to enable us to suit the
medium to the individual.

Concerning methodology, the research is almost equally inconclusive. Leith (1969 (a)) writes that it is becoming clear that
different instructional methods favour learning by different personality
types, but elsewhere (1969(b)) admits that'clear patterns are not yet established in this complex field'. There is some evidence that introverted pupils tend to favour more structured teaching while extroverts
tend to respond well to the challenge of discovery methods (e.g. Dallos,
1975); yet students who see themselves as 'tense and anxious' perform
better with independent study than with teacher-direction (Stanton, 1974).
However, items such as these do not let support to Cronbach's expressed
hope (Cronbach, 1966) that ultimately, enough knowledge would be gleaned
to enable us to say, for example, that a pupil with one 'personality
profile' needs discovery experience, whereas another will move ahead
more rapidly on all fronts if teaching is didactic.

In fact the few basic principles which can be gleaned from the
small amount of effective research are far less precise in their applic-
cability than this (Tallmadge and Shearer, 1969). For example, Glaser
(1971) suggests that one such basic principle in designing instructional
materials and environments for individual learning is to provide
situations which are 'highly responsive to the behaviour of the student'.
Thus the design of learning experiences should include a built-in
flexibility so that adaptations can be made when feedback from the
student indicates the need to adapt one's technique to suit him personally;
as Glaser puts it: 'An intimate dynamic relationship can be built up
between the teacher, the student and the environment.' The implication
is that the 'highly responsive' environment should include a variety
of resources (films, tapes, slides, teaching machines, etc.) from which the teacher and/or the student selects, and through which he learns. Gagné (1971) makes the further point that not only will the best resource or medium to use vary from student to student and from topic to topic, but also from one instructional function to another: thus his assertion is that the precise answer to the question of 'which medium' is not to be found by matching courses with media, or even topics with media, but rather in matching media with 'specific instructional functions'. With a given topic he suggests attention might best be maintained by the introduction of pictures whereas guided learning might best be accomplished by printed verbal instructions and feedback might best be performed by auditory language. Thus when choosing a particular medium for a whole course or even the development of an entire topic, one is usually making a value judgement that such a medium will be best suited to the various instructional functions involved. Briggs, et al (1969) provide some useful guidelines, e.g. they indicate how the teacher might usefully consider the objectives and 'conditions' of learning (Gagné, 1965) involved.

In the class situation, one solution is for the teacher to adopt a multi-media approach in the reasonable expectation that between them he will satisfy all the students' needs; Rowntree (1974) calls this 'media overkill'. Use of a variety of medium also helps to prevent boredom, but there are, of course, limits to this approach; excessively frequent switching from one medium to another can be distracting, and Gagne's task-centred approach must also be kept in mind. However, it is certainly time that teachers ought to become much more media-conscious than they are at the moment; innovations such as cassette loading tape-recorders and cartridge-loading film projectors have made the use of a wide range of equipment a comparatively simple matter, the main difficulty
now being the lack of suitable 'soft-ware'.

It is when individualization of instruction also involves a high degree of independent learning that the role of the teacher radically changes, and the media used need to be very different. The teacher largely becomes a 'manager of resources'; he selects and combines media and strategies in the light of what he knows of the students' learning styles, bearing in mind the cost-effectiveness and practicability of the many available options (Rowntree, 1974). Hawkins (quoted in Holt, 1970) underlines the need for a wide choice of resources in such 'learning-packages'; ideally there should be at hand multiply-programmed material, designed for the greatest possible variety of topics, ordering of topics, and type of resource, so that for every given way into a subject which a student may evolve on his own, there is material available which he will recognise as helping him along that very way.

A cautionary note should be sounded here. Devices such as teaching machines and programmed text-books do help the teacher to individualize instruction because they allow students to work on their own and therefore free the teacher to give individual attention when required. However, the devices themselves to not necessarily individualize the instruction they provide for the student. Indeed it is virtually impossible for them to do so since this instruction is 'programmed' beforehand by the teacher himself, or possibly a professional writer, and this inevitably means that the content is to a greater or less extent inflexible. This was certainly the case with 'linear' programmes of the Skinner type; thus the earliest type of multiply-programmed material, viz. the 'intrinsic' or 'branching programmes of the Crowder School, was developed in recognition of the need for individualization of some sort. Crowder was keenly aware of the range of individual
differences and soon realised the need for man-machine interaction to
guide the course of instruction (De Cecco, 1964). Romiskowski (1968)
describes how the development of the science of cybernetics led to the
'now historic' device, SAKI (Self-Adaptive Keyboard Instructor), which
trained punchcard operators by 'learning prompts' and whose course of
instruction was modified according to the error pattern of the student.
The credit for the success of such adaptive machines is not so much due
to the electronic complexity of the machine (the 'hardware') as to the
logic or teaching strategy built into it (the basis of the 'software').
Romiskowski (op. cit.) observed that less was known about the design of
such strategies than about the design of the necessary electronics to
carry them out; this is even more true with the advent of the micro-
computer (Summers, 1979).

Clearly the problems involved in producing similar machines to teach
curricular items of a higher order of complexity in the cognitive domain
are immense; it is here that the computer promises a great deal.
Computer Assisted Instruction (CAI) can satisfy the need for a large
number of different routes to the same educational objective; the branch
to be followed at a particular point of divergence in the material can
be determined not by the one response the student makes at that point to,
say, a multiple-choice question (as in simple intrinsic programming
machines) but by his pattern of response over a period of time - maybe
even over the whole period of instruction up to that point. Unfortunately
some would-be users are put off by the need to learn a computer language
with which one can 'converse' with the machine. It was realised in the
early days of the development of CAI that it was essential to develop
computer languages which would make it easy for the designers of a course
to put their software into a computer, and for a student to extract it,
without either having to become an expert computer programmer (Glaser, 1966).
Some progress has been made in this area so that after short periods of instruction at computer centres, students are able to 'converse' with the computer fairly confidently (Abbatt 1972, Lewis 1978, Hubbard 1979).

Glaser (1966) reminds us, however, that the analysis of student performance for 'wise instructional decision taking' is not the only contribution to individualization which the computer can make. With appropriately designed 'on-line stations', a computer can provide a rich environment for the student. New ways can be provided for him to interact with and manipulate subject material as he works with it. Through appropriate audio and video storage devices, the computer can control fast access to sound messages and pictures; thus a student might learn about the algebraic representation of an equation by manipulating different parameters on a keyboard and thereby changing the slope and intercepts of a curve displayed on a visual display unit. The computer can even be used in a 'simulation mode' (Blum 1971) wherein a student can simulate experiments and see what results he would expect to get from them; one advantage of such simulation is that one can simulate quantities which do not actually exist, e.g. field lines, light rays, non-Newtonian laws of motion, magnified relativistic effects, and this facility can be an extremely effective aid in science teaching.

Unfortunately, there is the problem of cost even more for the implementation of CAI than for the other types of media-aided instruction. Schools need considerable financial help if they are to instal a computer terminal and there are considerable running costs. Taylor (1971) suggests that a comparatively cheap arrangement is an alliance between a school and local industry for off-line facilities, e.g. at Sevenoaks school, boys learn 'Fortran', type their instructions on a computer programming desk and send the coded tapes to the Marley Tile Company where they are processed free of charge on a sophisticated computer using 'unemployed'
Similar 'off peak' use of a large computer is involved in the 'CAMOL' (Computer-Assisted Management of Learning) schemes at Belfast and Birmingham; the aim of these is to relieve teachers of the extra workload involved in the management of a highly-individualized independent learning system (Brown and McMahon, 1979; Tinsley, 1979).

However, the greatest hope for the reduction of the costs of computer assistance in schools lies in the development of the microcomputer. Provided that the Heads of Department in a school agree to pool part of their subject allowance, it is now financially feasible for a school to purchase its own computer system; much greater flexibility and variety of computer assistance is then possible (Hinton, 1977; Summers, 1979).

In spite of such developments as these, the cost of the 'hardware' is still a considerable obstacle to the development of systems of individualized learning. This was recognized by the Nuffield 'Resources for learning' project when it costed its proposals in some detail (Resources for Learning, 1971). It is quite clear that only when the holders of the educational purse-strings (i.e., the Department of Education and Science through the Local Education Authorities) are convinced of the benefits of adoption of individualized learning in schools will they effectively overcome the financial obstacle of the cost, not only of the 'hardware' but the considerable 'hidden' costs of producing the 'software' of individualized instruction, e.g. the cost of teacher time in its production. The design of effective programmes or packages is usually beyond the time resources of the individual teacher in a school; curriculum development teams often have to be formed so that the burden can be shared with colleagues in the same school or other local ones, and Teachers' Centres often become the foci for these groups. Considerable backing is necessary from local
Education Authorities for such activities with secondment being highly desirable for the team leaders (Sand, 1967).

More widely-based pooling of ideas has been achieved by such agencies as the Resources for Learning Development Unit, based in Bristol. This organisation was established as a direct result of the investigations and recommendations of the research funded by the Nuffield Foundation in its 'Resources for Learning' Project, 1966 - 71 (Taylor, 1971). The Project recommended the formation of local supporting agencies or 'hives' which would produce learning packages for the linked schools (Resources for Learning Project, 1971). Unfortunately, the Bristol Unit was the only one established and financially supported by a Local Authority; it has, however, demonstrated just how effective local co-operation can be, by fostering a considerable amount of independent learning in secondary schools in the Avon area.

The 'Independent Learning in Science Association' (ILIS) is a British national organisation dedicated to the more widespread exchange of ideas and materials, but only for use in the teaching of secondary school science (ILIS, 1975). To this end, ILIS produces a quarterly journal and an annually-revised address list and catalogue of 'software' which is available from members at low cost; thus unnecessary duplication of effort by teachers working in different parts of the country but in similar fields can be avoided, and learning packages improved by constructive criticism from other teachers interested in, and knowledgeable about, the same area of the curriculum.
2.2 INDEPENDENT LEARNING

It has been pointed out earlier that as soon as a teacher introduces a degree of individualization into the instruction of a group of students, he must, as a corollary, accept that the students' learning becomes to a certain extent 'independent', i.e. the teacher cannot remain the sole source of information for the students. In fact, in any independent learning system, the teacher becomes a 'manager of resources', and this, as we shall discuss later, can give rise to 'role' problems for some teachers. Our present purpose, however, is to suggest that the independent nature of such learning itself has considerable advantages, over and above those which it has by virtue of being linked with individualization.

2.21 The Special Advantages of Independent Learning

(a) The learning achieved is more efficient

It is one of the ten commandments of successful education that participation of the learner in the process of communication is an indispensable requirement of efficient teaching (Curr, 1966). Pidgeon (1965) suggests that children often realise far too late that learning is something they can only do for themselves; they think they can be 'passive' learners.

Unfortunately, the traditional classroom tends to encourage passivity; the greater part of the teaching is to large groups of pupils, nearly all of whom have to be silent and docile for nearly all of the time or else chaos results. Even in the practical work of a science subject, as Bosworth (1967) points out, many of the children in the class do not need to do any work for themselves; all too often results and conclusions are copied into notebooks without any real understanding of what is being shown.
In an individualized learning system, however, there is very little opportunity for passive listening. There is a marked shift from learning 'by being told' to learning 'through a personal interaction with people and things' (Taylor, 1972 (b)); moreover, the responsibility for learning is clearly seen to shift from the teacher to the learner, and Gleason (1967) reminds us that behavioural psychology has shown that the learner's acceptance of this responsibility generates the motivation necessary for effective learning. As Sears (1967) puts it: the 'effectance' theory of motivation suggests that pupils experience an internal urge to accomplishment on their own, deriving self-reinforcement therefrom.

At this point it should be mentioned that some critics of independent learning have suggested that when students are learning at their own pace from, say, teaching machines, they lose the motivation generated in the traditional classroom by competition with one's fellow pupils. However, as Borger and Seaborne (1966) point out, since only one pupil in a class can come out 'top', comparisons with other members of a class are likely to be discouraging rather than encouraging. In addition the programme used with such a machine will include a pattern of 'positive reinforcement' and constant activity on the part of the student, and these are generally strongly motivating.

(b) Reduction in discipline and drop-out problems

One spin-off benefit from this more efficient and better-motivated learning is a frequently-experienced reduction in discipline and drop-out problems. Discipline problems are often a matter of poor communications between teacher and pupil, and good communications are clearly of the essence in an independent learning system, in the form of continuous feedback and feedforward between the pupil and the teacher, especially in the frequent one-to-one situations which are made possible.
there are improved personal relationships between teacher and pupils, based on the fact that the teacher is seen as an ally in overcoming the problems of learning, rather than on the side of the "knowledge enemy" which has to be 'conquered'. As Jackson (1968) puts it, there is less 'psychological distance' (as well as physical distance) between teacher, learner and materials.

A third factor is the (at least partial) removal of the 'aversive' control of the traditional classroom. Skinner (1968) contends that the openly aversive control of fifty years ago (e.g. the memorisation of tables in order to avoid the cane) has been replaced by another form of aversive stimulation. The child does his work primarily to escape from the threat of a series of minor aversive events - the teacher's displeasure, the criticism or ridicule of his classmates, an ignominious showing in a competition, low marks in a test, a talking-to by the Headmaster, etc. Skinner suggests that 'getting the answer right is in itself' an insignificant event, any effect of which is lost amid the anxieties, the boredom, and the aggressiveness which are the inevitable results of aversive control'. However, the keynote of independent learning is frequent positive reinforcement and this has none of the above unfortunate by-products.

Fourthly, unfairly critical assessment of pupils is replaced by reappraisal of the system itself; a high degree of mastery by all pupils is the desired goal, and if this is not achieved then the system is regarded as having failed and needing adjustment. This was well put by Keller (1968) when he answered a student's criticism of the behaviour of the white rat he was using in an experiment by the remark: "the rat is always right".

Finally, as Brown (1963) points out, a common cause of discontent in traditional school classes is the suppression of curiosity and
imagination because the lockstep insists that the pupils should all be curious and imaginative together. Independent learning allows much more freedom to explore and discover, guided by the teacher, and this affords considerable intellectual satisfaction. Brown (ibid.) quotes the 'Quest phase' of his curriculum at Melbourne High School as a major factor in the reduction of the drop-out rate there to 4% compared with a national average of 30%.

(c) The quality of the teaching provided is frequently improved

As in all professions, there are good, bad and indifferent exponents of the art of teaching; even within a school, the teachers in a given subject department will have different abilities, different strengths and weaknesses, different personalities and different teaching styles. Taylor (1971) reminds us that it is most important to a pupil which teachers he draws in the 'lucky dip' of the timetable. He quotes a questionnaire issued by the Royal Society to its members in 1970 concerning the influences which led them to become scientists. Much the most important was found to be the 'good' science master; it is not known how many others are deterred by a 'poor' teacher.

Again in both science and mathematics, but particularly the latter, the severe shortage of specialist teachers has for some time produced ill-effects. The Dainton Report (Council for Scientific Policy, 1968) suggested that one of the causes of the swing from science and maths in recent years is the fact that children are committed to career choice before they experience good science and maths teaching by specialist teachers. Again, science teachers find it very difficult to keep abreast of recent developments in their field; the result is often sterile science teaching without mention of modern applications to elucidate basic principles.
The teacher's personality and teaching style are important too; there can be a lack of sympathy between a particular teacher and a particular pupil, and Jackson (1962) summarises some interesting research in this field. Another important observation in this connection has been made by Peters (1976). He suggests that even where a school has a brilliantly original teacher, it can sometimes create problems in the long run. Innovations which such a teacher introduces can flounder and break down if they later have to be implemented by an 'average' teacher without his special gifts.

A well designed independent learning system minimises the above defects owing to variation in teaching quality, by aiming to standardize the level at that of the best teachers in the school, or the district (if the system is to be used by the schools in an area) or the country (if it is to have national coverage). Thus the best teachers must be involved in the design of the course materials (programmes, booklets, audio-visual aids, etc.); all pupils using the system are then exposed to high quality 'teaching' and this we have seen above is particularly important for the younger, uncommitted pupils whom it is important to persuade to take up scientific or engineering careers in the national interest. In effect all of the pupils are being taught by a specialist expert, and if the contingencies of the time-table so demand, non-specialists could 'administer' the system, with a specialist in overall charge of several such groups and reasonably close at hand to cope with special difficulties. This is the technique adopted for example (a) by the Surrey Auto-Tutor Mathematics Project team at France Hill, Camberley, who underline the ease with which non-specialist teachers can make an effective contribution in this way (Surrey County Council, 1970) and (b) by the I.L.E.A. 'APPIL' system for sixth form science teaching, wherein one specialist physics teacher, say, is peripatetic for a number
of comprehensive schools, each of which might have only three physics
customers in the sixth form, i.e. the specialist is present for, say, two
periods out of the eight for Advanced Level Physics in a given school,
non-specialists administering the system materials for the other six
periods (APFIL, 1979). One 'spin-off' here is that smaller comprehen-
sive schools become more viable; without this kind of peripatetic
teaching of small groups, a comprehensive lower school has to be very
large for the sixth form which it feeds to contain economically-sized
groups in the less popular but important subjects (e.g. physics). Such
large comprehensive schools (>1200) have been found to have many social
and disciplinary disadvantages (Taylor, 1971).

Further, the up-to-dateness problem is fairly easily solved by
someone who has the time and facilities to keep abreast of modern
developments (e.g. a County adviser) periodically up-dating the material
by inserting recent applications. Also the learning system has no
'personality' for a particular student's personality to clash with;
true he might not get on with a learning package's teaching style, but
there would be more than one route through the material, and the super-
vising teacher would always be close at hand to provide tutorial help
in such cases.

Lest it be thought that the above discussion is hinting at the
possibility of the teaching machine completely replacing the teacher,
let us emphasise the need for the specialist teacher to manage the
resources involved in the system, and to act as a tutor when the student
needs personal assistance. The aphorisms: 'better a good machine than
a bad teacher' and 'the teacher who can be replaced by a machine deserves
to be' (Carr, 1966) certainly go too far; they are answered, for
example, by Borger and Seaborne (1966), who underline the influence of
educational tradition (and the institutions which embody it) which encourages and sometimes constrains teachers to engage in replaceable activities. The incursion of the machine into human preserves, they assert, only highlights the extent to which teachers have to carry out routine tasks which are not worthy of their potentialities. This surely is the point; the machine and the teacher can each to certain things better than the other. Schram (quoted by Gilbert, 1969) sums up the position very well in his discussion of research comparing the effectiveness of media and human beings as teachers; when the comparison emphasises things a teacher can do especially well (take care of individual needs, answer questions which can't be easily anticipated before the lesson, conduct a discussion, and the like) the more learning is likely to take place via the teacher. When the comparison emphasises the things a machine plus other media can do specially well - present truly excellent material, present a lesson that has to be prepared with more care and free time than a classroom teacher can usually afford to give it, give audio-visual demonstrations that would be beyond the ability or resources of a classroom teacher - then the advantage falls on the media side.

The answer clearly is in a teacher - machine partnership and this is what independent learning systems aim to provide. As Taylor (1970) observes, the teacher can then utilize what is his true expertise viz. the devising and organising of the learning process, relating to the needs of individual pupils, and giving help and support only when necessary. By accepting courses prepared by others, by permitting various technological devices to take over the work they can do as well as or better than the teacher (and encouraging the integration of educational technicians in the rooms where learning is taking place), the teacher is multiplying his effort and deploying it where it is most needed.
Taylor (ibid.) also reminds us that the salient feature of the first industrial revolution was the use of machines to multiply human effort in the factory: one important feature of the second (and current) industrial revolution may well be the extent to which technology enables teachers to divert their intention to the organisation of learning in terms of the individual child, i.e. doing what he is best at doing. The 'job-satisfaction' so derived is a particularly valuable spin-off here; it makes sense of the title of a recent lecture: "Individual learning, or how to live to draw your pension" (Gilbert, 1973).

(d) The 'status' of teaching is improved

The status of the teacher in the eyes of his peers and his pupils is of considerable importance to him; without the respect of his pupils, he cannot hope to teach them effectively, and since he is working in partnership with parents in the education of their children, it helps considerably if those parents have respect for the profession to which he belongs. Unfortunately the teaching profession has all too often failed to move with the times, losing status as a result. In his presidential address of the 1972 conference of the Association for Programmed Learning and Educational Technology, Sir James Pitman observed that many classrooms exist in which a Victorian teacher would feel at home, and that the depth of feeling of the opposition to change would be more appropriate to religion than education. He further suggested that it was as unprofessional for a teacher to proceed as he would have done fifty years ago 'as for a doctor to operate without the use of antiseptic' (Pitman, 1972).

Yet the teacher all too often does. For example, until the changes brought about in the mid-1960's by the activity of the Association for Science Education and implemented by the Nuffield Foundation, school science syllabuses were almost identical with those of 1900; indeed
a pre-knowledge survey for University Science entrants (O'Connell et al., 1969) showed that even at the end of that decade, 'modern physics' in many schools ended at about 1900. Certainly it is in the technological field that education has most clearly not moved with the times; teachers have been slow to draw upon the extensive educational technology that now exists. As Sand observed (Sand, 1968) the '2 x 4 x 6 teacher' is still prevalent in our schools; one who is stuck between the two covers of a text book, the four walls of a classroom and the six periods of a school day. Unfortunately for such teachers, there is considerable competition for the attention of children from the 'horizontal' transmission of culture via television and other media; the de-schoolers have not been slow to point out that with the expansion of books, films, records and tape recordings, the social capacity for learning outside the school is greater than it has ever been (Lister, 1971). Children are bound to compare such slick presentations with what they are given at school, with considerable damage to teacher status; and not only the children - also their parents, who are ultimately the educational paymasters. The result is, as Glaser (1963) points out, a vicious circle in which 'present educational practice has little status as a technological application based on underlying science', therefore little research is done ('there are no Cape Canaverais in educational technology'), therefore there is no rise in status. Musgrove and Taylor (1969) urge that what is needed is a 'veritable army' of educational technologists; 'charisma' has almost been driven from our schools without replacement by 'technical competence'.

Unfortunately, in those places where teachers do introduce radical changes the bitterest opposition does seem to come from the parents; they talk about the good old days as if in the educational field they really were better. As John Watts, Headmaster at Countesthorpe (where
radical moves toward independent learning have been made) pointed out 'they wouldn’t talk of the good old days in the hands of other professions such as dentistry' (Makins, 1972).

Certainly in independent learning systems there ought to be technical competence for all to see. Not only do they often incorporate prestigious modern 'hardware' but their effectiveness can be seen to derive from the application of a sound systematic approach to the problems of education - which, of course, is what educational technology is all about (Hubbard, 1970). Teacher status must be enhanced as a result.

(e) Students become less dependent on their teachers

Traditional teaching methods tend to produce students who are extremely dependent on their teachers. As Jourard (1967) puts it, independent learning is now a 'pedagogenic' problem; he suggests that teachers (they should rather be called 'trainers') have been commissioned by social leaders to 'shape' youngsters to an acquiescent mould. They insist that students learn only when and what they are taught; thus they rob students of autonomy and produce a 'golem', a humanoid, a 'dependent learner'.

Now many teachers would deny this, but others would agree that it is basically true, albeit expressed rather strongly. However, it is the 'consumers' of the teachers' products who can really assess the situation; in particular teachers in higher education. Elton et al (1971) certainly feel that the problems of transition from school to University are often due to excessive teacher-dependence. Keohane (1974) writes that he finds that a third of his first year physics students were still having notes dictated in the Upper Sixth, and this is bound to produce problems when the lecture is no longer the unchallenged mode of communication at Universities, with the increase
in self-study method there. Keohane also expresses concern over the difficulty in conducting tutorials with students used to passive learning; Lees (1976) writes of similar problems even in the post-graduate certificate-of-education year. Entwhistle and Wilson (1976) also blame the mismatch between school and university teaching styles for many student difficulties; school pupils' working habits are controlled by the teacher, with many small pieces of work to be done on a regular basis, whereas at university the student will find large first-year classes, ill-defined course objectives and infrequent assessment of progress. Only the comparatively few students who have been given some practical experience in independent study, they suggest, can hope to be able to cope with such changes. Beard (1970) underlines the need for students at school at least to have the experience of independent learning from a resource centre when she describes a situation which Walker (1973) suggests would be incredible if it did not appear in black and white; Beard found annually that graduates in a Department of Education did not think of looking up topics in the index of psychology books which were handed to them but began systematically to search from the first page. A suggestion to consult the index invariably caused initial surprise and some of these post-graduate students even needed to be told where to find it! Surely some experience of independent learning in schools ought to lessen the possibility of such lamentable ineptitude. As Glaser (1966) writes, the teacher should play the significant role of helping the student discover how he learns best; 'the teacher needs to learn from the learner how to teach, and teach the learner how to learn'. It is remarkable that teachers still ignore after more than fifty years the excellent advice of two educationists of the calibre of Elbert Hubbard and Sir John Adams (quoted by Curr, 1966): 'the object of teaching a child is to enable him to get along without the
teacher' and 'there comes a stage in education when every teacher should say to his pupils, "it is expedient for you that I go away".'

It is however important to emphasise once again that an independent learning system may only be individualized to a small degree, and that the degree of learner independence generated is linked closely to the amount of individual choice the system allows. Parnes (1976), an Open University teacher, quotes the Open University courses as being heavily 'structured' and therefore non-individualized - necessarily so, he suggests, because a University which has little face-to-face contact with its students has to be more authoritarian and inflexible than residential Universities. As a result, the students appear not to want the delegation of educational decisions to them; there is also very little 'quality' learning achieved, by which Parnes means the ability to ask questions, hypothesise, evaluate, and organise one's own learning. Some O.U. courses are, however, learning the lesson and including 'independent' project work; others are developing a framework which allows the student to select his own objectives and method of achieving them. It has to be admitted that such frameworks would probably be too open-ended for school use.

A similar plea for de-structuring is made by O'Connell et al (1975), who list the qualities necessary to be developed in preparation for ongoing education at the end of a course; among these are ability to work independently, to work in groups, to identify problems, to make decisions, to plan ahead, to analyze critically, to communicate, to adapt to unfamiliar situations, to keep an open mind. Unfortunately, they assert, learning related to these considerations is not readily examinable and what is not examined tends not to be taught, and therefore not to be learned. In particular, they suggest that to develop the ability to learn independently, it is important that the student should be motivated
from within rather than by pressure from the assessment procedure; thus the course should be self-motivating. Again, more open-ended project work is urged.

However not only in Higher Education is independence desirable; society at large needs autonomous, freely-thinking individuals. Keuscher (1967) underlines the need for people who dare to be different, people who will assert themselves, lead, experiment, change; he censures the schools who do not produce self-directed individuals as having failed the students, the profession, and the society they are designed to serve. It is to be expected that the greater use of independent learning in the classroom would reduce the tendency of schools to fail in this respect, and there is a strong case for giving this a high priority when designing and developing the secondary school curriculum.

2.22 Particular Problems associated with Independent Learning

There are several difficulties linked with the learning independence which necessarily accompanies attempts to achieve individualization in a group situation. Among the most important of these are:

(a) The teacher's change of role

In an independent learning system, traditional class teaching, to which the teacher is most accustomed, has to be very largely abandoned. Instead the teacher becomes a 'Manager of learning' (Layton, 1970); he has to step down from his traditional place on the dais at the front of the class, and organise a number of individual or small group activities. Davies (1971) sees the four broad functions that characterise the work of a teacher - manager as:

(i) Planning e.g. forecasting requirements, defining objectives, detailed syllabus writing, allocating time available, budgeting the resources involved.
(ii) Organising e.g. arranging and relating learning resources so as to create a learning environment which will realise objectives in the most effective, efficient and economical way possible.

(iii) Leading e.g. motivating, encouraging and inspiring students. Here the teacher is on fairly familiar ground, but there are extra difficulties when the emphasis changes from leading a group of students to drawing out the best in individual students.

(iv) Controlling i.e. monitoring, re-assessing and regulating the learning situation where necessary, so that difficulties in the realisation of objectives might hopefully be overcome.

Davies further suggests that even though these appear to be disparate activities, they must be regarded as a closely related cycle:

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Planning  Controlling
  \       /  \\
   /     \   \\
/       \  \\
|       |   |
  |       |   |
/       \  \\
   \     /   \\
   \   /     \\
    \ /      \\
    V        V
Leading    Organising
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Lonnon and Bodine (1971) make similar points in their discussion of the five 'behavioural shifts' which they regard as essential changes in the role of the teacher. One which they certainly underline is that from 'enforcer of coverage' to 'assistant in students' self-evaluation'; in this connection the teacher has particularly to develop the skills of listening (many teachers are especially poor at this!) dealing with emotions and developing an individual rapport to a much greater extent than is commonly practised.

Green (1976) stresses the importance of long term planning on the part of the teacher; the idea of preparing material for tomorrow's lesson has to be abandoned. He also emphasises other managerial skills such as ability to devise simple and efficient methods for the storage and retrieval of resources, keeping of records, and of marking students' work. Taylor (1970) mentions the need to keep control without the
rigidity of discipline insisted on by many teachers. Thus absolute stillness and silence are clearly inappropriate to the independent learning situation; a more relaxed atmosphere with students on a longer rein is clearly required. In this connection Glaser (in Hooper, 1968) quotes the frustration experienced by some teachers who point out that they have been trained to teach a class and that their pedagogic techniques are based on their training; they find it particularly difficult to acquire the flexibility of approach quoted by Rowntree (1974) as necessary when the teacher moves from group to group, having to adjust each time to a new problem and new learning difficulties. As Rowntree says, the teacher tends to feel that he is working for his students rather than they for him. Glymer and Kearney (1967) summarise the problem in the words of the bewildered student teacher who said: 'the trouble is that there are more of them than there are of us'.

Teachers, taken collectively, tend to be conservative in nature, resistant to change unless the reasons for it are clearly and overwhelmingly advantageous. It follows that the radical changes in role outlined above are met with considerable resistance from many teachers who do not feel that they have the ability to tackle the changes involved. The problem of the feeling of lack of control has been emphasised by Gray and Sare (1970), who suggest that the teacher's ability to organise a situation in which many different activities are going on is vital to the success of any independent learning system. Many teachers are not used to having to keep a methodical record of the variety of information about individual student's performance and progress; many also find difficulty in early diagnosis of pupils' problems, having to decide quickly on remedial action and to see that it is carried out. Gray and Sare point out that these necessary activities bring the pressures on the teacher closer to those of an executive; Jackson (1968) would compare them with
those involved in 'engineering' and suggests that if there is one thing that the teacher is not it's an engineer.

The problems of an increased managerial role for the teacher in 'resource-based' learning are not confined to those of the different skills required; there are psychological problems of attitude too, largely centred on the removal of the teacher from the central position, as only source of information, to the periphery, as 'merely' one of many resources upon which the student can draw. Because professional teachers like to feel that they are as indispensable to their students as doctors are to their patients, there is obviously a 'status' problem here. Indeed far from the enhanced status educational technology ought to bring to teaching as a profession (as discussed earlier), some teachers feel that they personally lose status by its introduction into the classroom in independent learning. There is, of course, some truth in this; London and Bodine (1971) emphasise the increased democratic process involved in the 'equality-base' of the new 'management structure', vis-a-vis the teacher-dictatorship of the traditional classroom. Older teachers obviously find this a greater problem; not only were they taught in teacher training to adopt an authoritarian pose, but they have been used to adopting it for many years.

Closely linked with this difficulty, and found to be equally imaginary when investigated after actually trying resource based learning, is that of an expected reduction in personal contact between teachers and pupils, with the 'software' and/or 'hardware' of the learning system coming between them. In fact, of course, as Taylor (1971) says, the instructor's 'knowing and caring' i.e. his tutorial and pastoral functions, cannot be replaced by the machine. Teachers are plainly of critical importance in caring for, and about, children; the inspiration, encouragement, control and guidance they provide matters profoundly. When
we talk about alternative systems of learning we are asking only where, principally, the burden of instruction should rest. Thus the title of one of the most important articles expounding on the virtues of independent learning, "Goodbye Teacher!" (Keller, 1968), was most misleading; as even the article itself makes abundantly clear, the teacher's personal involvement with the student in such a system is even greater than with traditional teaching. Glaser (1971) writes that, even in CAI, where the teacher might appear to play a very small part, efficient use of the computer is best seen as providing more time for the teacher to 'devote to humanitarianism'. Taylor (1970) agrees; teachers new to independent learning often see themselves as mere observers, organising and assessing the students' work but letting them get on by themselves for the most part. However, when the teacher actually participates, he soon finds he still has to guide, criticise, encourage and share fully in practically all that the students do. Thus, far from having a smaller personal involvement, a teacher using independent learning methods usually has to deal with students on a one-to-one basis in a 'tutorial' manner much more frequently than he was able to previously; indeed, for some teachers - with a more introvert nature who might have 'got away with' little personal involvement (especially in traditional lecturing in higher education), this is the problem rather than the converse.

(b) Students themselves feel that Independent Learning is impersonal

The students themselves also tend to feel that they must inevitably lose much of the personal contact with the teacher which is so valuable. As we have seen above, this concern usually lacks foundation in the event, but there is often greater substance in the students feeling that, far from the greater individualization being aimed at, they are merely live 'fodder' for the system machine. Peters (1976) warns against this when discussing the move towards comparing the role of the modern headmaster
to that of a business manager; he suggests that among the attitudes to learning which might unfortunately be reinforced by the adoption of this model of 'management' is that of pupils who feel that they are providing 'material' which is being 'processed' very efficiently and turned out as a typical 'product', with their academic achievements as 'marketable commodities'. It is unfortunate that much of the literature linking systems-analysis with education tends to give this impression; for example, Rowntree (1974) writes of education being a sub-system within the suprasystem of society as a whole, from which it receives its 'input' (students, teachers etc.) and which expects from it a certain kind of 'output' (people possessing certain skills, attitudes, etc.). As Rowntree says, the systems metaphor is a fruitful one, but it does have the above-mentioned dangers from the student's point of view.

(c) Some practical problems

There are several practical problems encountered by teachers administering an independent learning system or contemplating doing so, which are real obstacles to its continuation or implementation. Among these are:

(i) Conflicts between the Head teacher and the teachers involved

Butler and Cavanagh (1969) quote this as one of the difficulties most frequently described by teachers using independent learning. The conflict arises because of a clash of aims, the head teacher seeing such a curriculum development as an opportunity for window-dressing, whereas the teacher is often far more aware of the donkey-work involved in keeping the system running. There are no hours available for development tasks and the school management has no insight into the organisational structures needed to support their efforts.

(ii) Shortage of time allowed for teachers developing and trying out the system

For any major curriculum development, there is a great deal of
time needed by a teacher in getting to know the content of the new
course materials and in working out how best to implement it (Butler
and Cavanagh, ibid.). The teacher might fondly imagine that he would
be released from actual teaching during lessons, but he soon finds that
he spends a great deal of time in class as a 'machine-minder' and 'test
administrator', or in helping with students' individual difficulties.
Consequent uncertainty as to how best to implement the course leads to
lack of confidence, and is a considerable obstacle to its effective use.

If the teacher tries to reduce the time he spends in pupil-contact,
motivation can be diminished instead of being enhanced as we have
suggested earlier; when the novelty of the machine, or system materials
has worn off the teacher is very much needed as a motivator. A pupil
faced with an impersonal machine for long periods can easily become bored
without encouragement from the teacher. As Walker (1973) says, the
'teacher-as-inspirer' comes in between the 'teacher-as-oracle' and
'teacher-as-organiser' and such inspiration usually happens during
personal contact. Walker also refers to Bruner's theory of 'motivation
generated by reciprocity' i.e. the deep human need to respond to others
and to operate with them towards an objective. There is a clear danger
that this source of motivation might be ignored in independent learning
and this would certainly be to the student's disadvantage; this probably
explains Gray and Sare's observation (1970) that children (and even
adults) only remain fully involved with a learning programme when they
feel the personal concern of a teacher in their progress.

(iii) There is a tendency for students to work on their own too much.
We have seen the tendency for individualization to be confused with
working alone, and the social and pedagogic advantages which are lost
by solitary working. Linked with this danger is the fact that learning
packages tend not to encourage students to ask questions (Walker 1973)
nor to take part in discussions (George, 1974). As Gagne (1967) reminds us, such activities - the cut and thrust of question-and-answer and discussion - are important for refining and embellishing one's understanding of basic principles.

(iv) A frequent cause for concern is the slow rate of progress achieved by students in even partially self-paced learning. Thus since most secondary school examination syllabuses (e.g. both O-level and A-level physics) now tend to be very large and candidates' chances are severely prejudiced by poor syllabus coverage, this is then reflected as criticism of the adoption of independent learning. Unfortunately there is little conclusive evidence in favour of independent learning in terms of examination performance to counter-balance this criticism; for example, Dubin and Tavaggia (1966) reanalysed data for ninety-one comparative studies and came to the conclusion that there were no measurable differences between 'distinct' methods (lectures, discussions, independent study, etc.) when judged by student performance in final examinations.

(v) Undoubtedly one of the greatest obstacles in the way of adoption of independent learning is simply inertia, the fact that it is far easier to carry on doing as one has been doing rather than to change, especially when the change is a radical one. The trouble is, as Taylor (1972 (a)) writes, all the arrangements in our schools (insulated egg-box architecture, period time-tableing, prescriptive syllabuses for all to follow, slight use of learning materials - all equipment and books amounting to some 5% of the educational budget), are functions of the assumption that children will get most of their learning from the lips of teachers. Oettinger (1969) underlines this by complaining about the misuse of even the single most common tool of education, the book. Taylor (1971) agrees, suggesting that the text book, except occasionally in literary subjects,
acts chiefly as a compendium of exercises for homework ... 'the normal sequence of instruction is that the book helps to guide the teacher who then teaches the child'.

However, Gettinger does support the development of independent learning by using the text book itself more sensibly; he contends that the book in principle lends itself very well to individualization (Gettinger, op cit.). Hills (1971) agrees, commending the flexible use of which the text book is capable; Jevons (1969) would even advocate the replacement of teaching by lectures in higher education by self-teaching from a detailed reading list. Armstrong (1970) disagrees, however, asserting that a text book cannot meet the new demands of individual work; he suggests it is relatively unresponsive to a child's individual questions, doubts and profiles. Sanders (1966) even suggests that the text book is too perfect, i.e. writers assume that students learn best by studying a 'polished' product, in which complex ideas are clarified by dissection, integration example and visual images. Thus he accuses the text book of weakness in that it offers little opportunity for any mental activity except remembering.

Research is needed to provide evidence as to which of these points of view is most nearly correct; the learning system devised by the present writer contributes to this research in that text books are the main resources of independent learning provided.

2.3 THE ROLE OF EDUCATIONAL TECHNOLOGY IN INDEPENDENT LEARNING

In the 1960's there occurred a flood-tide of curriculum development in Great Britain, largely stimulated by an upward surge in interest in educational research in the United States in the previous decade; one important result, for example, was the range of 'Nuffield' science syllabuses produced from 1963 onwards. A contemporaneous development was the meeting of programmed learning specialists and audio-visual
enthusiasts in the general activity of re-thinking methods and re-
designing curricula; also many of the concepts of systems analysis,
useful in management theory as well as in computer technology spilled
over into adjacent areas. From this interaction came the new concept
which came to be called 'Educational Technology' (Beswick, 1977).

Unfortunately, confusion soon arose (and to some extent still
exists) owing to the 'engineering' connotations of the word 'technology';
educational technologists (self-styled, it has to be admitted) were
thought of as being 'something to do with machines', or 'audio-visual
aids people', and this narrow interpretation of their role has been the
complaint of most authors writing in this field (e.g. Rowntree 1969 and
1974; Black, 1972; Marson, 1972). The distinction is clearly made in
Unwin (1969) between 'education plus technology' (where uses are found
for available instructional equipment in educational establishments) and
the 'study of instructional methods and systems' which is what the true
discipline of 'educational technology' is really concerned with.
Rowntree (1974) goes further: 'educational technology is as wide as
education itself; it is concerned with the design and evaluation of-
curricula and learning experiences and with the problems of implementing
and renovating them'. Essentially it is a rational problem-solving
approach to education, a way of thinking critically and systematically
about learning and teaching; in fact, Rowntree (ibid.) and Hills (1971)
both point out the similarity between this approach and that of
'scientific method', with the teacher identifying his problem, suggesting
a hypothesis to solve it, and then testing his hypothesis 'experimentally'
by trying out the new instructional system in the classroom.

It is apparent therefore that educational technology is funda-
mentally concerned with the process by which instructional methods are
developed rather than with the end products. Becher (1968) emphasises
this and quotes the 'official' definition of educational technology stated by NCET (The National Council for Educational Technology): 'the development, application and evaluation of systems, techniques and aids to improve the process of human learning'. Marson (1972) even suggests that the use of the term 'programmed learning' should be extended to cover any instructional method which is developed by a systematic 'programming' process of a quasi-scientific kind as described above. It is certainly true that the systems approach of educational technology can be applied to any curriculum development, large or small, and the processes involved include all of those which were undergone when, for example, programmes were written for a teaching machine. These can be represented diagrammatically thus (Rowntree, 1969):
It should however be pointed out that there are other aspects of systems analysis which can be brought to bear on curriculum development, the use of these being intended to elucidate and sharpen the processes involved. For example, Erzut (1970) observes that many systems have a number of sub-systems and that the development of the whole and of the several parts will probably be mutually dependent. Thus he gives the following representation of a course development:

![Diagram]

Again, Black (1972) examines a rather different kind of system consisting of the various influences of the teacher and learner on the different parts of the educational process and the resulting interaction and reaction between all of the components; this shows the result of subjecting the traditional teaching-learning situation to simple systems analysis. Black advocates discussion of this kind of system as an aid to breaking down teachers' resistance to the use of educational technology in schools; such resistance stems from ignorance concerning the true nature of educational technology as mentioned earlier.
Such prejudice certainly has to be overcome if independent learning methods are to be received enthusiastically in schools.

It is not really surprising to find that it is in the development of independent learning systems that Educational Technology has had the greatest impact to date. If any degree of independence of a teacher is to be enjoyed by a learner, then some kind of system of guidance for the learner clearly has to replace the immediate, day-by-day control by the teacher; it is natural therefore for the developmental methods previously designed for programmed learning to be adapted and extended for this purpose. Thus almost without exception, the independent learning systems described in the next chapter are based on the principles of Educational Technology outlined above.
CHAPTER 3

INDEPENDENT LEARNING IN PRACTICE

In this section of the literature review we shall survey the attempts that have been, or are being made to implement systems of independent learning in secondary, further, and higher education. It is, of course, impossible to mention every one, but those selected for inclusion here can fairly be claimed to be among the most successful and influential upon later developments. They may be broadly subdivided as follows:

3.1 Early attempts in American Schools
3.2 More recent systems in American Schools
3.3 The Nuffield Resources for Learning Project
3.4 I.L.I.S. - a national organisation
3.5 Independent Learning in Higher Education
3.6 Independent Learning in the Services

3.1 Early attempts in American Schools

In 1919 a group of teachers at the American State School at Winnetka (near Chicago), highly critical of the results achieved by the school, insisted that the school should adopt a more individual system of instruction - otherwise, they threatened, they would leave and establish a private school.

The result was the first school of which the curriculum became entirely devoted to the individualization of instruction (Washbourne and Marland, 1963). The school closed two days early at vacations for the writing of materials; arithmetic was the first area tackled and this was quickly made self-correcting with individual pupil progression allowed for. There was a 'goal-record' system for academic accounting, and a high emphasis on group and individual creativity with individual
projects strongly encouraged. Science was highly individualized with
differentiation in the content as well as self-pacing. The Winnetka
story has been one of continuous development, a 'constant and never
quite victorious struggle for true individualization' (Washburne and
Marland, ibid.). Yet these writers could point to several basic
elements of the curriculum of the 1920's which were still present in
1963, e.g. the elimination of grading by the use of a goal-record card
and specific and candid personal evaluation. It certainly had considerable
influence on subsequent curricular thinking; e.g. Bruner (1960) quotes
the Woods Hole conference of 1959 as echoing Winnetka principles.

Even more infectious than Winnetka, in that it spread around the
world with astonishing speed, was the 'Dalton Laboratory plan'. It
started in 1919 when Helen Parkhurst, a girl of 16, was appointed to
teach in a village school in rural Wisconsin, a school for forty
crippled children ranging in age from seven to fourteen and of widely
different ability. She thus had to provide occupation for seven classes
while she taught one and the first thing she did was to get the older
children to help the little ones. This kind of thing has been done -
before, of course, but organizing such methods into a system that
could be applied to a large secondary school was quite new; it was
when it was applied in the High School at Dalton, Massachusetts, in
the following year that the name 'Dalton plan' stuck.

Helen Parkhurst herself made it quite clear that the Dalton plan
did not involve a change in subject content or curriculum - simply in
the method of working. The basic principle was that the child was made
responsible for his own work and progress; he was made to feel that
it was his own concern rather than the teacher's. Having made him
responsible for the job he must be allowed freedom to organise his
work, his materials and his time and to secure whatever help from his
teachers, his books etc., which he finds necessary for the successful completion of the task (Parkhurst, 1922). Such a prescription is clearly one for highly independent and individualized learning.

Any school adopting the Dalton plan first had to break down the curriculum into, say, monthly portions; and these were set out in the form of detailed assignments, typed on cards. The pupil's first assignment each month would declare the 'purpose of the work, the problems he would learn to solve, the skills he would acquire', (Taylor, 1975); this was clearly an early use of behavioural objectives. A good assignment conveyed some information, references to reading, helpful suggestions, interest pockets, questions to be pursued and written work to be completed; today we would call it a 'learning package'. The assignments could be modified for pupils of different ability, in fact three categories were commonly available. The term 'laboratory' was used for a class where such resources were kept to emphasise the different use of the classroom, with pupils moving about freely, i.e. they were not to be thought of merely as 'study rooms'.

How was the school to 'keep tabs' on all these children freely moving around? Each assignment carried a 'time weighting', e.g. one day for this, two for that. Each pupil had an assignment card divided into subjects and day units. On completing an assignment, he checked his work with the subject-teacher in the 'laboratory' and filled in his own card. But the key to it all was the fifteen minutes spent each morning, with the class teacher, who checked his assignment card and advised accordingly. Such budgeting of time was considered by Helen Parkhurst to be essential; the teaching staff were no longer to be taskmasters and inquisitors but people to whom pupils could turn for help.

The thoroughly practical nature of the Dalton plan was soon recognised in many countries, but not many schools which immediately
adopted it still use it today (although, for example, Bryanston and Gordonstoun still base their teaching methods on Dalton). Thousands of schools in Europe, China and Japan were reported as using it in 1926. What happened to them all? It is arguable that the Dalton plan never really died; Taylor suggests that 'learning by doing' was a stream in full flood with Helen Parkhurst, went underground, and now emerges as springs in unexpected and apparently unconnected places (Taylor, 1971); for example, there is a close likeness to the Dalton plan in the 'integrated day' in fashion in primary schools today. However, it is certainly true that the Dalton plan, per se, did cease to exist as an effective force in the 1930's. The likely reasons are those discussed earlier under problems related to independent learning, e.g. slow rate of progress, changes in teacher's role, etc. Also a basic fault was the fact that users of the Dalton plan did not themselves produce materials for widespread use in schools; the Dalton Association in England, for example, contented itself with providing a forum for discussion - the Dalton materials were meant to be produced by local inspiration - thus the inspiration of the early days gave way to lethargy in the more 'humdrum' days which followed, with teachers tending to use dull text books as the only resources. The inefficient learning which followed led the public to believe that Dalton was an alternative to class teaching which had been tried and had failed; this accelerated its demise as an international (or even national) system of independent learning.

3.2 More recent and present day systems in American Schools

3.21 Individually Prescribed Instruction (I.P.I.)

This is an individualized learning system based on the application of programme learning principles to large areas of the curriculum and then prescribing a programme for each student, individually tailored to
his/her needs (Lindvall and Bolvin, 1967). The scheme recognises the basic principles that before one can effectively teach a student one must be able to state:

1) exactly what one wants the student to learn, i.e. specific behavioural objectives must be formulated.

2) how one will know when a student has learned a specific behaviour, i.e. a precise monitoring system is needed so that at any time a student's performance can be monitored and a detailed assessment of his progress made. I.P.I. insists on a 'post-test mastery criterion' of 85% before a student goes on to the next unit. There are frequent 'curriculum-embedded' tests which are regarded as part of the instruction; students look forward to these as providing an estimate of their progress and opening the door to the next section of the curriculum.

3) what the student knows already, i.e. detailed pre-tests are required.

Since the student is to follow a personally prescribed course, he must work independently of his group; an extensive inventory of self-managed instructional materials and environments, suitable for individual learning by learners varying greatly in learning ability and aptitude, thus had to be developed. For example, much use was made of programmed learning itself. This necessitated detailed analysis and sequencing of the objectives so that the route a particular student should follow through the materials could be optimally prescribed.

For effective I.P.I. some of the practical procedures found to be necessary were:

a) students should report to the instructors once a day in schools (at longer intervals in higher education).

b) a card system should be kept by instructors to keep a careful
check on progress.

c) 'carrots' in the form of standards to be reached at each grade level had to be established: 'work contracts' were found to be a useful idea.

I.P.I. was developed at the Learning Research and Development Centre at the University of Pittsburgh under its director, Robert Glaser, and has been used in the elementary schools in that area (Oakleaf School in particular giving the project its common name) (Glaser, 1967). However it has been favourably received in many university departments, which have adapted their teaching accordingly; the following advantages have been found (Goldschmidt, 1974)

a) greater student involvement leads to better retention of learning.

b) student-dominated discussions are more effective than teacher-dominated ones.

c) students are more ready to admit to the difficulties they are finding in their work; 'it is less embarrassing to admit failure to a tape-deck than to a professor'.

d) the much-more-frequent feedback is appreciated by students.

e) not only is self-pacing found to be effective, but also the self-initiation, self-direction and self-evaluation of learning are found to be motivating.

f) frequent evaluation of the course leads to considerable improvements.

Criticisms have however been expressed (e.g. Duda, 1970); the main one is that in some schools and universities where it is used, the available resources are a long way from the "well-stocked" shelves that would enable teachers to diagnose and prescribe as promised. In fact, in some institutions claiming to be using it, the only individualization achieved is that of self-pacing (Oettinger, 1969).
3.22 Program for Learning in accordance with Needs (Project PLAN)

This learning system was devised in 1965 as a model for 'Education in the Seventies' (Flanagan, 1967). It grew directly out of the findings of 'Project TALENT' by which the individual education of a representative sample of 440,000 students in all types of school throughout the United States was surveyed by the U.S. Office of Education; it is planned that they should be followed up ten and twenty years later, to see what use will have been made of the individual talents of the students. The early findings of Project PLAN showed up very inadequate educational provision for the very large individual differences to be found in any age group; also schools were found to be failing to develop a sense of responsibility in students for their non-educational, personal and social development. Further, very little preparation for the responsibilities of citizenship and for the use of leisure in later life was found to be provided.

It was in order to remedy these deficiencies that the Centre for Research and Evaluation in Applications of Technology in Education ('CREATE') initiated Project PLAN. It applies modern decision-making and operating procedures and cost effectiveness; it therefore requires clear definition of objectives and relatively precise measures of effectiveness and costs by operation analysts, i.e. the input and output of the educational system are to be accurately measured and all relevant conditions described and defined. Thus the approach is a 'systems engineering' one which emphasises evaluation at all stages of the educational process. It is therefore regarded as essential that each school building has a computer terminal linked to a computer which stores detailed information on each child, including special aptitudes, patterns of learning, interests and background. In addition,
record is kept of the skills and knowledge he has acquired prior to reaching any given decision point. The computer also stores a complete list of instructional materials in the form of modules or manageable segments called 'teaching-learning units', systematically indexed in terms of what the student is expected to learn from them, what the prerequisites are and for what type of student and situation this unit is especially well suited; a teaching-learning unit would ordinarily be a combination of textbook material, workshop exercises, audio-visual materials, small-group discussions, and project activities. The Director of Project PLAN, Dr. Flanagan, says that the program could operate without the computer but it would obviously be more expensive and less responsive (Taylor, 1971). The material needed for the project has been written by some forty full-time writers and thirty-five teachers on secondment and they cover maths, history, languages, science and social studies.

At the beginning of any child's course (the fifth-grade class in the High School), the child and his teacher will receive information from the computer as to what the child knows, how he learns, what his interests are, etc., and they are thus able to set tentative goals for the school year in terms of the objectives to be covered across the curriculum. For each of the immediate objectives there will be clear statements of the behaviour changes expected and the content to be learned, together with a test or assessment procedure for confirming the student's attainment of these objectives. On the basis of these tentative goals, the computer also provides descriptions of two or three teaching-learning units in each of the various fields which are best suited to that individual student. The system is based on the 'success' principle, i.e. it is intended that the student be assigned only objectives which he can achieve at his present stage of development;
failure on a unit test represents a breakdown in the system and will be the source of immediate investigation to identify and remedy the observed deficiency in methods and materials assigned. At the end of that unit of work (roughly a fortnight later), answer sheets are marked by the computer, and the student proceeds to the next unit, suitably prescribed.

The system took about four years to complete, pooling the resources of fourteen school districts with those of the Westinghouse Learning Corporation and the American Institutes for Research. Many schools in these districts (in California, Pennsylvania and New York) are using the plan, linked to a computer in Iowa City.

3.3 The Nuffield 'Resources for Learning' Project

This was established in 1966 for a five year term to investigate how the resources available to schools might be more profitably used. At the project's inception, there was a bewildering profusion of changes and novelties in such resources becoming available, e.g. publishers had combined with manufacturers into new large consortia, seeing in programmed learning, mediated by print or various mechanised or electronic systems, the prospects of a new bonanza. Television seemed to offer unexploited possibilities, especially with the reduced cost of closed-circuit systems, the imminence of cheaper video-recording and of various (total incompatible) video-cassette or disc systems. Such dramatic changes in the field of available resources were born out of even more radical curriculum developments, e.g. in the primary school the Plowden report chronicled a major (albeit much disputed) shift in teaching method - the integrated day. However, changes in the secondary school overshadowed this; comprehensivisation had just been urged by Circular 10/65 as a fundamental revision of the tripartite system and
scarcely a subject escaped the attention of curriculum reform teams whose findings made great, unco-ordinated demands on the schools' resources and organisation.

Thus the brief for this particular 'Nuffield' educational project was of a different order to those for previous ones. Those projects had arisen from a consensus among leading teachers in established professional organisations about desirable changes - towards an oral/aural approach to languages, for example, or a more heuristic method in the sciences. The product expected of all of the other projects was clear: new curriculum materials. To the contrary, the brief given to 'Resources for Learning' was limited neither by age, nor subject nor ability level; it built on no consensus, it was preceded by no feasibility study. In fact the nature of its activities was undefined and the first necessity was to establish the starting point and explore possible directions.

**Phase One, 1966-7**

The contemporary use of educational resources and the controlling administrative practices were examined. As part of a costing study of various innovations, existing costs in schools were analysed into more informative and useful patterns than those provided by conventional (and far from uniform) county authority budgeting practice. Meanwhile, other members of the Project were investigating the newer developments in 'Learning'. Visits were made to promising developments in Britain and abroad (America, Scandinavia, Russia, West and East Germany, Japan). Various researches already in existence were chosen for development; in other cases, experiments were initiated with a likely person being picked out and being helped to carry through the experiment. Financial considerations were most important; so wide was the Project's brief that it was essential to encourage local authorities, publishers or manufacturers to contribute assistance in money or equipment. Fortunately,
the Project's persuasive power was considerable.

Phase Two 1968-71

Research into the administrative problems and economic implications of reallocating familiar educational resources and of introducing new ones was continued. Much of this was done in conjunction with the National Council for Educational Technology, set up in 1967, e.g. two of the three NCET committees investigating the future role of the computer in education had directors of the Nuffield Project as Chairman.

However, equally, if not more important, was the decision at the end of Phase One to concentrate on one particular aspect of curriculum development as the core of the Project's work. Out of all the various possibilities, it was decided to look in detail at Independent or Resource-Based Learning; the reasons were:

(i) a remarkable number of problems afflicting secondary education were seen to stem from class-teaching methods.

(ii) Development of Independent Learning would bring secondary schools into line with current primary school thinking.

(iii) Little work on independent learning had been done in a sustained fashion since the apparent demise of the Dalton plan and since the first flush of enthusiasm for programmed instruction waned.

Thus it was decided to provide financial and other backing for the development of 'learning packages' and the 'learning systems' in which they could be used. It was realised that it was important for such developments to be dissociated from the previous programmed learning 'image'; schools were rapidly turning from highly structured curricula and would not accept the high degree of formal structuring to be found in programmed learning - at least, not on a large scale. Programmes
could, it was understood, be used but only as part of a more flexible scheme of activities. The teacher should certainly play an important part in such learning systems; however, the emphasis should be on 'active learning modified by teaching' rather than 'teaching modified by active learning'. Thus it was recognised that only when a more independent style of learning from resources is habitually used is a new 'system of learning' being used; the occasional practice of independent learning in homework and individual projects, or its more extensive embodiment as heuristic method in recent (at that time) 'Nuffield' science courses, admirable though these were seen to be, did not constitute a change in the system used from teacher-based to resource-based and would not qualify for consideration by the Project (Taylor, 1972a).

Besides the investigations into appropriate materials and teaching arrangements for resource-based learning, the Project investigated how such materials might be produced on a local basis; in collaboration with several L.E.A's (including I.L.E.A.), Teachers' Centres were staffed and equipped to discover what was involved in the extensive preparation of curriculum materials. This 'Hive Experiment' covered a representative range of subjects and produced materials for one year's work with design notes and full costing (Taylor, 1972b).

We now look at some of the independent learning systems which were investigated by the Project.

3.3.1 The I.M.U. Project

This system for the teaching of mathematics was developed in Sweden in the mid-1960's (I.M.U. in translation is: Individualized Mathematics Teaching). It arose out of research done by the Swedish Board of Education into the benefits of individualized learning in the (then) new comprehensive schools (grundskola); it had been already
realised that conventional class teaching just would not work in the
new unstreamed classes, especially in sequential subjects like mathematics,
where different students' optimal rate of progress varies so widely. Thus
an independent, self-paced learning system was devised for use with the
thirteen to sixteen year olds in the grundskola (Hastad, Ivesson,
Oreberg, 1971).

The course is set out in workbooks with text, problems and answers
all together, only periodic tests being done on separate sheets.
Diagrams and pictures are liberally used, integrated with simply written
explanations. Each point is illustrated by numerous examples, reinforced
by exercises. About every tenth page there is a section entitled 'Test
Yourself'; the pupil does the test, checks his answers and enters his
results on a record sheet. At the end of a work book the pupil collects
a tape which, in conjunction with related illustrations, provides him
with a review of the work he has done; a recapitulation exercise is then
done which tests whether he really has understood the section and refers
him to the teacher for help if he gets answers wrong. A 'Diagnostic'
test is then done which, after marking by the teacher, (or by the aide
in a team-teaching arrangement) serves not only to assess a pupil's past
and present deficiencies but also to show what his subsequent programme
should be. Each of the three years of the I.M.U. course is divided into
three 'modules' which in turn are divided into three 'sub-modules', say
A, B, C. A diagnostic test comes at the end of each component and a
grander version at the end of a whole module. In component A (of any
module) there are two levels of working available, in components B and C
there are four levels; when a pupil takes a diagnostic test, the
teacher will suggest the appropriate level for him to follow in the next
component. There is also a component C containing materials for
additional group activities and for remedial tuition. Thus the pattern
of work of each of the nine modules is as shown in the following diagram. An individual student could follow any path through the components as indicated by the arrows (Taylor, 1971).

I.M.U. materials were painstakingly compiled, thoroughly field-tested and carefully revised. They represent 'package' materials of a different order of sophistication from Dalton-plan assignments, correspondence courses, or published pieces of programmed instruction. I.M.U. represents what the Swedes think necessary if independent learning is to work in wide-ability secondary schools.

The reactions of children and staff provide interesting insights into this method of learning. One major criticism which was offered was that the materials had been so thoroughly tested that a teacher hardly dare make an alteration. After all, the first version of the
course was tried on seventy-five children and careful note taken of their difficulties; any problem not solved by eighty per cent of those who tried it was rewritten. The second version was tried on three hundred children with minute study and modifications made. The third version was used by 11,500 children, of whom 3,000 took part in an efficiency examination; subsequently the course was revised six times. Unfortunately, the human reaction to such perfection is far from friendly. Feedback has been hailed as bringing the scientific method at last to education; in fact, it may prove a lasting blight if teachers feel diminished by slavishly having to follow a teaching-learning package, forbidden to make the variations which their common sense and pedagogic flair suggest would be valuable (Williams, 1973).

Not only do some teachers experience feelings of constraint; it has been suggested that pupils also tend to. Even though there are booklets of varying difficulty, places in each booklet where alternative paths are possible, additional material outside the main booklets for the least and most able, so that many alternative routes through the course are provided - yet these routes are contained within the course; there is a sense of being led along carefully trimmed, approved paths. This can be aggravating particularly to students used to an 'open-ended' approach, such as is found in the 'discovery learning' methods used in several curricular subjects.

Notwithstanding such criticisms, however, I.M.U. has spread to many countries, e.g. in 1970 the Nuffield Resources for Learning Project, in conjunction with O.E.C.D., sponsored the translation into English of part of the course; this was received favourably by the schools involved in its trials. However, a rather more important consequence of I.M.U. is its influence on other Secondary Mathematics Learning Systems. Some of these use actual I.M.U. sequences because I.M.U. carried no copyright,
but others (e.g. Hej Mathematik) can be seen to be basically I.M.U. but modified to be less self-instructional in their materials, less individualized in method, less systematic in control, but much cheaper to buy. Such courses have enjoyed considerably greater success; however this does not detract from the pioneering success of I.M.U.; it mapped paths worth pursuing and pitfalls to avoid in the hunt for more humane variants of resource based learning.

3.32 The Surrey Auto-Tutor Project

This independent learning system for secondary school mathematics had its origins in 1965 in the severe shortage of mathematics teachers in Surrey Secondary schools, and the concern of the County Education Committee over the effects on the quality of mathematics teaching of having to use non-specialists in many lower-school forms. The Committee decided to find out whether the extensive use of Programmed Learning would enable teachers to make more effective use of the time they have, and whether it would assist non-specialist teachers to perform more effectively (Surrey County Council, 1970).

Thus teachers in four secondary schools were asked to collaborate with professional programmers from the firm 'ESL Bristol', to write programmes for the firm's 'Auto-Tutor' teaching machine. However, at the end of the two-year exploration period, the Nuffield Foundation Resources for Learning Project became interested in the work at one of the larger Surrey schools, France Hill, and it encouraged this school to develop during the session 1967-8 a complete Learning System of which programmes would be the core, with consolidation material in the form of work books containing practice exercises. The system in fact became an independent learning one when the staff at France Hill provided detailed schemes of work called 'Assignment Schedules'. These involved
practical work, visits out of school, discussions, etc., built around
the programmed lessons as the essential core and providing an organised
and varied sequence of work for several weeks. Typically a machine
programme consisted of six or seven lessons on one topic; the student
would therefore alternate between working at the machine and performing
other tasks throughout the study of the programme. He kept a record of
his progress and made any necessary notes in a 'Pupil's Record Book'.
At one or two points in the programme a student worked a Tutor Test,
written by the programmer and designed to diagnose the knowledge acquired
from the programme; it therefore provided the teacher with detailed
information on the progress of each student but also indicated those
sections of the film which were suitable for revision. On the evidence
of the Tutor test, the teacher could decide whether or not the pupil
should revise part of the work, tackle some enrichment activity, or
move to a new topic. There is also a need for Accumulative Tests to
check retention and indicate when revision is needed. The diagram (overleaf)
shows how all these activities are linked together (Nisr and Gray, 1970).

The system was individualized because the Auto-Tutor had a branching
facility, and this has made possible the development of programmes
suitable for children of a wide range of mathematical ability. Pupil's
responses could thus be used to determine the most suitable sequences for
them; even though it was originally intended that the programmes should
be suited to children of about average ability, they have in fact been
used successfully over a much wider spectrum, even down to the borderline
non-reader. So successful was this breakthrough that in June 1968 other
Surrey schools were invited to use this scheme and the materials which
France Hill had devised under their own conditions. There was no doubt
that the system worked, and that when it was used children enjoyed
mathematics, their enthusiasm being evident from the fact that manywould
opt to do extra work in their own time. Many schools have adapted the system for their own needs and there has always been a free interchange of information between the schools participating (Gray and Sare, 1971).

3.33 The Kent Mathematics Project

This project has produced a 'material bank' of mathematics learning tasks for children of all abilities between the ages of nine and sixteen. It developed in eight years from a simple experiment with two groups of children at Ridgewaye School near Tunbridge Wells, to take in more than
sixty Kent schools involving about 20,000 children and more than 300 teachers. Bertram Banks, the Director, admits that this was only made possible through the support of the Nuffield Resources for Learning Project and the generosity of secondment by the Kent Education Committee; otherwise the expansion of the system, with its semi-programmed worksheets producing a very low 'ratio of running to preparation time', would have been extremely slow (Banks, 1968; Taylor, 1972 a).

The project offers each student an individualized course in mathematics using materials from a bank of programmed booklets, tapes and worksheets organised into mathematical curriculum areas and attainment levels ranging from that for the average nine year old primary school child up to 'level 8' which contains O-level material. Children entering the scheme take a diagnostic test which helps the teacher design a bundle of suitable tasks for that particular child, written out on what is called a matrix; there is space for the teacher to initial and date each task when completed. After working through the entry matrix with help and guidance from the teacher when needed, the pupil takes a test from the test booklet; from these results another matrix is made up by the teacher, using a flow diagram showing desirable sequences through the concepts involved and making use of 'remedial' material to reinforce the understanding of a concept where the test shows that this is needed. Where a pupil works so fast that the teacher considers he is wasting his time on trivial work he can pass over some tasks; if any vital learning is contained in a task he misses out, this can be quickly taken in his stride later. Making up new matrices is therefore a vital step in the scheme and because it is at this point that weaknesses are exposed and special interests expressed, teachers can be urged to consult the pupil at this stage.

Each student's matrix is recorded on a continuous record card and
the attainment levels are averaged. Thus a continuous assessment of
the pupil's mathematical development is obtained and at the end of the
course the pupil is either entered for O-level Mathematics, or his/her
attainment levels are used to provide a C.S.E. Mode 3 grading. These
grades are checked against those awarded on the evidence of conventional
examinations and a high correlation has been found. In general, it has
been observed that children 'remain happier longer' with their
mathematics using the project, and their examination results are also
improved as a result (Banks, 1974).

3.34 Individualized Biology

This started in 1967 as an experiment to see how first and second
year pupils in a comprehensive school (Thomas Bennett School, Crawley,
Sussex) might learn their Biology (based on the Nuffield O-level Biology
course) independently from suitable resources (Reid and Booth, 1969).
The originators, D.J. Reid and P. Booth, attended a course at the
National Centre for Programmed Learning at Birmingham University in
April 1967, and were released on half-time secondment from teaching from
September 1967, secretarial and some financial help being provided by
the Nuffield Project (Taylor, 1972 a). Messrs. Heinemann Educational
Ltd., who agreed to publish the work eventually also helped financially
so that a budget of over £2,000 was available for the first year of the

The first year was designed as a 'control' experiment, with nine
of the twelve first year classes at the large Crawley comprehensive
school working individually, the other three being taught conventionally
but by staff who were also supervising some individualized groups. The
groups were all of more than 35 pupils, large for experimental classes.
The experimental materials at first were largely of a more-or-less
orthodox programmed kind (with relevant equipment at hand), and the
children were allowed to work through them at their own pace. The easiest part of each re-written Nuffield chapter came at the beginning of a programmed sequence, the more difficult parts later; this allowed the presentation of the materials to pupils of a wide range of ability, on the assumption that only the faster pupils would reach the later sections. Each topic therefore consisted of basic material, aimed at all pupils, followed by work of increasing difficulty and often ending with a task which stretched the ablest. Short tests were included in the programmes and their results were discussed with the teacher who could then give help, allow them to continue, or ask them to repeat work as appropriate. Some talks and class discussions were included from time to time.

In May 1968 it was possible to assess the results of the experiment (Reid and Booth, 1971):

(a) The high ability pupils did slightly better individually than their conventionally taught equals, while those of lowest ability did slightly worse, in terms of learning as shown by test results.

(b) The individualized classes worked noticeably faster overall than the conventional classes.

(c) Less favourable results were obtained with attitude tests; there was a small but definite preference for conventional teaching (as shown by pupils' rankings of biology as a subject vis-a-vis other subjects in 1967 and in 1968). It was felt that this was probably due to over-exposure to programmed learning; comparison was made with the early efforts of Bertram Banks, who found that 40% of his pupils felt that programmed learning should not occupy more than three-quarters of the available time.

(d) Staff attitudes were highly favourable; they were particularly happy with the improved teacher-pupil relationship in the individualized
classes.

(e) One major problem was the logistical one. It was no longer possible to predict exactly where a child would be in the course by a certain date; thus estimating apparatus needs involved much guesswork - a considerable problem in biology where specimens for dissection are frequently needed.

(f) Savings on cost were expected to be greater than the increases; capital costs in terms of 'class' sets of apparatus would fall, whereas costs of audio-visual aids would rise through increased wear and tear.

It was decided that the results of the first year's experiment certainly justified continuation of the development of an independent learning course, with several improvements in the materials already produced obviously being necessary. For some topics independent learning seemed to be unsuitable, e.g. class discussion is more appropriate where choice has to be made between two or more hypotheses. Thus eight topics covering large areas of work in the first two years of the Nuffield O-level Biology course were chosen for eventual publication and these were published as 'Biology for the Individual' in 1970-2. However, trials were first held of all materials in about 50 schools throughout the U.K. with encouraging results. The texts which emerged have moved away from conventional programmed learning; each contains short sections of theory, interspersed with detailed instructions for practical work and occasional reference to film loops where relevant (Heinemann, 1974).

Reid and Booth are at pains to point out that the best way to regard independent learning is as a useful addition to the variety of teaching methods already available; it has proved to be exceptionally useful to teachers of mixed ability groups and has been especially welcomed by non-specialists, e.g. physics graduates about to tackle biological topics in a Combined Science Course. As with other independent learning systems,
the role of the teacher has been found to be crucially important; in the few cases in the trials where the teacher withdrew from active participation in the work, the pupils rapidly became dissatisfied and the less well motivated ceased to work altogether. The key to success with independent learning is seen to be to regard it as a tool and never a master (Reid and Booth, 1971).

3.4 I.L.I.S. - an Attempt at Rationalisation

It should be clear from the above that the development of independent learning has been haphazard and piecemeal, even under the sponsorship of an organisation as large as Nuffield. However, since 1975 an attempt has been made to co-ordinate independent learning in Britain in one area of the curriculum, viz. science, by the establishment of the "Independent Learning in Science" organisation (I.L.I.S., 1977). This is a loosely-knit association of school science teachers, county advisers, university lecturers, etc., all of whom have shown an interest in the possibilities of developing independent learning methods in science teaching, particularly in secondary schools. The central figure and inspiration behind this movement from the outset has been Eric Green, Head of Science at Countesthorpe College in Leicestershire, a school well known for its determinedly experimental outlook on education; it was at Countesthorpe in April 1973 that I.L.I.S. was set up at a conference involving school teachers, university and college of education lecturers, and representatives from industry and the Inspectorate.

The primary aim of the organisation has always been to support and stimulate individual and small group methods in science education in all types of institution. To this end, I.L.I.S. has three major activities:

(i) it organises meetings for members at which several of them can work at the production of resources suitable for independent learning. These 'workshops' occur at weekends or in school/college vacations and
are held in centres provided by a local authority, or maybe a college
or university. Once held in a given area, it is hoped that thereafter
local teams of teachers would meet on a regular basis to produce materials;
this has in fact happened in several cases, e.g. the Physics group in
Oxfordshire.

(ii) It provides financial support, albeit limited, for members
to produce materials either individually or by leading teams which they
can establish. Secondment from part of a members' normal teaching
commitment has been possible in a few instances; e.g. Peter Ashworth
was given secondment from his post as Head of Science at Budehaven
School to write materials for sixth form Physics courses. The I.L.I.S.
Secretary/Co-ordinator, Eric Green, was provided with a grant to enable
him to visit the U.S.A. during 1974 to investigate and report back on
current developments there.

(iii) Possibly the most important I.L.I.S. activity is the regular
publication of information which furthers the development of independent
learning by keeping members abreast of developments throughout the
country. The publications are:

the quarterly 'Newsletter' containing articles written by members;
the Directory which is a list of members' addresses, grouped under
particular fields of interest - this is revised annually;
the 'Catalogue' which gives details of materials produced by
members and which are usually available for use by other members,
either free or at a small charge.

The Catalogue is a particularly useful work of reference which
confirms the observations of Reid and Booth (1974) that 'short term'
independent learning (i.e. typically taking place in single lessons
using worksheets, etc.) is quite common. 'Medium term' independent
learning (typically lasting about four weeks covering single topics of
a syllabus) is practised by a limited number of enthusiasts, often in newly opened middle schools or junior forms of new comprehensive schools. 'Long term' independent learning (i.e. pupils working entirely at their own pace for a term or more, with little class teaching) is relatively rare in this country; Reid and Booth's own work (1969), reviewed earlier, Bosworth (1967), and Green (1972) are the only published references, but the catalogue indicates a few more in preparation, e.g. Brown's work in Belfast (see below).

When teachers are contacted through the Directory or Catalogue, it is remarkable how generous they are prepared to be to other I.L.I.S. members in sending bundles of samples by post and allowing materials, which they have spent many hours preparing, to be inspected, modified if necessary, and then used in other schools; in my own research in the field of A-level physics, I have found the work of several I.L.I.S. members highly relevant and influential when preparing my own materials. The most successful of the systems these teachers have developed compare favourably with most of their predecessors described earlier, and they merit some description here:

3.41 Independent Learning in Physics at Countesthorpe College

Countesthorpe College was founded in 1970 as a comprehensive school under the Leicestershire Plan. From the outset it was surrounded with controversy resulting from the opportunity it was granted to experiment with and develop a variety of radical ideas in education. Among these were participatory democracy at every level of decision making, and the setting up of an organisation which would allow the development of individuals along lines suited to them personally. It was these aims which determined the methodology of the teaching across the curriculum i.e. with an emphasis on individualized learning, completely self-paced
so that teaching groups would be mixed-age as well as mixed-ability.
Complete independent learning systems would therefore be necessary in
all subjects; Eric Green devised the one in physics and it has become
the model for other long-term independent learning systems in the science
subjects such as the one used in this investigation.

Green's approach has been to adapt the existing 'Nuffield' type
syllabuses for independent working (Green, 1972). The resources used are:

'guide sheets' which list the activities expected of a student in
order, with guidance as to whether or not the teacher is to be
consulted, whether a piece of work is to be marked, etc.;

'work sheets' covering practical work when it occurs;

'information sheets' which supplement the text books which are
basic to the course;

'text books' which are, in the case of the Nuffield A-level
Physics Course, the specially written 'Unit' books;

'project sheets' which suggest possible investigation and projects,
usually as enrichment for the more able;

'programmed learning materials', usually for remedial purposes;

'audio visual resources' such as cine-films, film loops, video-
tapes, slides, for individual and sometimes group viewing;

'test sheets' which assess the student's understanding of the work
just completed.

The Guide Sheets give a fair degree of structure to the work but
considerable variation within this structure (according to the needs and
interests of the student) can and does occur; thus a 'loop' which is a
carefully graded learning scheme between two stages in the basic course,
might be followed by a student who is finding the conceptual demands at
that point too great.
All the above written materials are stored in a filing system carefully sorted and labelled to provide rapid access for both teacher and student. The teacher has a 'checklist'; whenever a student takes any item from the filing cabinet, the teacher insists that it is marked off on his checklist (which is really a copy of the guide sheet for that unit). No attempt is made to use the 'topic by topic' approach resorted to by Reid and Booth (discussed earlier) in order to keep the students all progressing at roughly the same pace; external examinations are taken as and when the student is ready for them, post-examination work being done if the student has to wait for any length of time before an external examination becomes available.

Examination results for the students using this approach have been well up to standard; students' attitudes too are favourable, with the variety of approach being the feature most favourably commented on (Green, 1976).

3.42 CAMOL at Methodist College, Belfast

'CAMOL' stands for 'Computer Assisted Management of Learning' and was a project based on the New University of Ulster; it was part of a national project called the 'National Development Programme in Computer Assisted Learning' which started in 1973 and ran for five years with a budget of around £2 million, funded by the Department of Education and Science and six other government departments. The National Programme supported 30 projects all over the United Kingdom in primary, secondary and tertiary education with administrative services provided by the Council for Educational Technology (CET); CAMOL was one of these projects aimed at providing an individualized course in physics with computer management, suitable for students preparing for the Northern Ireland A-level examination.
Methodist College, Belfast is a voluntary-aided grammar school of over 2,000 pupils with 150 pupils a year enrolled for A-level physics. Since 1971, the College has been teaching the Nuffield physics course in the sixth form, but in 1973 dissatisfaction with conventional teaching methods led to the development of an independent learning scheme; then in 1975 the College was invited to take part in the CAMOL project so that computer management could be applied to the learning system. An extra part-time physics teacher and a full-time administrative assistant were provided and during the three years of the project, the funding provided by the National Programme amounted to £10,000. (A further estimated £15,000 was supplied by the College and the Northern Ireland Education Department.)

The resulting system comprises a course of about 50 modules of study, by no means all of which have been completed to date; the considerable time needed for familiarisation with the use of the computer (at the New University of Ulster) for managing learning is quoted as the reason for much of the delay in producing the early modules but this should clearly be a much smaller obstacle to subsequent development.*1

Individual student files, together with test, text and routing files, are prepared and encoded at the College by the project team but the coding sheets are passed to the University for punching and establishment on its computer. Each module has:

- an introduction;
- an outline of pre-requisite knowledge;
- a list of objectives;
- directions for the main learning activities, including reading, practical work, problems, use of audio-visual material;
- a list of supportive materials, such as additional texts;
- a post test, with detailed answers and comments provided by the
computer which also suggests remedial material or recommends the next step to be taken.

Evaluation of the system has been done by a method based on "Monitorkit" prepared by the Institute of Educational Technology, University of Surrey (Brown and McMahon, 1979). Questionnaires completed by students indicate a large majority in favour of the scheme provided it is mixed with traditional teaching. The opportunity to work at one's own pace is the most appreciated feature of the system and there seems to have developed an element of competition between friends as to how far one has progressed in the system. One fairly general criticism is that delay in receiving the computer print-out following a test means that a student has by then started on the next topic and is reluctant to go back to take any remedial action suggested. Apart from this the system works smoothly for the vast majority of students with nearly all appreciating the value of the assistance provided by the computer.

In terms of examination results, A-level grades B and C have tended to improve to A, and O and F to E. A small minority of students seem not to have the maturity to cope with the self-motivation situation; ways of identifying these students are now being looked at so that they can be taught more directly in the First Year Sixth and then introduced to independent learning gradually during the Second Year. (Brown and McMahon, ibid.).

3.43 APPIL

This independent learning system is an attempt to overcome the severe difficulties experienced in Inner London Education Authority comprehensive schools owing to the smallness of the numbers (sometimes one or two) opting to take A-level science courses (APPIL, 1976). Specialized staff are hard to come by in Inner London schools and it is clearly not viable to teach such small numbers on virtually a one-
to-one basis.

The APPIL scheme is one which has therefore produced independent learning packages to be used by small Sixth Form science groups supervised by non-specialist staff. Specialist staff then visit the groups on a peripatetic basis and deal with difficulties; they also prescribe the subsequent instruction to be followed.

The students from several schools in an area also meet together in one school at intervals for discussion and group teaching of certain topics. Practical work can also be done then.

The learning packages have been produced since 1975 by a team based on the South London Science Centre; three 'advisory teachers' have been seconded to the team on a full-time basis and they have the assistance of four technicians/clerical staff who produce the finished version of the materials. The printed materials are supplemented by television programmes broadcast over the authority's closed circuit system; thus the whole scheme bears a marked resemblance to Open University system of instruction. Following trials in Inner London Education Authority schools, the project is being published in 1979 jointly by the I.L.E.A. and a national publishing house. Published materials consist of two handbooks (Student's and Teacher's), ten Student's Guides and ten Teacher's Guides (CBT, 1979).

3.5 Independent Learning in Higher Education

It might be expected by the laymen that the teaching methods used by universities would change more rapidly than those in the primary or secondary sectors, keeping pace with developments in teaching resources and techniques; this expectation would be based on the presumed autonomy of university departments in that they are able to be far more flexible than the schools in terms of syllabuses, allocation of resources etc., and would be assumed to have greater resources, material and human, to
allocate anyway. Recent changes in the university population should also be an influence for progress; previously most universities tended to follow a pattern of teaching and learning suited to students who were there to pursue learning largely for its own sake but more recently learning has become more career-orientated, a means to an end rather than an end in itself. This is especially true for the new type of undergraduate resulting from the opening of the doors of higher education to anyone who wishes to enter (Hills, 1975).

However, in spite of these influences, traditional university methods have largely remained almost unchanged, even in science and engineering courses where the rapid escalation in the mass of knowledge in itself demands that the universities should adapt their methods. Another influence which is being largely ignored is the concern that the universities no less than the schools should evolve methods which help the student to adapt to continuous change, i.e. not only to learn while at university but also to discover how to continue to learn throughout his life (Brook, 1965). As Mountford (1966) suggests, a university needs to:

(i) provide a body of knowledge
(ii) train a student to collect evidence for himself and form balanced judgements, and
(iii) help a student to think for himself.

Where the need for change has been recognised, it has also been realised that what was needed most was not a reform in teaching methods (necessary though this was) but an improvement in student learning methods (Elton et al, 1971). Of course the latter is dependent on the former; no change in student learning method is likely to occur unless the system of presentation of materials and the resources available are changed too. The merits and demerits of the lecture have been widely
discussed (e.g. Bligh, 1972; Costin, 1972); what cannot be denied is the lack of individualization provided by a lecture. Hills (1973) suggests that lectures have considerable appeal for students; there is certainly no need to abolish them completely. They should, however, be supplemented by more individualized, independent learning (Elton et al., 1971), in some kind of integrated system of instruction; other desirable features of such a system would be the clear delineation of objectives, active student participation, frequent feedback and evaluation, and individual pacing (Goldschmid and Goldschmid, 1974).

Goldschmid (1975) does in fact suggest that recent trends in instruction in higher education do show these desirable features, e.g. the increased use of audio-tutorial and modular instruction, computer-assisted instruction, information-retrieval systems, individually prescribed instruction. However such development has been piecemeal; very few complete learning systems, backed by sufficient learning resources tailor-made for those courses, have been introduced in university courses; I propose to discuss the two most well known and influential of these briefly:

3.51 The Postlethwait Audio-Tutorial System

This systematic approach to the teaching of botany was introduced by Professor S.N. Postlethwait at Purdue University in 1962 (Postlethwait et al., 1964). He decided to put his lectures to first year students into permanent form, and provide them for self-instruction by the students. In the resultant 'audio-tutorial laboratory', open from 7.00 a.m. to 11.30 p.m., the student would come at a time of his own choosing. At the entrance he would receive a description hand-out explaining what books, notes, equipment it would be necessary to bring along; once inside he would be given, say, a specimen and enter an area equipped with booths or carrels. Each carrel contained a tape-
recorder and headphones, probably a microscope and whatever audiovisual equipment and 'software' was required for the week's exercise e.g. a slide-viewer, or film loop viewer. Guided by the tape, the student would examine his specimen, consult his work book, compare with a slide, respond to questions, etc. He could stop the tape and replay it whenever he wished, or if really stuck could seek guidance from a teaching assistant or a fellow student, or the library. When he had completed the tape, he completed a test and then discussed his progress with a lecturer. His work was then graded and he went on to the next assignment.

Such an Independent Study Session (ISS) was roughly equivalent to about four hours of conventional instruction but was only part of the instructional provision for the week. In addition there was:

(i) a 'General Assembly Session' (GAS), lasting one hour per week for all students; this would have a Senior Instructor in charge and might consist of a guest lecture, or a film, or a major exam, etc.;

(ii) an 'Small Assembly Session' (SAS), sometimes labelled 'Integrated Quiz Session' (IQS), which involved groups of eight students each with a tutor and lasting 45 minutes. Each 'SAS' included a talk given by one student to the other seven, after which he would be 'quizzed' by the others; he would be given a mark on a ten-point scale by the tutor on his overall performance.

Thus the essence of the system is the combination of group activities with independent work; however it was the excellent design of the latter which determined the success of the scheme overall and which has led to much use of the approach in other institutions. The learning achieved at an 'ISS' was efficient because it was student-centred, with flexible use of diverse resources; indeed its skilful use of media compared very favourably with the contemporary use of television
for instruction, which seemed to be unable to get away from a lecture style. Considerable emphasis was placed too on the student 'knowing where he was going' in that he was given the objectives for each week's instruction - usually in behavioural terms. However, it has been observed by Hills (1976) that Postlethwait's frequently expressed claim (e.g. Postlethwait et al, 1971) that students were able to work at their own pace was somewhat illusory. A certain amount of work was set each week, at the end of which the assignment changed; thus individual self-pacing was really regarded as secondary to the need to maintain a set rate of progress. In fact, a 'weekly lockstep' was in operation. Doubt has also been expressed by Oettinger (1969) who suggested that the success of the system can largely be attributed to the enthusiasm of Postlethwait and his followers. He comments that the good results achieved by use of the system might well have been obtained by conventional instruction by such an inspired teacher.

3.52 The Keller Plan or Personalized System of Instruction (PSI)

Kulik et al (1974) have traced the origins of this independent learning system in the Winnetka plan of 1919 with subsequent revival and development in the schemes of Glaser (IFP), Flanagan (Project PLAN) and Postlethwait (ATS). In its present form, the Keller plan was first described in a paper by Professor F.S. Keller entitled "Goodbye Teacher ..." (Keller, 1968); Keller had, however, been developing the system for the previous four years in his psychology courses at the Universities of Brasilia and Arizona.

The Keller plan is based on Skinnerian reinforcement theory and its main principles are: mastery, individual pacing and repeated instant feedback. The basic premise is that every student should demonstrate mastery of all sections of a course since an imperfect understanding of a number of small points could lead to the misunderstanding...
of major concepts. Since mastery would only be obtained by students of different abilities in different times, each student must be allowed to work at his own pace; thus the course material could not be presented by group teaching such as lectures. The materials can therefore be in written form or on film, videotape or audiotape, where they can be studied at any time convenient to the student. To assess the student's mastery, tutors must be available (one for, say, ten students) to mark and discuss tests and help with individual difficulties (hence the alternative name); only if tutors are available in such numbers is positive reinforcement and instant feedback possible. In the U.S.A., tutors are often students who have recently completed the course, called 'proctors' by Keller and chosen for their mastery of the course content and their maturity; in Britain they are usually lecturers or postgraduate students.

As with the audio-tutorial approach, a course is divided into units of about a week's work. For each unit the student is given a 'study guide' which lists the behavioural objectives of the unit, suggests study procedures (e.g. reading, viewing film loops, doing an experiment) and provides some self-assessed problems. Students can work when and where they like; they do not have to attend regular classes. The normal class periods are used for unit assessment and individual tutoring.

When a student thinks he has mastered the unit, he takes one of the three or four tests for the unit, randomly chosen; there is no time limit for the test, which should take about twenty minutes. As soon as the test is finished, it is marked by a tutor in the student's presence, giving immediate feedback. For mastery the answers should be completely correct, but in practice the tutor decides after considering the answers and discussing them with the student whether or not the student knows the material.
If the student passes he is given the study guide for the next unit; if not, he does further work and takes another test. There is no penalty for not passing but he must ultimately pass before proceeding to the new work. There is usually an examination at the end of the course, but a 'course work' mark may sometimes be added to this, related to the number of units completed; a further mark may be added for laboratory work, the total mark then obtained being used to grade students (and, in Britain, to assess eventual degree class).

Thus we see a basic difference between the Postlethwait and Keller systems; in the latter, self-pacing is not artificially restricted by a weekly change in the work assignment. If a student proceeds so slowly that at the end of the course he has completed only part of the course, then this is the part of the course on which he is assessed. In the U.S.A. procrastination often results in students withdrawing before the end of the course or being awarded 'incompletes' which allow them to complete the course the following year. The latter possibility is usually not available in this country and to avoid large scale withdrawals (i.e. effectively failures) methods of reducing procrastination are probably more important. Keller himself advocated ignoring them on the grounds that 'surely they know what is expected of them at a University'; however he offered 'tit-bit' lectures ('shows') which could only be attended by students who were 'on schedule' as an element of motivation. Green (1971) advocates (a) handing out a list or graph giving target dates for passing units (b) displaying a chart showing the number of units passed by each student (c) making the passing of each unit count a little towards the final course mark (d) offering an early final examination to those who finish the units early. As short term rewards, Green also offers admittance to 'fun-lectures'; however he has admitted that this device rarely works for teachers other than
Keller (quoted by Matthews, 1975). Elton et al (1973) admit that in a Keller-plan course, weaker students never get to the end of the course but it is hoped that what they have learned they have learned much more thoroughly; they suggest that whether it is better to know 40 per cent of 100 per cent (as in a traditional course) or 80 per cent of 50 per cent (as in Keller) may depend on the content of the course. Willoughby and Boud (1973) make the point that the need to make such a choice as this highlights the problem that there is generally too much material in most courses to enable them to be mastered fully, and this merits investigation. Earlier, Glaser (Oettinger, 1969) had questioned the need for complete mastery before proceeding to the next topic in a course; he asserted that as long as the fundamentals are clear, it would be wrong to procrastinate in getting all the details right. He also suggested that it might be better to be still learning the details of a section while tackling the fundamentals of the next one.

The use of the Keller plan has expanded considerably in the United States; many subjects are now presented in this way, including the sciences, history and speech communication. Since the first application in Britain at the University of Surrey in 1971 (Elton et al, 1973), several institutions of Higher Education have adopted it, with considerable success, e.g. at Strathclyde (Boud et al, 1975); Lancaster Polytechnic (Matthews, 1975). In a review of the research, Kulik et al (1974) states that evaluation has shown that the Keller plan (a) is attractive to students, the self-pacing and closer interaction with tutors being especially well liked; (b) produces content learning far better than by lecture methods; (c) engenders greater efforts by students than do traditional courses.

They agree that procrastination by students and consequent withdrawal rates can be rather high, but that in most institutions
methods have been found to control this defect.

3.6 Independent Learning in the Services

It was to be expected that the possibility of using the principles of Educational Technology would be of considerable interest to employers outside Higher and Further Education in those fields where cost-effectiveness is of paramount consideration. In particular, H.M. Services were among the first to adopt independent learning on a large scale, and a closer look at one of the training schemes at a Royal Naval establishment follows.

3.6.1 The Part III Training of Radio Electrical Mechanics at H.M.S. Collingwood

H.M.S. Collingwood is the training establishment for the Royal Navy's Electrical officers and ratings and was the first establishment of any kind in this country to make large scale operational use of independent learning by teaching machines (Cavanagh and Jones, 1969). Some 180 'branching' machines (mainly 'Auto-Tutors') were used to teach electrical theory to 'heavy electrical' and 'radio' maintenance ratings; the practical part of the course was also taught by 'Grundy Masters'.

However what generated considerable interest was the development in 1969-71 of this use of teaching-machines into a completely 'free-running' course of training for the Radio Electrical Mechanics (REM's). An article by the original designer (Collins, 1971) shows that the main attraction of such 'free-running' was the opportunity to take advantage of the variable speed of learning of REM students. However other advantages were recognised, in fact most of those advantages of independent learning discussed above, e.g. the production of less dependent learners, and the motivation likely to be generated by positive reinforcement. In the Naval context there were likely to be special advantages, e.g.:

(i) there could be closer quality control of the output of
REM's from the system;

(ii) the course would probably be shorter for a large number of ratings and this would be particularly important in the light of the newly introduced 'notice engagement' whereby ratings could opt out after 3 years of their engagement.

In the naval context, a further speed-up of course coverage could be expected by the introduction of pay bonuses for fast working. Also the possibility of getting away to sea at the earliest opportunity would provide even further inducement; any tendency to rush and skimp would, however, be checked by the need to pass 'stage tests' before being allowed to go on;

(iii) a saving of instructor-manpower was expected with machines taking over from human instructors; also new instructors would be able to help to run the course without a great deal of training. Both of these features were considered to be important in the light of a forecast shortage of instructors at that time.

All of these advantages meant that a higher cost-effectiveness would be likely, and on these grounds a complete independent-learning, free-running course was decided upon and started in operation in 1971. A detailed job specification was drawn up for the output REM's and in the light of this a training specification was produced. These were in themselves extremely useful exercises because at that time, employers (i.e. commanding officers of ships on which the REM's would eventually serve), the trainers and the trainees themselves all had different interpretations of what the REM was supposed to be able to do. Indeed in the light of these specifications it was hoped to reduce the basic course length by as much as one third.
Unfortunately, the course had only been running for about two years (i.e. about four courses of 24 weeks) when several problems were recognised. These were:

(a) **loss of 'class identity':** the 'team spirit' generated by a class undergoing long courses of instruction together has always been found to be of considerable value in the Navy; the fear of 'letting the team down' helps to produce high standards of behaviour, dress and discipline. Further, leadership qualities tend to be generated only in a group situation; the natural leaders emerge in the give-and-take of learning together. Such advantages of group learning clearly tend to be eroded when ratings work largely on their own and at their own pace. However it is recognised that there is a compensating benefit in training the ratings to work on their own (which of course they usually have to do when drafted to a ship); independent learning, as has been pointed out earlier, is best at producing independence in learners;

(b) **inflexibility:** such an independent learning course, relying as it does on expensive 'auto-tutor' machines, can only cater for a certain number of students; the numbers cannot be increased as demand requires;

(c) **'bottle-necks':** the level of difficulty of parts of the course was not assessed accurately; thus these sections produced queues of students waiting to repeat them and these blocked the system. Considerable re-writing was found to be desirable, but the time for this was not easy to find;

(d) **equipment maintenance:** the instructors were occupied throughout the day and in the event of a breakdown of the instruction equipment, they were not easily able to withdraw and remedy the fault. The high usage rate of the equipment (even after outside working hours) exacerbated this problem;
(e) **staff morale**: this suffered on two counts. Firstly, far from being less employed than previously as expected, the instructors found themselves working far harder and for far longer hours under the free-running system. Secondly the instructors found the change of role from teacher to 'fault finder' and 'answer bank' a difficult one. Many instructors applied to be taken off the REM training scheme;

(f) **staff training**: the hope that instructors would not need much training before taking up duties proved to be unfounded. They were found to need courses on programmed-learning methods, and delays occurred in providing these. Unfortunately the rapid turnover, and hence lack of continuity in staff, did not help matters either;

(g) **forecasting course output**: a computer was used to forecast the probable date for each trainee to complete the course, based on his performance in the 'basics' module. Unfortunately, this was subject to error in that speed of coverage of later parts of the course depended on rather different skills; sickness too, would obviously affect rate of completion. Thus expected dates of availability for draft were very often inaccurate and this was a big disadvantage compared with the previous 'fixed schedule' training course. The cost-effectiveness of the scheme was therefore much reduced because of the resulting 'waiting-time' for drafting;

(h) **quality of learning**: the earliest students undertaking the free-running course achieved considerable success, but this was found to be an illustration of the 'Hawthorne effect'. Subsequently retention of learning was found to be considerably lower than that produced by conventional teaching. Motivation was generally lower, the students being unable to generate the self-discipline needed to keep concentration at a high level. The instructional materials were found to be lacking in quality too; the programmed texts for routine skills like 'procedure for
tuning a radio set' were adequate, but those for teaching radio theory were much less effective;

(j) assessment: the assessment of ratings undergoing the course was based on criterion-referenced tests at frequent intervals during the course, and 'norm-referenced' tests at the end of each module (Popham and Husek, 1969). It soon became clear that the criterion-referenced tests were of little value in assessing the ratings' retention of learning and it was suggested that increased weighting should be given to the end-of-module tests when grading a rating's performance for future reference, i.e. for promotion opportunities. The time taken by a rating was also used for assessment; a mean time taken for each module was established after a few groups had taken the course and subsequent groups assessed in the light of these 'reasonable' times, e.g. a rating taking more than two 'standard deviations' longer than the mean time was regarded as having failed that module.

Revision of the Course

In the light of criticisms of the completely free-running course implied by the above-mentioned problems, it was decided to abandon the concept of self-pacing for the course as a whole but to retain it within each module. Thus much more 'enrichment' (buffer-option) material has been provided to occupy the faster working ratings at the end of each module or sub-section of a module, so that at a number of points in the course the whole group starts off together again. Thus there is a much greater emphasis now on quality of learning rather than speed, and early evidence indicates that this is being achieved.

As stated at the beginning of this section, this has inevitably had to be only a survey of the field, e.g. computer assisted learning
has been very briefly touched upon even though it offers the greatest scope for future developments in independent learning. The foregoing selection does however indicate the wide variety of systems of independent learning that have been experimented with; on the other hand, it is important not to confuse variety with quantity. The actual extent of implementation of systematised independent learning in schools and colleges is unfortunately still very limited, especially at sixth form level; this is very often due to a disturbing lack of appreciation on the part of Headteachers of the principles and benefits of Educational Technology. Conferences such as that organised recently by the Council for Educational Technology for Headteachers and Principals of Schools and Colleges with sixth forms should help to lessen the ignorance which hinders progress (Nichols, 1979).
EVALUATION: A HISTORICAL OVERVIEW

Evaluation as a field of education research is coming under increased critical scrutiny. In particular, meetings of curriculum evaluators have become much more frequent; committees have multiplied, and funds have been earmarked solely for effecting evaluation of a wide variety of curriculum innovations.

There seem to be three major factors which have precipitated this spate of activity (Parlett, 1974):

(a) Increased concern over accountability and attention to cost-effectiveness, at both government and other levels.

(b) It has become increasingly troublesome to choose between the abundance of curricular innovations in circulation at the present time; there is no 'Consumer's Association magazine' which enables one to decide on a 'best buy' if one is considering a curricular change.

(c) There is increasing questioning about evaluation methods, as a result of severe criticism of past evaluation studies; it is felt in many quarters that they have been seriously inadequate as aids to practical decision making. Thus there is now increased demand for the service of evaluators and at the same time a scepticism about evaluation methods.

During the past fifteen years the previously disjointed practices of curriculum evaluation have gradually emerged as a formal technology. As this technology has emerged, changes in the philosophy underlying evaluation have also occurred. The history of curriculum evaluation can be divided into three parts. Prior to the 1930's, evaluation was concerned almost exclusively with the administration of standardized tests. Comparisons when appropriate were made between two groups or between a target group and a set of norms. The origins of this kind of
evaluation were the preoccupation with 'content objectives' which characterized education in the early part of the century.

The second era encompasses the interval between the 'Eight-Year Study' by Tyler et al (Smith and Tyler, 1941) and the post-sputnik curriculum projects i.e. from about 1935 to 1960. A basic pattern of evaluation activities was established during this period based on an increased concern for the higher-order cognitive and affective objectives and the consequent inappropriateness of evaluation using a control group or a set of norms for comparison.

The final, post-sputnik era is characterized by attempts to formalise paradigms, i.e. models which would be applicable across many curricular innovations and projects. Chief among the advocates of the development of such models for evaluators has been Cronbach (1963).

4.1 The Second Era

The activities of the pre-1930 period cannot properly be called 'evaluation' in today's sense. However in the second era, the guidelines for establishing evaluation programmes as formulated by the Tyler group of the Eight-Year Study are worth further consideration. These were:

1. Formulation of objectives

The pure Tylerian approach required a prior specification of objectives. Probably the most exhaustive attempt to classify educational objectives was made by Bloom (1956) and later Krathwold, Bloom and Masia (1964), who identified three domains of educational objectives: cognitive, affective and psychomotor. For more effective evaluation, the objectives established for the project in question were then to be classified into one of ten categories suggested by the Tyler group:

a) The development of effective methods of thinking
b) The cultivation of useful work habits and study skills

c) The inculcation of social attitudes

d) The acquisition of a wide range of significant interests

e) The development of increased appreciation of music, art, literature and other aesthetic experiences.

f) The development of social sensitivity

g) The development of better personal-social adjustment

h) The acquisition of important information

i) The development of physical health

j) The development of a consistent philosophy of life.

The use of this classification was justified on two counts: it suggested areas for emphasis and it focussed attention on the evaluation instruments needed.

2. The second step was the expression of the objectives in behavioural terms, i.e. stated in specific terms of observable pupil behaviour.

Mager (1962) suggested three basic steps in the formulation of behavioural objectives:

(a) The kind of behaviour the pupil should be able to demonstrate to achieve the objective must be stated explicitly.

(b) The conditions under which the pupil demonstrates his competence must be stated.

(c) The criteria of acceptable performance must be specified by describing at least its lower limit:

- e.g. when provided with drawings of a variety of triangles (2) the pupil can correctly identify them by name (1) at least 90 per cent of the time (3).

3. The evaluating group were then required to specify the situations in which such behaviours might be observed. This was relatively easy if step 2 was done carefully.
4. The next step was to select and try promising evaluation methods; if the standardised measuring instruments already available were not appropriate, new appraisal techniques were to be developed.

5. Finally, the results were to be interpreted in terms of the objectives, and hypotheses suggested for improving the programme.

4.2 The Third Era

In the second era, the evaluation of the objectives themselves was apparently not considered to be a concern of the evaluator. Thus the slogan of the second evaluation era was: "How well does the programme achieve its goals?", with the vital question: "How good is the course?" receiving no attention. Such value judgements were however to become a major concern in the third evaluation era, together with a corresponding deeper concern for the understanding of educational process. Thus Scriven (1967) distinguished between the 'goals' and 'roles' of evaluation, the 'goals' being "what we are aiming at" and the 'roles' being "to what use the evaluation will be put". Scriven considered that 'goals' have been sacrificed to 'roles' in the emphasis on the use of evaluation; he urged the reversal of this trend with an increased weighting on assessment of the merit of the goals (i.e. objectives involved). Thus Scriven suggested that 'evaluation consists simply in the gathering and combining of performance data with a weighted set of goal scales to yield either comparative or numerical ratings, and in the justification of (a) the data gathering instruments, (b) the weightings, and (c) the selection of goals' (Scriven, 1967).

Apart from his contribution to the movement for value judgement in evaluation, Scriven (1967) helped considerably to clarify the evaluation "vocabulary" and to formulate its conceptual framework so that 'models' of curriculum evaluation could be developed for application across many programmes and projects. For example, Scriven developed and distinguished
between the concepts of 'formative' and 'summative' evaluation
(i.e. 'ongoing' and 'final'), and 'intrinsic' and 'pay-off' evaluation,
(i.e. consideration of the content, goals grading procedures, etc., of
a programme vis-à-vis its effects on the students undergoing the programme).

Following Scriven, (although his paper did not appear in print until 1967,
it had been available in mimeographed form for several years) Stake (1967)
produced a fairly general model. He pointed out that judgement about
courses can only be performed adequately on the basis of detailed and
reliable information and that the recording of this data is more than an
incidental preliminary chore; analysis and judgement is matched by a
parallel descriptive function. Stake provided a neat classification of
data into three categories; antecedent, 'transaction' and 'outcome'.
Antecedent data is information on 'any condition existing prior to
teaching and learning which may relate to outcome; transactions are the
'succession of engagements which comprise the process of education', and
outcomes are the end result of the educational process which comprise not
only those which may not be available till long after, e.g. transfer
effects. These three categories may be collected separately for each of
four classes of information which Stake calls 'intents', 'observations',
'standards' and 'judgements'; respectively these relate to programme goals,
observable situations, absolute or relative standards of excellence and to
assessments of value. Thus using these four classes in conjunction with
his three previous divisions, Stake builds up a matrix displaying twelve
groups of information as a model for the descriptive functions of
evaluation. The 'Integrated Studies Project' (Jenkins, 1973) and the
'Humanities Curriculum Project' (MacDonald, 1971) are illustrations of
evaluations where this descriptive function is particularly emphasised;
they are 'horizontal' models, in the sense that the aims, learning
experiences and the materials used were developed concurrently in contrast
with a vertical 'Tyler' model in which the aims are defined near the
start of a project and attention is devoted to refining the material
so that these aims can be realised.

Having underlined the importance of the descriptive function in
evaluation, it should be noted that Scriven was at pains to emphasise
that description is one thing, judgement is another. He charged
evaluators with the responsibility for passing judgement upon an
educational practice, asserting that there was no evaluation until
judgement had been pronounced and he was highly critical of the
surprisingly large number of evaluators who refrained from doing so.
As to what kind of judgement was needed, Scriven was again adamant;
it should be comparative; i.e. it should answer the question which he
asserted the educator really wants answered - 'Is this programme better
than the others of its kind?'.

However a fundamentally different school of thought was led by
Cronbach, whose paper: 'Course Improvement through Evaluation'
(Cronbach, 1963), has been quoted (e.g. Taylor, 1973) as heralding the
start of the 'modern era in evaluation, with its wider horizons and
greater responsibilities'. Cronbach urged evaluation with respect to
'absolute standards as reflected by personal judgement', e.g. one would
evaluate a new mathematics curriculum with respect to opinions as to
what a mathematics curriculum should be. Cronbach suggested that
generalizations to the local school situation from curriculum-comparison
studies are sufficiently hazardous (even when the studies are massive,
well-designed and properly controlled) to make them poor research
investments; he therefore advocated fewer comparisons with matched
groups, and more intensive 'case studies' with extensive measurement
and thorough description. His analogy is that of the engineer examining
a new car; he sets himself the task of defining its performance characteristics and dependability, and it would be 'merely distracting' to put his question in the form 'is this car better or worse than a competing brand?'

Stake (1967) comments on the Scriven-Cronbach disagreement and offers a partial resolution of the 'relative v absolute' argument in terms of the type of educator likely to prefer one rather than the other; thus he suggests that a teacher or faculty committee faced with an adoption decision would prefer answers to the question: "which is best in my particular situation?" and would therefore prefer a Scriven-type evaluation. However, a curriculum innovator or instructional technologist would prefer a Cronbach-type evaluation because it would try to answer the question: "how can I teach this better?".

Evaluation in terms of objectives, however well defined and justified along the lines suggested by Scriven, was subsequently criticised on other grounds. For example, Hastings (1966) asserted that it took only a little experience on an evaluation task to convince one that 'such a procedure was laden with problems of several kinds'; while Eisner (1967) listed the limitations of educational objectives themselves. An earlier indication that such problems stem partly from an inadequate conception of the scope of evaluation was to be found in the seminal Cronbach paper (1963) quoted above; he suggested a wider range of functions of evaluation than had previously been accepted. It was to draw attention to these that he provided a definition of evaluation which has often been quoted; 'the collection and use of information to make decisions about an educational program'. Thus the implication was that there was more to evaluate in an educational programme than its stated objectives, however behavioural; evaluation was a much more diversified activity. Cronbach urged the need to observe what changes
are produced by the programme along several dimensions, and how the changes are produced, e.g. how great is the influence of the teacher himself. Process studies, attitude measures, proficiency measures, and follow-up studies should be included; Cronbach justifies the use of each of these. He also advocates the use of generalised objectives (again the 'absolute' approach) rather than ones special to the programme.

Wittrock (1970) agrees that it is of little use knowing 'what' an innovation does without knowing 'how' and 'why', i.e. he emphasises the need to uncover cause and effect relationships between the environment of learning, the intellectual and social processes of learning, and the learning itself. Moreover, he suggests that one of the reasons why earlier evaluation studies were of little help to teachers (i.e. the users of the evaluation) was because these relationships were not revealed; the environment and the learner were studied separately, their interaction often being ignored. Extrapolation of the evaluation conclusions to other situations was thus very difficult.

The Phi, Delta, Kappa National Study Committee on Evaluation (Stufflebeam et al, 1971) confirms the usefulness of the Cronbach approach. Moreover they emphasise the need to separate the provision of information from the passing of judgements upon it by the decision-maker. Their model of evaluation is therefore (Stufflebeam et al, op cit): (see diagram overleaf)
Tawney (1976), in a review of British evaluation studies of the Cronbach type, suggests that, even though these have varied greatly in their approach, their focus has been almost exclusively on the information which decision makers might need. Thus MacDonald (1973) focussed on the information which users of the programme might need, while Harlen (1975) concentrated on what the project revisers would find useful. Rather more generally, Crossland and Moore (1974) based their evaluation on the questions which persons 'external to the project' might ask.

Tawney also asks an important question: how can evaluators coming new to the job, and using techniques wider than just the assessment of attainment of behavioural objectives, know what the
right questions to ask of a project should be? He offers some general
guide-lines, suggesting consideration of feasibility, effectiveness,
and educational value and he incorporates these in his wider definition
of evaluation (Tawney, op cit): 'curriculum evaluation is the
collection and provision of evidence, on the basis of which decisions
can be taken about the feasibility, effectiveness and educational value
of curricula'.

Definitions of evaluation such as those of Cronbach, Stufflebeam
et al, and Tawney, quoted above, are clearly open-ended as to the
methodology of the evaluation. One useful classification (Eraut, 1972)
is categorised in terms of the main sources of information used in each
case; this is a meaningful classification because even though one would
expect that many sources would normally be used, Eraut claims that with
a few exceptions a narrowly based evaluation has been adopted. Eraut's
classification, together with models of each type, is as follows:

A. Evidence from Students
   1. The Tutorial Model - most used by programmers, and
      psychological researchers.
   2. The Agricultural - Botany Model - we shall discuss this later.

B. Evidence from Teachers
   3. The Anthology Model - an unreliable method based largely on
      hearsay evidence.
   4. The Teacher Opinion Model - used by the Nuffield Science
      Projects evaluators.

C. Evidence from Classes
   5. The Interaction Model - based on direct classroom observation
      and first used on any scale by the Schools' Council Humanities
      project (MacDonald, 1971).
6. **The Environmental Model** - based on direct evidence from visits and used extensively in the 5 - 13 Science Project (Harlen, 1971).

D. **Evidence from Institutions**

This kind of evidence has rarely been used by projects themselves (MacDonald, 1971) but has always been the concern of potential adopters.

7. **The Cost-Benefit Model**

Unfortunately it is difficult to assess all the benefits and existing accounting procedures make assessment of the real costs almost as difficult (Taylor, 1970).

8. **The Political Model**

Assessment of motives behind the adoption or rejection of an innovation.

9. **The Anthropologist's Model**

We shall discuss this later.

E. **Evidence from Experts**

The term 'expert' is meant to imply a person whose judgement is considered likely to be of value, e.g. curriculum specialist, experienced teachers etc.

10. **Desirability Model**

The likely outcomes are considered and their desirability and the priority given to them investigated.

11. **Feasibility Model**

The likelihood of intended and unintended outcomes is looked at and alternative strategies considered.

A simple alternative to Eraut's eleven-fold classification is suggested by Brewer and Hills (1976). They consider the spectrum of sources of information used by evaluators to range from 'formal' to
'informal'; thus the corresponding evaluation methodology ranges from
the attempt to obtain 'objective, scientific data through carefully
structured research', to one in which there is a preference for 'a
subjective, humanistic interpretation and a relatively unstructured
approach to data collection'. These two ends of the spectrum of
evaluation methodology have characteristics very similar to those of
two in Erut's list, namely, the 'Agricultural-Botany' and 'Anthropological'
models and it will be helpful to look at these in some detail.

4.3 The 'Agricultural-Botany' Paradigm

The 'traditional' methodology of evaluation involved the subjection
of students to an educational innovation and the collection of information
about their progress for evaluation purposes in a similar manner to that
employed in the field of agricultural botany. Thus 'students - rather
like plant crops - are given pre-tests (the seedlings are weighed or
measured) and then submitted to different experiences (treatment
conditions). Subsequently after a period of time, their attainment
(growth or yield) is measured to indicate the relative efficiency of
the methods (fertilizers) used' (Parlett and Hamilton, 1972).

Unfortunately, even though such techniques would appear to be logical
and objective, this evaluation strategy has been criticised on several
grounds (e.g. Brewer and Hills, 1976):

(i) Education is a rather more complex process than growing
seedlings, with far more relevant variables in any local situation.
Thus generalization from local statistical measurement has obvious
dangers; in order to draw conclusions in a human situation, one has
either to exercise strict control of all the variables (obviously
impossible), or randomize the effects by using large samples (and this
is very expensive in terms of time and money). Since the time and
money available are usually very limited, the generalization which is
allowable tends to be very restricted. Research therefore tends to be divorced from reality, couched and pursued in its own framework, often studying concerns far from the classroom. (Miller and Parlett, 1974).

(ii) The strictly objective nature of this method means that subjective data are often ignored. However such data can often be more revealing than mere statistical results, e.g. the impressions and feelings of teacher and students about the course are clearly important when assessing it - indeed these are what determine the modifications made by the teacher as the course progresses.

(iii) If the objectives and other criteria in terms of which the evaluation is to be done are pre-specified, there will be a tendency to ignore benefits and undesirable side effects which have not been anticipated but which occur inadvertently. There will even be the possibility that the study proceeds even though the objectives which are achieved turn out to be hardly worth attaining.

Such criticisms are easy to make, but it is difficult to provide a satisfactory alternative, largely because any subjective considerations tend to weaken the logical structure of the evaluation and make the results difficult to substantiate. Indeed it may be seen to be just as subjective as the formative evaluation any good teacher makes when receiving feedback from students in conversation, and when marking 'homework' and examinations; since there is a considerable volume of information from these sources, a formal evaluation has to be systematic and well-structured if it is to be seen to have lessened the effect of its subjectivity and thereby make a special and significant contribution. The results of a study which emphasises impressionistic data rather than measurement may be interesting and even useful, but the evaluation 'customers' have to be convinced that such data are sufficiently comprehensive and conclusive if they are to serve as evidence in decision
making.

If, then, a new evaluation methodology is to be accepted in place of conventional techniques based on the 'learning-effectiveness', psychometric tradition, with its criticisms of narrowness of concern and lack of utility of results (Parlett, 1974), it has to be sophisticated enough to explore the complexity of the teaching situation (including the human relationships involved), without a serious loss of objectivity. In essence, it has to be concerned with answering not only the question 'how good is it?' but also 'what is actually happening?' (Parsons, 1976), and, if possible, 'why?' (Harlen, 1975).

4.4. The Anthropological Paradigm - Illuminative Evaluation

One possible solution is that of 'illuminative evaluation' as advocated by Parlett and Hamilton (e.g. 1972, 1974) who propose the replacement of the agricultural-botany paradigm with one based on research in social anthropology and psychiatry, and 'participant observation' research in sociology. Thus the emphasis on large samples, control groups, and quantification is replaced by one on small sample studies but taking account of the wider context in which the educational innovations are to function. Data is to be gathered from a number of sources by a variety of methods, thus 'illuminating' the situation so that it can really be seen 'what is happening' at the 'chalk-face of education' (Parsons, 1976), with all its complexity and subtlety; a comprehensive understanding is aimed at (i.e. it is a 'holistic' approach (MacDonald, 1971)), but by description and interpretation rather than by measurement or prediction.

The intention is thus to give evaluation a 'humanistic' rather than a scientific base (Brewer and Hills, 1976). Thus one is looking for a better understanding of the forces which would shape the fate of the curriculum innovation were it to be offered in a school (Hastings, 1966).
For example, one should take account of the effects of teacher enthusiasm and involvements, as opposed to the requirement that these should be ignored in a traditional evaluation; teachers have to be seen as creators of curriculum change rather than mere spectators (MacDonald, 1973; Trown, 1970).

Emphasis is also placed on flexibility; there is no suggestion of a closely defined sequence of operation to be followed, but a general strategy with each investigation treated as a separate case with techniques adopted to suit its particular requirements. Such a variety of approach is indeed essential if the practices and processes of teaching and learning are to be analysed, elucidated and portrayed in their natural educational settings (Miller and Parlett, 1974). Likewise an eclectic methodology is required, drawing upon interviews, questionnaires, observation, etc., in various combinations; in fact the whole approach is 'heuristically organised', redefining the areas of enquiry and progressively refocussing as the study proceeds and different critical issues to be studied become uncovered. With these aims in mind, Parlett (1974) suggests that there should be five different phases of an illuminative evaluation study.

Stage 1: Setting up the evaluation

At the outset the evaluation has to clarify what type of report is envisaged, in consultation with those who are most directly concerned (e.g. Head teachers, LSA officials). Decisions are made about the size, duration and overall plan of the study; but there is no detailed pre-specification of variables to be included - no closing of research doors before discovering what lies behind them.

Stage 2: Open-ended exploration

This phase is usually one of the longest and most significant. The researcher must familiarize himself thoroughly with the day-to-day
reality of the scheme in schools, visiting and observing, listening to teachers and pupils, getting to know each school's particular circumstances - in fact, generally behaving like a 'social anthropologist on location'. During this phase the researcher is receptive to a mass of different information; he listens and becomes 'knowledgeable' about the total scheme: how teachers use it, how it fits into long term curricular plans, what resources and hidden costs are involved, and what activities and intellectual tasks pupils are asked to perform. His enquiries are not confined to the schools themselves; he will also trace the background, rationale, and history of the curriculum or innovation - thus he tries to build as comprehensive a picture as possible.

**Stage 3: Focussed enquiries**

There is no sharp dividing line between Stages 2 and 3. During Stage 2, the researcher is constantly sifting through his experiences, spotting similarities and differences between viewpoints expressed, noting the issues and problems most frequently raised and observing recurring classroom events and trends. Stage 3 begins when these phenomena, occurrences etc., become topics for more sustained and intensive enquiry, in a more directed and systematic way. Interviews become more 'focussed', observation in classes more selective; pencil-and-paper enquiry may be introduced and questionnaires may be used where appropriate (e.g. as an independent check of interviews). If conventional tests of achievement and attitudes are used they occupy no privileged position; they are simply other sources of data.

**Stage 4: Interpretation**

Illumination is really clarification and interpretation. Extensive description alone is not enough; the investigator must order and organise the description, and add interpretive and explanatory comment.
By Stage 4 the evaluator is weighing alternative interpretations and is already structuring his report. Thus beginning with an extensive data base, the evaluator systematically reduces the breadth of his enquiry to give more concentrated attention to the emerging issues; this 'progressive focussing' permits unique and unpredicted phenomena to be given new weight, preventing 'data overload' and the accumulation of a mass of unanalysed material.

Stage 5: Reporting the Study

The illuminative evaluator is conscious throughout his investigation of the eventual readers of his report. Thus his report must provide the information his readers will wish to have at their fingertips; he will discuss the issues which concern them and will use an appropriate format and style. However, sensitivity to the need of his audience must not undermine his autonomy nor cause him to censor what he has discovered; he must remember that the report is likely to be read and used by widely different groups, administrators, teachers, etc. 'Straight' reporting is certainly called for. The evaluator is thus seeking to provide a non-recomendatory information service to the whole community; he acts as a 'broker' in exchanges of information between groups who want knowledge of each other. He recognises value pluralism and the 'right to know' of the different groups involved; i.e. it is a 'democratic' view of evaluation (MacDonald, 1976).

The general principles of illuminative evaluation as outlined above are clearly applicable to most evaluation studies but are probably most useful as guidelines to be followed when conducting large scale evaluations of innovations being tried out in several educational establishments. However, Parlett and Hamilton also make useful practical suggestions as to the procedures to be followed when evaluating a small scale innovation, e.g. one which might be introduced
by a teacher in one school. They suggest that one cannot consider
an innovation apart from the 'learning milieu' surrounding the
introduction of that innovation; the learning milieu is defined to
be 'the unique pattern of circumstances, pressures, opinions and work
styles which suffuse the teaching and learning' (Parlett and Hamilton,
1972). Five features of this learning milieu are suggested:

- **Constraints** (legal, administrative, architectural, financial),
- **Pervasive operating assumptions** (curricula, arrangements of
  subjects, teaching methods, methods of student assessment,
  size and diversity of classes, availability of teaching
  assistants, copying and library facilities, etc.),
- **Individual teaching characteristics** (teaching style, experience,
  private goals),
- **The 'hidden' curriculum** (i.e. the conventions, beliefs, models
  of reality constantly being transmitted through the total
  teaching process), and
- **Student perspectives and preoccupations.**

Parlett and Hamilton insist that one cannot separate the innovation
from the learning milieu of which they become a part. The introduction
of an innovation sets off a chain of repercussions throughout the
learning milieu, but there is then a feedback which affects the
innovation itself, changing its form and moderating its impact. Thus
they assert that it is the examination of the learning milieu itself,
the effect on it of the innovation concerned, and the feedback of the
milieu on the innovation which should constitute the evaluation process.
Indeed they suggest that this is so different from previous concepts of
evaluation that it warrants a new name, viz. "investigation".

For a small scale 'investigation' they therefore advocate the
following procedure:

a) Before the innovation is actually tried, some general questions about its likely effect on the learning milieu and the feedback on the innovation, are formulated;

b) The innovation is then tried, and its effects are observed by the teacher/investigator. This 'observation' phase occupies the central place in the investigation; the investigation builds up as complete a picture as possible of events, transactions and informal remarks, adding interpretative comments on both manifest and latent features of the situation as it develops.

c) A number of phenomena are now selected as worthy of more sustained and intensive enquiry. This 'Further Enquiry' phase is thus one in which the emphasis is changed, becoming more focussed, directed, systematic and selective.

d) The final phase is one in which general principles concerning the interactions between the innovation and the learning milieu are searched for and formulated. During this 'Search' and Explanation' (or possibly 'Evaluation') phase, individual findings of cause and effect, patterns of behaviour and their explanations should if possible be placed in a broader, generalized context.

In conclusion, it is important to recognise and guard against the dangers of excessive subjectivity and lack of rigour in using 'illuminative' techniques. It is not so much the techniques themselves that are in question (e.g. Costin et al. (1971) quote high reliability and validity for ratings of courses by students) but the application of them and interpretation of the results obtained. Parlett (1972) lists some
checks on the 'personal' interpretation of the researcher, e.g.: negative evidence is to be noted down;
established fact and cheerful speculation are to be carefully separated;
no 'pig-headed reaction' against quantitative data is to be allowed.

Parsons (1976) would go much further, advocating a survey of the practices and conceptualizations of field workers in the social sciences. Becker (1958), for example, has useful advice on 'participant observation' and how to cope with the vast quantities of data it provides in a 'scientific' manner; in particular he suggests ways of checking on the credibility of informants. However, Trow (1970) puts this matter in a reasonable perspective. While asserting that one needn't set aside academic standards or notions of craftsmanship in one's consideration of educational innovation, he underlines the value of an illuminative approach as 'enlightening to the innovator himself' and to the whole academic community, by clarifying the processes of education and by helping the innovator and other interested parties to identify those procedures which seem to have had desirable results. Thus he suggests that researchers should 'forego the dubious pleasure of awarding gold stars and demerits to academic innovators, but must try instead to serve them'.
CHAPTER 5

THE DESIGN OF THE INVESTIGATION

The fundamental aims of this research were to design an independent learning system for use with a sixth-form science group, and to use the system to investigate the advantages and disadvantages of such a method of working compared with traditional science teaching in the sixth form.

5.1 Limitations Imposed

As outlined in Chapter 3, several independent learning, or resource-based learning systems have been developed by teachers or groups of teachers provided with considerable financial backing by a Local Authority, one of the Services, or a commercial enterprise. In this investigation, it was hoped to determine how much could be done by a teacher working with only the financial resources of a typical secondary school science department and with neither extra time, such as by secondment, nor extra laboratory assistance, provided.

As a result of these self imposed constraints, the system was a fairly simple one and was designed to cover only a part of the Advanced Level Physics syllabus.

5.2 The Syllabus Covered

The system was designed to cover Sections 17 - 23 of the University of London Advanced Level Physics Syllabus (1978), a copy of which will be found in the Appendix.

This is the 'Mechanics and Properties of Matter' part of the syllabus; it was chosen because it is largely mathematical in nature: since the mathematical ability of the students was widely different, the pace of coverage of the work by the students would be expected to vary widely. Thus the ability of the system to cope with a considerable variation in student pace should have been more severely tested by this area of work than by an area where the work is more qualitative in nature.
The syllabus covered by the system was divided into three parts for the following reasons:
(a) the subject matter sub-divided logically into three areas;
(b) the pre/post-tests would be unwieldy if covering the whole area of work;
(c) greater flexibility would be available if changes were necessary during the trials.

5.3 The System Itself

The resources provided were:
(a) Learning Materials

These were standard text books supplemented by specially written information sheets and work sheets for experiments.
(b) Directive Materials

These were 'Guide Sheets' which listed all the work to be covered and stated the order in which it should be done. There was one guide sheet for each of the three parts of the syllabus.
(c) Assessment Materials

These were the Pre/Post-Tests and the Question sheets. The Pre-Test and Post-Test for a guide sheet were identical; they contained questions of A-level standard on a part of the syllabus, i.e. there was one Pre/Post-Test per guide sheet. It would therefore be expected that the marks earned would be low when set as a Pre-Test, and high when set as a Post-Test, if the instruction provided by the system was successful. Thus these tests were 'criterion-referenced', in that they determined the degree to which the student achieved the criterion of 'mastery' of that part of the A-level syllabus. 'Norm-referenced' testing, i.e. with a view to determining the relative order of examinees, was not provided by the system itself; it would be provided by the School's Annual Examination. This would contain questions which the students had not
seen before and would be expected to give a reasonable estimate of likely performance in the A-level examination itself.

The Question sheets contained simpler questions designed to clarify concepts and provide practice in their application. The system provided for a discussion period after the students had worked through a Question sheet so that the important points could be emphasised.

Samples of all these materials will be found in the Appendix; however the system may be illustrated diagrammatically by the 'flow chart' shown overleaf.

Note:

(i) Although it is a common feature in self-teaching systems, no 'pre-knowledge test' was provided. The main reason was the particular nature of the subject matter involved here; A-level questions in Mechanics are frequently only marginally more difficult than those appearing in an O-level paper. The concepts ought, of course, to be understood more fundamentally, and the calculations involved are likely to be more difficult arithmetically; I therefore felt that it was better to 'start again' and re-develop all of the concepts in this particular field with a more mature use of language and mathematical illustration. Further, the text books tend to use this approach in their treatment of Mechanics.

(ii) The system was fundamentally an 'independent learning' one vis-à-vis an 'individualized learning' one (as defined in Chapter 1). The emphasis was clearly on the student learning by himself from resources provided by the teacher rather than the provision of instruction which could be varied to suit the student's individual ability, style, etc. One important individual difference between students could, if so desired, be taken into account, viz., variation of learning pace.
FLOW CHART

General Instructions

Guide Sheet I
- Pre-Test I
  - Text Books
  - Information Sheets
  - Work Sheets
  - Question Sheets
  - Discussions
  - Post-Test I

Guide Sheet II
- Pre-Test II
  - Text Books
  - Information Sheets
  - Work Sheets
  - Question Sheets
  - Discussions
  - Post-Test II

Guide Sheet III
- Pre-Test III
  - Text Books
  - Information Sheets
  - Work Sheets
  - Question Sheets
  - Discussions
  - Post-Test III
However, as noted in Chapter 2, reviews of the research into the benefits of self-pacing have been inconclusive; in any case, A-level students cannot be allowed to take as long as they wish over a part of the syllabus. Physics teachers rarely find that they have sufficient time to complete their course with the expansion of A-level syllabuses of recent years.

With these points in mind, it was decided only to take partial advantage of the full individualization with respect to learning pace that the system could have allowed (see Section 5.6 below).

5.4 The Target Population

The students for whom the system was designed were those preparing for the University of London Advanced Level Examinations in Physics. This is an example of a 'traditional' physics examination, a term used to distinguish it from the radically different 'Nuffield' course and examination, which is pursued in many schools in parallel with the traditional course.

In most traditional A-level physics courses, the 'Mechanics and Properties of Matter' part of the syllabus would be covered during the first of the two years, i.e. the students involved would be in the 'Lower' Sixth. This should have the advantage that the students would learn to read a text book 'independently' early in their sixth-form career and later parts of their course should benefit accordingly.

5.5 Introduction by the Teacher/Manager

There were several things which had to be said to the students by the teacher before the course was started. Not only should the system itself, as outlined above, be explained in detail but an outline of the advantages of covering part of their A-level course by an independent-learning method should help students at least to start the course with sufficient motivation to overcome their initial apprehension. It was
particularly important that the students knew the parts of the course for which they were free to work with other students, also those questions which they could do as 'homework' (i.e. using notes and text books) and those which they should do without help from other students and also, if possible, without the use of text books, e.g. the pre/post-tests. (Indeed, some teachers might prefer to set the pre/post-tests as examinations. However, this puts too high a premium on memory rather than understanding and denies the purpose of those tests in assessing the system rather than the students, as explained above).

In addition, since the learning system was being used not only as part of an A-level course but also to provide information for research purposes, this had to be made clear to the students and their cooperation was to be asked for. There would thus be a danger that the knowledge that they were the subjects of research would affect the behaviour of the students (the 'Hawthorne' effect). However, since the use of 'illuminative' investigation techniques made it impossible to conceal this from them, it was better to reveal it at the outset; also the fact that the students involved would be personally known to the investigator meant that he would be likely to notice any unusual 'Hawthorne' effects and would be able to make allowances for them.

5.6 Speed of Working

Having decided, as mentioned above, to impose some restraint on self-pacing when using the system, students were to be told that they would be able to study the texts, information sheets, etc., at whatever speed they wished, but that it would be insisted that they 'catch up' their faster colleagues at certain points, by doing extra work in private-study periods or at home. The technique I decided to adopt was to insist that the answers to the various 'Question Sheets' should
be handed in by the whole group at the same times, the dates to be
determined by observation of the fastest speed of working of the group.
This had the additional advantage of providing a number of periods, viz.,
the 'Discussion' period following each Question Sheet marking, when the
group could enjoy the benefits (social and psychological as well as
academic) of discussing their difficulties with the others in the group.

5.7 Working in Groups

As discussed in Chapter 2, students often work better in pairs or
in larger groups. I therefore decided that I would allow this to
happen except during the Pre/Post-Tests (during which an individual's
progress is, of course, being measured); indeed, some of the practical
experiments needed at least two to work together and this would not
detract too much from the essentially independent nature of the work.

5.8 Marking

Answers to the Question Sheet questions, the Pre-Test, and the
Post-Test would all be marked to give an indication of progress but
since these were criterion-referenced, these marks should not contribute
to any End-of-Year mark used for A-level grade forecasts, etc. These
forecasts would be based on the End-of-Year examination.

5.9 Provision of Apparatus

The apparatus needed for any work sheet had to be available
whenever a student (or pair of students) reached that point. Since a
certain amount of self-pacing was likely (see above), it was probable
that the apparatus would not be requested by large numbers of students
all at once. Indeed this is one advantage of a system of this kind;
in traditional methods of teaching, the whole group would like the
apparatus for an experiment at the same time and this is usually not
possible. A common way round this is to organise a rota of experiments,
but this means that many students are doing an experiment before they have covered the necessary theory.

It was to be noted that if a short delay was necessary until a piece of apparatus became available, the next piece of work listed in the Guide Sheet could be started meanwhile.

5.10 Preliminary Lines of Investigation

As discussed in Chapter 4, it is important in an illuminative investigation that the outcomes should not be pre-emptively restricted by excessively detailed objectives at the outset. However some general questions were clearly in mind when this investigation was formulated and these formed the basis of the 'Preliminary Investigation' or 'First Trial'. These questions were:

i) Can part of an A-level Physics course be adequately covered by an independent learning system?

ii) How does the learning efficiency (e.g. pace, depth of understanding etc.) compare with that for a traditionally taught course?

iii) Do the students enjoy independent learning as much as, more than, less than, traditional teaching?

iv) Do any of the expected 'spin-off' advantages of independent learning (self-pacing, improved ability to organise one's study time, etc.) in fact materialise?

v) Are better personal relations with the teacher achieved?

vi) Do the teacher and students find their changes of role difficult to accept?

vii) Is the 'team spirit' resulting from a group working together, and by which members of a group learn from each other, reduced significantly by independent learning?
CHAPTER 6

THE FIRST TRIAL

This was in the nature of a 'feasibility study' or 'preliminary investigation' and corresponds in general terms to Parlett and Hamilton's 'Observation Phase' (described in Section 4.4). It took place at Farnborough Sixth Form College in the Summer Term, 1976.

6.1 The Students

The students involved were those of my Lower Sixth A-level Physics group; they were therefore completing the first year of a two year course preparing them for the University of London Advanced Level Examination in Physics in June 1977.

In this particular year, there were 43 'traditional' Physics students and 25 'Nuffield' Physics students in the Lower Sixth. These students were also studying for at least one other A-level examination, selected from Mathematics, Biology, Chemistry and Geography; the only exception to this was student 'L' whose only A-level subject was Physics. Since the portion of the A-level syllabus involved in this trial was the 'Mechanics and Properties of Matter', there was some overlap between the A-level 'Physics' and 'Mathematics' syllabuses in this area of work. Thus it was particularly relevant to the analysis of the results of this trial if the students were studying A-level Mathematics; this information is therefore provided with the First Trial Data (Section 6.32) and some discussion of its effects is included in the First Trial analysis.

Also included with the First Trial Data are the marks and positions for the trial students in the College's 'End of Year Examination' in 'traditional' Physics. This examination occurred during the period of the trial; in fact the trial had to be suspended for the ten days of the 'Examination Period', and this was one cause of curtailment of the
First Trial (see below). The distribution of the examination positions of the trial students as members of the group of Lower Sixth 'traditional Physics' students (43 in number) is shown as follows:

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<tr>
<th>Number of Trial Group Students</th>
<th>1 - 6</th>
<th>7 - 12</th>
<th>13 - 18</th>
<th>19 - 24</th>
<th>25 - 30</th>
<th>31 - 36</th>
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Thus, even though it was not possible deliberately to select the trial group with a view to a spread of ability, (the Lower Sixth groupings being largely a matter of time-tableing convenience), it can be seen that the group was representative of the 'traditional A-level Physics' students at the College, in that they were fairly evenly distributed among the examination positions for all the Lower Sixth traditional Physicists.

6.2 The First Trial Timetable

It was decided to devote the second half of the Summer Term of 1976 to the First Trial; this was explained to the students involved in the first lesson after the half-term break. This first lesson was also used to discuss:

i) reasons for using the system;

ii) various administrative details (filing of notes, provision of apparatus, etc.);

iii) the limits to the self-pacing allowable, i.e. the fact that the group would be expected to hand in the answers to each Question Sheet at the same time (see Section 5.6).
They were also told that I would be using the results of the experiment as part of a research project and their co-operation in providing data for the research (e.g. how long they took over various sections) was requested.

The weekly time-table was as follows:

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The whole of the time allocated to Physics during the week was devoted to the system for that half-term. However, as explained below, there were in the event two major disruptions in the running of the system.

6.3 Observations on the First Trial

6.3.1 Rate of Progress

(a) Individual (or pair) Pacing

As explained above, self-pacing was only possible between the Question Sheet sessions, i.e. over a period of ten days or so. However, (as also explained above), it was expected that over a period such as this, a considerable variation in rate of progress would be evident. In the event, this did not materialize; over each ten day period, very
little catching-up seemed to be necessary. The explanation for this seemed to be:

(i) the more able students were content to work steadily making sure that they well understood the subject matter even where this was already fairly familiar to them. Thus these students did not forge ahead as expected.

(ii) The most able students in this group also tended to be the laziest; thus they were content to keep just a little ahead of their less able but harder-working colleagues who were prepared to do extra work after each lesson in order that they did not fall behind.

(iii) Students who missed lessons took advantage of the independent nature of the system to catch up quickly with extra private study.

(b) The Group as a Whole

The group progressed at a much slower rate than I had expected. The main reasons seemed to be:

(i) the timing of the 'reference-points', i.e. the group-answering of the Question Sheets, was determined by the speed of working of the fastest students. As pointed out in part (a) of this section; these students did not work at as high a speed as they probably could have done, consistent with understanding the work well. Thus the group speed was correspondingly low.

(ii) The trial period happened to coincide with a period of extremely hot weather, (indeed this was a feature of the whole summer). The students therefore tended to lack concentration and worked slowly. This was especially so during the afternoon sessions, the weekly allocation of periods for Physics in the Lower Sixth being one morning double, one morning treble, and one afternoon treble (see Section 6.2).
In a traditionally-taught course one can partially overcome the problem of hot afternoon sessions by arranging that they should be used for practical work, the experiments being allocated on a rota basis over a period of several weeks if, as is likely, there is not enough apparatus for the students to do a particular experiment all at the same time. Then the physical activity involved in doing an experiment tends to keep students mentally awake. However this being the first trial of a learning system which would ideally involve the experiments being performed at precisely-determined points in the sequence of work, it was thought to be undesirable that a large-scale removal of the experiments from the sequence and translation of them into a separate rota should occur. In fact this would tend to disrupt the whole system since the 'Question Sheet' questions frequently refer to experiments which it is assumed have been done previously; there is clearly a lack of flexibility here which must be recorded as a probable disadvantage of the system.

(iii) Just after the middle of the trial period, there was a fortnight of movement of laboratory apparatus and furniture into new accommodation. This caused considerable disruption of lessons.

(iv) The College's End-of-Year Examinations which occurred just before the middle of the trial period, were this year arranged to take place over a longer period than hitherto. Since the students were allowed to be absent from College for the whole of the examination period, this resulted in a shortening by several lessons of the time allocated to the trial.

The end-result of all these factors was that approximately two thirds of the system was covered in the time available, viz., up to about stage 13 of the second Guide Sheet; the time could not be extended because I was leaving the College at the end of the term. This
meant that a complete Pre- and Post-Test analysis could only be done for the first Guide Sheet.

6.32 The Students' Course Marks

The marks for Pre- and Post-Test I for each student are listed below. Also provided is the result of the End-of-Year College Examination in Physics for each student (percentage and position); the performance of the trial group students vis-à-vis the other Lower Sixth students doing the same examination course can thus be determined.

First Trial Data

<table>
<thead>
<tr>
<th>Student</th>
<th>Sex</th>
<th>Pre-Test (X)</th>
<th>Post-Test (Y)</th>
<th>Raw Gain (Y-X)</th>
<th>End-of-Year %</th>
<th>End-of-Year Position</th>
<th>A-L Maths</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>M</td>
<td>62</td>
<td>81</td>
<td>19</td>
<td>46</td>
<td>26</td>
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<td>B</td>
<td>M</td>
<td>31</td>
<td>68</td>
<td>37</td>
<td>48</td>
<td>23</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>M</td>
<td>37</td>
<td>79</td>
<td>42</td>
<td>51</td>
<td>16</td>
<td>Yes</td>
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(a) **Group Performance**

Mean Group Pre-Test Score \( (\bar{X}) \) = 24%

Mean Group Post-Test Score \( (\bar{Y}) \) = 62%

Mean Group Raw Gain \( (\bar{Y} - \bar{X}) \) = 38%

How to use such figures to obtain the most meaningful 'index of learning' has been a matter of some discussion (Roebuck, 1975).

McGuigan and Peters (1965) suggest: 'gain as a proportion of possible gain' and 0.50 as the lowest group value for an acceptable programme of instruction. For this trial:

the Group McGuigan Gain Ratio

\[
\frac{\bar{Y} - \bar{X}}{T - \bar{X}} \quad \text{where } T = \text{Maximum Score} = 100
\]

\[
= \frac{62 - 24}{100 - 24} = 0.50
\]

Thus the system appears barely to succeed by the McGuigan criterion.

However the McGuigan criterion is really only applicable to the type of programmed materials where the Post-Test should yield high marks, i.e. the students should show a high degree of mastery of the questions set in the Post-Test. The Post-Test used here contains representative A-level questions and as such are likely to prove difficult for the less able candidates however well they have been taught, or however good the system used by which they have taught themselves; thus it would seem to be impossible for the weaker candidates to achieve mastery (e.g. 90% success) over Post-Test questions when these are A-level type questions designed to discriminate between able and less able candidates (and whose 'facility' is therefore ideally about 0.5). Further, the McGuigan Gain Ratio is likely to be low when the Pre-Knowledge (i.e. Pre-Test) Score is high; only if the actual gain were greater in proportion would the McGuigan Gain Ratio be high. I therefore considered the McGuigan Gain Ratio achieved here to be acceptable; it was certainly high enough
for this feasibility trial to be considered successful in terms of group performance.

(b) Individual Performance

There was considerable variety in the results achieved, with 'raw gains' ranging from 11% to 62%. For example:

Student A knew quite a lot about this work already (Pre-Test: 62) but gained a depth of understanding to a Post-Test score of 81.

Student G remembered very little of the work at the beginning (Pre-Test: 21) but performed extremely well at the end (Post-Test: 83).

Student L remembered almost nothing at the beginning (Pre-Test: 2) but as with the rest of his A-level work he found much improvement to be well beyond his reach (Post-Test: 23).

Student P was the most able student in the group but I observed that he found motivation difficult throughout the year and this trial period was no exception. His Post-Test mark (64) by no means reflected the standard he could have reached had he tried harder; he knew he would get quite a good mark and was not prepared to make the effort to turn this into a very good mark. From my knowledge of this boy I suspected that he would have performed better with the later sections, where the challenge of more difficult work would have provided the necessary spur to greater efforts.

(c) Assistance from A-level Mathematics

The results indicated little correlation between student performance using the system and having a background of A-level Mathematics. The top two gain ratios (0.78, 0.74) were in fact achieved by non-mathematicians but so were the three worst (0.21, 0.34 and 0.41). Only for Student A was the above-mentioned influence of a high Pre-Test score causing a low gain ratio likely to be important.
The end-of-year Physics examination results also showed little effect of mathematical background. The best performance (2nd) was achieved by a 'mathematician' but the two next best (6th and 7th) were not.

From my own experience, these results were unexpected; the great majority of the good physicists I had previously taught had very good mathematical backgrounds and almost invariably they were also taking A-level Mathematics. However the average level of ability of the students in this particular group was rather lower than I had taught previously; one result of the 'comprehensivisation' of the intake into the sixth form at Farnborough where the grammar school became a sixth form college was the 'unstreaming' of the science groups. Thus it was perhaps unrealistic to compare this First Trial group with the high flying groups I had previously taught.

(a) Depth of Understanding

Since the Pre-/Post-Test questions were actually taken from A-level papers, they were a good test of whether the students had understood the subject matter to a depth sufficient for their 'target' examination.

However, the Pre-/Post-Test clearly did not test whether the system would help students remember the subject matter better than 'traditional' teaching methods, i.e. 'retention' was not measured. The following year's 'mock' examinations (before the actual A-levels) would possibly indicate this, but they would range over the whole syllabus, most of which was covered by traditional teaching.

6.33 The Question Sheets

These were answered by the students in their own time, using text books etc., and in consultation with other students if they wished; I therefore decided to mark them in the same way as I had previously marked the group's 'homework'. The questions and answers were then
discussed with the whole group; this was possible, as explained above, because it was insisted that answers to Question Sheets were handed in at the same time.

As with any homework, not too much attention was paid to the grades (A, B, C) awarded to the students for their answers to the Question Sheets. Lots of working together was obviously going on, and it was freely admitted that fathers (and occasionally mothers) were helping when they felt it was necessary; I have always encouraged this provided that the student understands what father has said and that there is no attempt to try to pass off the work as entirely his or her own. I have always found that discussion of homework with the whole group can be most valuable; students really do learn from each other's mistakes, provided that a sensible attitude is adopted. In the case of the Question Sheet discussions, they seemed to be even more appreciated than usual in that they provided a welcome break for students from working on their own, and the opportunity for them to check their progress against that of the others.

6.34 The Practical Sessions

The need for most experiments to have at least two students working together was met very well during this first Guide Sheet by the fact that the group kept roughly together, i.e. whenever a student reached an experimental stage, there was always someone else very close to that stage who could do the experiment with him or her. In fact the variation of pace between the Question Sheets being rarely more than two periods meant that there were some points of congestion and therefore 'queueing' for apparatus. However, students were able to go on to the next section and go back when the experiment became available.

As expected, the students appeared to appreciate the variety of activity introduced when they reached a practical stage; they certainly
went back to their reading afterwards with somewhat greater motivation.

6.35 **Some General Observations**

(a) 'Team' Learning

One preliminary hypothesis was that the 'team spirit' engendered by the working together of a small group of students for two years might be reduced by the 'fragmentation' of the group into fourteen individuals learning independently. There were indeed signs of this at the beginning of the First Trial but any dangers due to it (such as lack of confidence, and concern over one's own progress in relation to the others) were soon seen to be minimised (i) by the Question Sheet discussion periods which I deliberately made very informal, encouraging contributions from as many students as possible. (ii) by allowing quiet conversation and free consultation of each other's work between the members of the group during class time; this usually took place between the students working on one laboratory table, i.e. mostly in pairs. As mentioned earlier, some students found a greater need for this than others, it being particularly noticeable with students M and Q, and D and F.

(b) **Text Book Reading**

Some students took to the large amount of text book reading more readily than others. It was certainly noticeable that some frequently found concentration over a double period very difficult and quickly became bored; I usually encouraged such students to change their activity at intervals, e.g. to try some Question Sheet questions in between note-taking. This seemed to be quite successful.

(c) **Inflexibility**

The comparative inflexibility of the system has already been noted. On several hot afternoons during this hot summer, it would probably have been helpful to have had a complete break from the system, e.g. to tackle a practical project of some sort.
(d) **Staff and Student Absence**

The likely advantage of use of the system when staff or students were absent certainly emerged. For one complete week of the First Trial period, five students were away on a Geography Field Week, but of course the others were able to make unimpeded progress. The absentees soon caught up with extra work when they returned.

(e) **Change of Teacher Role**

The anticipated problems for the teacher involved (i.e. myself), owing to the considerable changes in the role he plays, did emerge but were fairly easy to cope with. There was, of course, considerable motivation for me to overcome these problems since it was my own system we were using, and it is not likely that I would feel frustrated at being 'relegated' to the sidelines with the main learning resource for the student being the text books he was using. Similarly, I had a strong personal interest in overcoming any problems of organisation and administration of the system, i.e. in 'managing' rather than teaching. However, I did experience quite strongly the temptation not to make adequate use of the classroom time made available by the fact that the students were working without any apparent need for assistance; it was very easy to make use of this time in doing things (e.g. school administration) which one should have done at other times such as one's 'free' periods. I found I had to make myself observe the students, discreetly of course, and look out for any difficulties they were experiencing. Also, if the teacher is obviously working **himself** the students are reluctant to come up and ask for help for fear of intruding; it is so important to be **seen** to be 'willingly available' for consultation and periodically to **urge** the students to ask for help when in difficulty. I personally found the change of role very enjoyable; however I have always taken pleasure in all aspects of teaching (large groups, small
groups and the one-to-one 'tutorial' situation) so that it was always likely that I would find little difficulty in the changes involved and would indeed welcome the variety of activity the system afforded.

(f) The Resources Provided

From the small number of queries raised by the students, it appeared that the text books explained the subject matter clearly and with about the right amount of detail. There appeared to be a slight preference for one of the two books, the less 'wordy' one, and this merited further investigation. The balance between quantity of reading material between Question Sheets and length of Question Sheets also appeared to be about right, i.e. the students did not seem to be 'over tested'.

(g) Teacher-Student Relationship

In this short First Trial, it was difficult to assess accurately the value of the system in making for better personal relations between teacher and students. I was certainly able to spend more time talking to individual students but it was difficult to assess how much better one knew them and (possibly more importantly) how much better they knew me.

6.4 Some Suggestions for the Second Trial arising from the First Trial

The Second Trial should test the whole system and should give some indication of how much of the A-level course could effectively be covered by an independent learning system.

The Second Trial should 'focus' on some of the issues raised by the First Trial. Since much of the information produced by the First Trial was a number of my personal impressions of how I felt the system was working, it was important that the Second Trial should concentrate on the feelings and opinions of the students themselves. I decided therefore to draft a Questionnaire for issue to the students at the end of the Second Trial so that their personal impressions of how
effective the course was, whether they enjoyed their work with it, how they felt about their change of role, etc., could be ascertained and some assessment made of the link between effectiveness of the system and personality of the student using it. A record would also be kept of the lesson-by-lesson progress of each student so that the extent to which each one took advantage of the limited opportunity of self-pacing could be more closely examined.
In September 1976 I took up my post as Second Master at Reigate Sixth Form College, so that the Second Trial was held there. The facilities for science teaching were not so good as those at Farnborough: less laboratories, less plentiful and lower quality apparatus, and less adequate laboratory technician assistance. However, it was possible to arrange for the group I was teaching to be in a laboratory for a sufficiently large proportion of Physics time-table time for the system to be workable; further, the apparatus available, though different, was sufficiently adaptable for the purpose. Thus it was decided to go ahead, after obtaining the permission of the Principal and the Head of Science; this was necessary since I was appointed Second Master at Reigate and therefore had no authority within the Science Department itself.

7.1 The Students

The students involved in the Second Trial were of lower average ability than those for the First Trial, judging by their O-level performance. As a result of comprehensive reorganization in the Reigate area, Reigate Grammar School for Boys had just decided to become Independent; thus very few 'grammar school' ability boys enter Reigate Sixth Form College. In terms of general ability therefore, the Second Trial group was also somewhat unbalanced with respect to general abilities of males and females; this can be seen from the analysis of the qualifications of the Second Trial group students on entry in Table I (overleaf). However, in Physics and Mathematics alone, the abilities of the male and female students were very similar; allowing points for O-level grades ($A = 5$ down to $E = 1$) the mean for the males was 7.6 and females 7.3, (two-subject totals).
### Table I

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**Former Schools:**

A: Reigate County School for Girls: 3-stream entry 'grammar' school, gradually phasing out.

B: Redstone Secondary Modern (becoming comprehensive) School for Boys. It ran its own A-level courses prior to the establishment of Reigate College.

C: Dunottar School: Independent Day School for Girls.

D: Court Lodge Secondary Modern School (becoming comprehensive).

E: Albury Manor Secondary Modern School (becoming comprehensive).

F: Woodhatch Secondary Modern School (becoming comprehensive).

G: Royal Alexandra and Albert: Foundation Boarding School.

H: Others - mostly independent schools.
Because the number of students studying A-level Physics at Reigate is much smaller than at Farnborough, there was only one 'traditional' Physics group for the year of the Second Trial. This meant that the composition of the group could not be tested against the Lower Sixth intake as a whole for range of ability, as was the First Trial group. However, the numbers of O-levels with which the trial group entered the sixth form ranged from 2 to 10, clearly a fairly 'comprehensive' intake. The range of grades in O-level Physics and Mathematics with which the group entered the College was also wide-ranging: from C,C (the lowest with which they would be allowed to start A-level courses in Physics) to A,A earned by three (male) students from contributory school 'B'.

It can be seen from Table I that only three students (d, e, n) out of the sixteen of the Second Trial group were not doing A-level Mathematics as well. However, the variety of their O-level Mathematics grades (E, B, C respectively) meant that their performances using the system could provide useful evidence concerning the null result of the First Trial with respect to effects of mathematical background.

Table II (overleaf) shows the correlations between the 'End of Lower Sixth' Examination result and (a) the incoming O-level grades in Physics and Mathematics, (b) final A-level grade earned by the Second Trial students in 1978. The correlations being +0.65 and +0.75 (significant at the 1% and 0.1% levels respectively) suggests that the 'End of the Lower Sixth' Examination grade is a suitable measure of the ability of the students when considering the effect of ability on performance using the system. (See Section 7.32).
Table II

Correlation between O-level Grades in Physics/Mathematics on entry, End of First Year Examination Result and eventual A-level Grade

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<th>Student</th>
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Note: Joint Physics/Mathematics Point Allowance

\[ A = 5, \ B = 4, \ C = 3, \ D = 2, \ E = 1 \text{ (per subject)} \]

Spearman's Rank Correlation Coefficient

\[ r_s = 1 - \frac{6 \sum D^2}{n (n^2 - 1)} \]

Correlation between End-of-Year Examination Rankings and:

(a) Physics/Mathematics Grades

\[ \Sigma D^2 = 240.75 \]

\[ r_s = 1 - \frac{6 \sum D^2}{16 \times 255} = +0.65 \]

(b) Eventual A-level Grades

\[ \Sigma D^2 = 166.50 \]

\[ r_s = \frac{6 \times 166.5}{16 \times 255} = +0.75 \]
7.2 The Second Trial Time-table

The Second Trial was held during the Spring and Summer Terms of 1977. It was hoped to complete all three Guide Sheets of the system during the Spring Term if possible; however there were five weeks at the start of the Summer Term for over-run if necessary, before the real deadline of the Summer Half-Term holiday and the 'End-of-Year' examinations immediately following.

The daily time-table at Reigate consisted of eight 35 minute periods, four before lunch and four afterwards. Physics A-level courses were allotted four double periods per week, two in the morning, two in the afternoon:

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This arrangement, with its shorter, but more frequent, sessions was much more suitable for independent learning than the Farnborough one, with its two over-long treble periods, had been.

In the first period of the Spring Term the system was outlined to the group. As for the First Trial, the students were told that I would be using the results of their use of the system as part of a research
project and their co-operation in providing data was requested. This was even more important for the Second Trial because I would be asking them to fill in a Questionnaire and attend interviews at the end of the trial period.

7.3 Observations on the Second Trial

7.3.1 Rate of Progress

In order that the variation in pace of working achieved by students could be more closely investigated, they were all fairly frequently asked what stage they had individually reached. The results are shown in Tables III (pages 155 - 157); they show that:

(i) in spite of the restrictive influence of being told that they would all be handing in the Question Sheet answers at the same times so that the tendency was for the faster ones to wait for the others to catch them up at those points (again observed), nevertheless variations of several stages were recorded on a number of occasions.

(ii) At several Question Sheet stages, the faster students had gone a long way ahead. Clearly in a completely free self-pacing operation the total variation in time taken to cover the whole system would have been very wide indeed. For example, a student p was extremely hard-working and, given his head, would certainly have covered the course much more quickly than anyone else; further, his speed did not mean superficiality of coverage - he was also by far the most thorough of the students. In contrast, student d was not only very slow, but also lacking in thoroughness; it is likely that he would have taken at least a month longer to cover the whole course, and would have reached a more superficial level of understanding, compared with student p. Student m was discovered early in the course to be mildly dyslexic; this meant that he was bound to be very slow in covering the work, as shown very clearly by the chart for Guide Sheet 3. Lest it be thought that it was extremely
ill judged, even unprofessional, to subject student m to a learning system in which reading with understanding is so important a feature, it should be pointed out that I consulted him about it before we started the Second Trial, underlining the likely difficulties for him personally. With considerable maturity of outlook, he responded with a keenness to take part, referring to the point made in my introductory talk to the group that success or otherwise in using the system would be a useful pointer as to how they would cope with the independent learning situation in higher education. Thus student m was keen to test his ability to cope now, rather than later; he appreciated, very commendably, that he could have been 'spoon-fed' with an A-level course in which very little reading was necessary but the reasonable A-level grade he might then have achieved would have been almost useless as an indicator as to whether or not he should pursue the subject in higher education. (Student m's father is a lecturer in Physics at a polytechnic and was keen that his son should take his studies further; the student himself was not at all sure of this.)

Another point made clear by the self-pacing charts is that by the latter stages of the first Guide Sheet and then for the rest of the system, the students were quite prepared to carry on to the stages beyond a Question Sheet without waiting for their answers to those questions to be discussed. Thus the group's progress was more 'fluid' without halts and restarts at each Question Sheet stage. This was perhaps an indication of a reasonably high level of motivation, in that, after the initial stages, the students did not take much opportunity of stopping for rests.
GUIDE SHEET 2  STUDENTS' SELF-RACING CHART

Stage

Student

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

O = Question Sheets

H = 28th Feb.

J = 3rd March

K = 10th March

L = 21st March

M = 28th March

N = 5th April
Table III (c)

GUIDE SHEET 2. STUDENT SELF-SCORING CHART

Stage

Student

P = 26th April
Q = 5th May
R = 16th May
S = 2nd May
T = 30th May
U = 16th June
V = 16th June

Question Sheets
(b) **The group as a whole**

The times taken for the group to cover the work of the three Guide Sheets were as follows:

- **First Guide Sheet**: 7 working weeks
- **Second Guide Sheet**: 6 working weeks
- **Third Guide Sheet**: 6 working weeks

thus, as in the First Trial, the group as a whole progressed at a slower speed than I had expected. This was particularly true for the First Guide Sheet; since this was largely revision of O-level concepts, it should have been possible to cover this more quickly. However, it is possible that allowing the students to work their own pace exposed their need for more thorough revision of the O-level material than I would have given them had I been teaching the course in the traditional way; this is discussed more fully in the final evaluation.

It is certainly true that having revised the necessary basic concepts, the Second and Third Guide Sheets were covered at approximately the rate I would have expected, bearing in mind the level of difficulty of the concepts involved. The students seemed to get into a rhythm and the 'fluidity' mentioned in the previous section contributed to the faster pace. Compared with the First Trial, there was not the debilitating hot weather that had dragged back the working speed, nor were there the afternoon treble periods with their inefficient 'work per time' ratio. Also, the College's End-of-Year examinations did not interfere with the running of the Second Trial as they had at Farnborough. Conditions were therefore much more favourable for establishing an efficient rate of working and maintaining it.

7.32 **The Students' Course Marks**

The marks for the Pre- and Post-Tests for the three Guide Sheets are
shown in Tables IV - VI overleaf. Also shown are the Group McGuigan Gain Ratios for the three Pre-/Post-Tests, the individual McGuigan Ratios and their ranking, and the ranking of the students in the End-of-Year College Examination in Physics.
Table IV
Second Trial Guide Sheet I Data

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre-Test (X)</th>
<th>Post-Test (Y)</th>
<th>Raw Gain (Y-X)</th>
<th>Gain Ratio</th>
<th>Gain Ratio Ranking</th>
<th>End-of-Year Examination Ranking</th>
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$\bar{X} = 21.4\%$; $\bar{Y} = 68.3\%$

Mean Raw Gain = 46.9%
McGuigan Gain Ratio for Group = 0.59

Spearman's Rank Correlation between Pre-/Post-Test I Gain Ratios and End-of-Year Examination Rankings:

\[ \Sigma D^2 = 384.50 \]

\[ r_s = 1 - \frac{6 \times 384.5}{16 \times 255} = 0.44 \]
Table V

Second Trial Guide Sheet II Data

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<th>Post-Test (Y)</th>
<th>Raw Gain (Y-X)</th>
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\[
\bar{X} = 10.3\%; \quad \bar{Y} = 63.9\%
\]

Mean Raw Gain = 53.6%

McGuigan Gain Ratio for Group = 0.60

Spearman's Rank Correlation between Pre-/Post-Test II Gain Ratios and End-of-Year Examination Rankings:

\[
\sum D^2 = 284.00
\]

\[
r_s = 1 - \frac{6 \times 284}{16 \times 255} = +0.58
\]
### Table VI

**Second Trial Guide Sheet III Data**

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<th>Post-Test (Y)</th>
<th>Raw Gain (Y-X)</th>
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</table>

\[ \bar{X} = 2.1\%; \quad \bar{Y} = 73.6\% \]

Mean Raw Gain = 71.5%

McGuigan Gain Ratio for Group = 0.73

Spearman's Rank Correlation between Pre-/Post-Test III Gain Ratios and End-of-Year Examination Rankings:

\[ \sum D^2 = 275.00 \]

\[ r_s = 1 - \frac{6 \times 275}{16 \times 255} = +0.59 \]
(a) **Group Performance**

The three Group McGuigan Gain Ratios were 0.59, 0.60 and 0.73 respectively. This is in accord with the point made in the First Trial analysis, that the Gain Ratio should increase with decreasing pre-knowledge, i.e. Pre-Test score. Also the McGuigan Criterion (Gain Ratio to be greater than 0.5) was rather more comfortably met by these scores than by that for the First Trial.

The calculations of the Spearman-Rank Correlation coefficients between the students' End-of-Year Examination positions and their Gain Ratio rankings for each of the Pre-/Post-Tests are also shown in Tables IV - VI; the values obtained (+0.44, +0.58 and +0.59), significant at the 8%, 2% and 2% level respectively, indicate reasonable comparability between the independent learning provided by the system, and the traditional teaching and learning of the rest of the Lower Sixth syllabus. The fact that I allowed the students to do the Pre- and Post-Tests using their notes and in their own time probably explains the correlations being lower than those between 'End-of-Year Examinations' and eventual 'A-level' performance rankings (0.75 - see Table II on Page 151). Certainly the need actually to learn the work for the End-of-Year Examination resulted in the comparatively poor performance of some students compared with others who were able to learn the work thoroughly when required; the latter performed far better in the End-of-Year Examination (and eventually the actual A-level examination) than their Post-Test results would have forecasted.

(b) **Individual Performance**

As in the First Trial, there was considerable variety in the results achieved by individual students, with raw gains ranging from 22% to 90% and gain ratios from 0.25 to 0.91. However, they fall into the following
approximate groupings:

(i) **Students a, c, h** were of dubious A-level ability on entry (O-level grades C in Physics) and this was confirmed by their performance in both the 'End-of-Year' and actual A-level Examinations. They were all quite conscientious students, but the A-level standard questions in the Post-Tests often left them in considerable difficulty.

(ii) **Students b, g, n, r** These students were all extremely conscientious; however, they were of borderline A-level ability and frequently found the new concepts introduced during the course very difficult to grasp to any depth of understanding. They were, however, prepared to revise the work thoroughly before an examination and they performed creditably in both 'End-of-Year' and A-level examinations.

(iii) **Students j, k** In contrast to the previous group, these students possessed good A-level ability and were able to answer quite searching questions in class and in Post-Tests. However, their work totally lacked determination so that their initial advantage in understanding of new concepts seemed to have been squandered. Their A-level results were as a result well below what they might have achieved. For these students, therefore, the system did not work too well; in traditional class teaching situations, I found it was possible to stimulate them to greater effort by, for example, aiming the more difficult oral questions in their direction.

(iv) **Students l, q** These students had every incentive to achieve high grades as they hoped to enter the dentistry and medical profession respectively. However, although quite able their level of effort varied, and their achievement was not as great as could have been expected. Student l was rather precocious and did only as much as she thought she should do. Student q had attended schools in several
countries as her father is in the oil industry and this could explain her lack of self-confidence and tendency to give up whenever things became difficult.

(v) **Students e, f, p** Soon after the start of the course, these students emerged as the three most likely to produce the best quality of work. They were very conscientious and had the ability to understand and apply the more difficult concepts at this level. Indeed on the evidence of her work in the Lower Sixth, I was hoping that student f would be worth an "Oxbridge" attempt in her third year, especially as she was much younger than the others in the year group, and also was that comparatively rare phenomenon - an aspiring female engineer. Her performance during the independent learning period was good but not, however, outstanding; unfortunately, her work then tailed off in quality in the Upper Sixth and her eventual A-level grade was a disappointing C.

Student p produced copious notes on the text books and voluminously detailed answers to questions and accounts of experiments. His major problem in fact was an inability to select with judgement; he was afraid to leave anything out so he put everything in, the result being that any piece of work from him was of at least three times the quantity of anyone else's. It was likely therefore that an independent learning system would be of considerable value to him in developing discrimination and self-discipline before they became really essential in higher education. The system was in the event successful in a limited way in this respect; student p did learn to be a little more selective in his writing during the course.

**Student d and Student m** The remaining students could not be grouped with anybody else. Student d was very much an individual,
having a passionate interest in Natural History and little else; thus his note-writing was often superficial and his shallow understanding showed up in the quality of his Post-Test answers, and in his examination marks. In the Upper Sixth, he was frequently absent and gave himself no chance at all of achieving a pass grade at A-level.

Student m, as mentioned earlier, was mildly dyslexic and since this was unfortunately coupled with very limited ability in the subject, he made gradually smaller and slower progress until in the Upper Sixth he effectively gave up hope of success. The limited value for him of independent learning using textbooks as the chief resource has already been mentioned.

(c) Assistance from A-level Mathematics

Somewhat in contrast to the results of the First Trial, the Second Trial reaffirmed the supportive value of reading A-level Mathematics for A-level Physicists. Although nothing can be deduced from the performance of student d, as explained above, it was clear that despite their general ability the quality of the work of students e and n was much limited by their lack of post-O-level Mathematics.

7.33 The Question Sheets

As in the First Trial, the students' Question Sheet answers were done as homework and marked as such. The students once again seemed to appreciate the break from working on their own which discussion of their Question Sheet answers afforded, and the opportunity to check their progress at first hand against that of the others.

7.34 The Practical Sessions

The Second Trial confirmed the impression gained from the First Trial that there are no insuperable problems owing to practical experiments having to be done at various stages of the course. Once
again the students seemed to enjoy the variety thereby introduced and they were quite happy to go on to later reading stages and come back to an experiment when it became available. This was necessary a little more often than for the First Trial because of the slightly greater number of students involved.

7.35 General Observations

(a) 'Team' Learning

As in the First Trial, students were freely allowed to compare notes and converse quietly, so that as much learning from each other as possible would be encouraged. Again some students (e.g. e, j, s, p) found more need for this motivation and bolstering of self-confidence than others (e.g. b, d, f, h) who hardly conversed at all; however, they all seemed to appreciate the discussion periods after Question Sheets which I again made as informal as possible.

(b) Staff/Student Absence

The longer period of this trial underlined even more than for the first one the advantages of the system when staff or student are absent, or frequently late. The latter was a particular problem at Reigate; many students travelled considerable distances and bus services were very unreliable.

(c) The Teacher's Change of Role

The Second Trial gave greater opportunity for any worries on my part concerning my different role as teacher-manager to emerge. As mentioned earlier, I enjoy all aspects of teaching, not least the chalk-and-talk expositions of a subject, and I might have missed this had there not been opportunity to 'indulge' in it in the discussions about the Question Sheet answers. I certainly enjoyed the opportunity for more tutorial teaching, i.e. to one or two students only; quite often
difficulties became apparent which I could then enlarge on to the whole group. Such a 'feed-back' situation is clearly potentially of considerable value.

However, I did experience, as in the First Trial (Section 6.35), the temptation not to make adequate use of the classroom time made available by the students working without any apparent need for assistance. Having an even greater administrative load in my new position, it would have been even easier to slip into letting the students get on by themselves in most periods. I therefore had to make an even greater effort not to let this happen this time, but I was, of course, helped by my experience of the First Trial; it had shown that students do often need help and will come and ask for it if the teacher is seen to be willingly available.

(d) Textbook Reading

As in the First Trial, it was noticeable that the students varied in their ability to read at length and with concentration during the class periods. Frequent changes of activity were again recommended to those who found problems here and this seemed to be quite successful. However, I decided to investigate the students' own feelings about such difficulties by Questionnaire questions; they would also be asked about any preferences they had concerning the textbooks provided. Their answers are discussed in the next section.

7.4 The Questionnaire

This was devised in order to test the truth of my observations concerning the reactions of the students themselves to the learning system; thus the 'attitude' of each student concerning various aspects of the learning system and their responses to them could be determined. Each student's answers were then used to draw up a 'student attitude profile'. From all of the student attitude profiles a group attitude
profile was then drawn up; it is obtained by simply adding up the
group's responses to each question at each point of a five-point scale.
A copy of the Questionnaire, a sample 'student attitude profile', and
a copy of the 'group attitude profile' will be found in the Appendix.

The Questionnaire was followed up by an interview of each
candidate at which his or her answers were frankly discussed; I felt
that by then I knew the candidates well enough, and they knew me well
even enough, to be sure that this frankness was genuine. I was, of course,
able to assure them that the answers would be completely confidential
and that in any discussion or report on their views, they would not be
referred to by name. It was also important to reassure them that any
criticism by them would not affect any later College assessment of them
by me; in fact I made it clear that frank criticism would be very
welcome.

7.41 Question-by-question analysis

Question 1 How much of the 2 years of the A-level course do you think
ought to be spent in this way?

ALL / 5 TERMS / 4 TERMS / 3 TERMS / 2 TERMS / 1-TERM / NON-

A large majority (88%) were strongly in favour of part of the course being
covered by an independent learning system; the average number of terms
suggested (out of 6) was 1.5, with a range from none (students m and p)
to four (student b).

Question 2 You may have several reasons for your answer to question 1.

In particular:

(a) Do you think this approach has increased your ability
to learn by yourself?

A LOT / A LITTLE / NOT AT ALL

A large majority (94%) thought that the system had increased their ability
to learn by themselves to some extent.
(b) Do you think that you learned this part of the syllabus:

MUCH BETTER/ BETTER/ NO BETTER/ WORSE/ MUCH WORSE

than if a 'traditional' teaching method ('chalk and talk') had been used?

A small majority (63%) thought that they had covered this part of the syllabus better than by a traditional method. Student 1 commented that she found it easy to revise later from her own notes and she felt she understood the work well in spite of her frequent absences through illness (a previously mentioned spin-off advantage). Student a, however, felt that there was a tendency not to write good notes but just to work to cover the Question Sheet questions; her comment was 'it sorts out the workers from the shirkers'. Student e agreed that it was all too easy to just copy blindly from the book; however, student b expressed appreciation of opportunity to go back over work one did not understand on a first reading.

(c) Did you enjoy this 'guided self-teaching' method of working

MUCH MORE / MORE / NO MORE / LESS / MUCH LESS

than being taught in a traditional manner?

A small majority felt that they had enjoyed this method of working more than a traditional method, although there was a wider spread of answers to this question than for any other question. Student j suggested that occasional breaks from the system would increase overall enjoyment.

(d) Have you any other reasons for your answer to question 1?

Please specify.

Student f felt that the method was good for certain topics provided the sections were discussed adequately at the end. Students g and h emphasised the value of experiencing the method for future students in
higher education. However, student p justified his answer of 'none' by admitting his inability to precis notes from a book so that he wasted lots of time simply rewriting book sections. Indirectly he was surely giving good reason for having to experience the system at sixth form level. Student q appreciated the need to acquire self-confidence in learning by oneself.

**Question 3** How much was each of the following features of your ability to learn by yourself improved by this course?

(a) to read a book with concentration:

A GREAT DEAL / A LITTLE / NOT AT ALL

75% of the students thought that using the system had increased their ability to read a book with concentration a little. Even student p felt that the use of the system had helped him in this.

(b) to read with discrimination, i.e. to pick out the important points.

A GREAT DEAL / A LITTLE / NOT AT ALL

A large majority (94%) felt that their ability to read with discrimination had been improved at least a little. The students who thought this most strongly were those whose previous schools (A, B and C in particular) had 'spoon-fed' its students in its O-level teaching.

(c) to be able to read a book for longer periods than previously;

A GREAT DEAL / A LITTLE / NOT AT ALL

Not many students (19%) thought that their ability to read a book for long periods had been much improved.

(d) to organise your work more efficiently than previously.

A GREAT DEAL / A LITTLE / NOT AT ALL

A large majority (70%) felt that their ability to organise their work more efficiently had been improved, with half of the students answering
a great deal'. The comment to 3b also applies here.

**Question 4.** This question lists some of the reasons which could be given for a student being able to learn new work better by this method than by a traditional teaching method. Which of them (if any) apply to you?

(a) You have always found learning from books easier than by listening to someone talking;

YES / NO

A third of the students felt that they learned better from books than by listening to someone talking. A number were not sure, as might be expected.

(b) the textbooks you have been using put the ideas more clearly than your present teacher (be frank please!);

YES / NO

The students were roughly equally divided as to whether the textbooks used for the system put the ideas more clearly than their 'present teacher', i.e. myself. I had asked for special frankness in answering this question! Student c candidly admitted that he found difficulty listening to some teachers for any length of time! Student f suggested that a combination of textbook and teacher was most helpful.

(c) You were able to work at your own pace to some extent;

YES / NO

A large majority (81%) thought that self-pacing was a major reason for students being able to learn new work better through independent learning. Their views on self-pacing were clarified by their answers to question 7 later.
(d) I was able to give you individual help rather more easily with this method (and also when you needed it);

**YES / NO**

Half of the students thought that being able to have individual help when required was a useful benefit of independent learning. However, student b asserted that many students are reluctant to ask for help; this was probably a cri-de-coeur since both he and his close friend, student h, have shy personalities. Student d admitted that he did not ask for help because he needed it too often - a paradoxical new point. Student p continued his campaign for traditional teaching by asserting that if the teacher gave a good exposition of any topic, individual help wouldn't be needed anyway.

(e) having to think about the subject matter and summarise it yourself helped you to understand it and memorise it;

**YES / NO**

A large majority (75%) thought that it was helpful to understand and memorise new work to have to think about the subject matter and summarise it for oneself.

(f) any other reason? Please specify if you can.

Several students commented on the value of being able to adopt one's own 'style' of learning. Thus student c found it best to write things down twice and read them several times; student h found it invaluable to be able to concentrate on the things he himself found difficult. Student l liked being able to work on her own and at her own pace, and being able to work harder at home than in class because she could concentrate better there.

**Question 5** On the other hand, the following are reasons which might be given for *not* having learned as well by this method as
by a traditional approach. Which, if any, apply to you?

(a) You have always found learning from books more difficult than by listening to someone talking;

YES / NO

This question contained the same subject questions as Question 4, but set in the contrary sense, with a few variations. This served two purposes: i) as a check of the answers to Question 4; ii) to allow a student to express a strong opinion contrary to the thinking behind the Question 4 sub-questions. The answers turned out very similar to Question 4 (a) but one or two unintentional contradictions were found here and sorted out at subsequent interviews.

(b) the textbooks you have been using did not put the ideas over as clearly as your present teacher (be frank, please!);

YES / NO

The answers were very similar to Question 4 (b).

(c) You don't like being able to work at your own pace; you prefer to go at the same pace as the rest of the class;

YES / NO

Student d took the opportunity here to emphasise that he had not been able to work at his own pace. He had continually had to rush the reading just before the Question Sheets in order to keep pace with the others.

(d) You found doing so much reading boring so that it was often difficult to make yourself work;

YES / NO

This was a different question. Roughly half of the students admitted to finding it difficult sometimes to make themselves work, because of
boredom with the reading. These answers should clearly be the cause for concern. Possible remedies are discussed in the next chapter.

(e) some other reason? Please specify if you can.

Student a made the point that it is often difficult to precis textbooks such as Nelkon, so that one writes excessively copious notes. She suggested that many students need a lot of help with note-writing. She also emphasised that material which is merely copied and not really understood on reading is not retained for any length of time. Student e echoed this; she realised her lack of understanding of parts of the syllabus when revising for the 'Mock A-level' examinations a term later. Student e felt that her lack of self-confidence was not helped by worry over whether her notes were adequate. Student k thought it was difficult to link the different topics together and to see a pattern in their development; a teacher can of course provide such links if teaching traditionally.

Question 6 It would be helpful to have your comments on the materials used in this system. Please comment on them below, using words such as "could be (much?) improved", "satisfactory", "very clear", etc. Specify particular ones if you wish – this will be most useful.

(a) Reading references

Most students (63%) found the reading references clear and satisfactory. Most students found the concisely-written 'Nelkon' more helpful than 'Thorning' which provides much more information and therefore needs selection to be made.

(b) Information sheets

Most students (63%) found the information sheets useful, with a couple
liking them very much. They were felt to fill in some gaps left by both of the recommended textbooks.

(c) **Worksheets**

Most students (again 63%) found the experiment worksheets clear and useful. The experiments were certainly done well and written up clearly.

(d) **Question Sheets**

Nearly all of the students found the Question Sheets useful. Students k and l said that they helped a great deal to show up inadequacies in reading and note-taking, and to indicate the standard of A-level questions and how to tackle them. The main criticisms were: 'too long' (student g) and 'should be done under examination conditions' (students f and n).

**Question 7** (a) This learning system has allowed you to work at your own pace (apart from meeting Question Sheet deadlines).

Do you approve of such 'self-pacing'?

YES / NOT SURE / NO

Please explain your answer.

The advantages and disadvantages of self-pacing mentioned earlier were borne out by the students' own comments, the 'Yes', 'Not sure' and 'No' answers being roughly equally weighted. Thus they mentioned:

'I prefer to have to meet a deadline';

'I tend to get lazy at times without pushing';

'I found I worked far harder when allowed to go at my own pace';

'one might not know how slowly one is going compared with the others, and not finish the syllabus';

'one might not know one's own best speed' (very perceptive of student h!);

'it allows you to concentrate on the parts you really need'.
(b) The Question Sheet deadlines did impose an overall speed of working on the group. Comment on this speed as far as you were concerned.

MUCH TOO FAST / A LITTLE TOO FAST / JUST RIGHT /

A LITTLE TOO SLOW / MUCH TOO SLOW

A spread of answers was found here but the biggest group (38%) was the one which felt that the speed was 'just right'. Only two students felt that the speed was very unsuitable for them: (i) student g found it 'much too fast' so that he felt the pressure of having to catch up fairly frequently; the main reason was his inability to be sufficiently selective when writing notes from the books. (ii) Student q found it 'much too slow', but her notes were rather carelessly written, and her thinking about the ideas involved rather shallow. The result was that her subsequent examination performance was less good than it might have been.

Thus it could be argued that the speed wasn't badly chosen but the fact that these two students found it a 'mismatch' indicated that there was something amiss with their approach to the use of the system. This is discussed in the next chapter.

Question 8 The discussions after the return of your answers to the Question Sheets were interludes in your self-teaching during which you learned from your fellow-students and from my comments. How useful did you find these discussions?

VERY USEFUL / QUITE USEFUL / NOT MUCH USE

Please explain why.

Nearly all of the students felt that the Question Sheet discussions were useful, their reasons justifying my aims in including them. They were
thought to clarify difficult points in previous work and to help link
the various subject areas, apart from the obvious value in showing how
A-level questions should be answered.

7.5 Reflections on the Second Trial

As indicated at the end of Chapter 6, the Second Trial was designed
to focus on some of the issues raised by the First Trial and to
concentrate on the effectiveness of the system from the students' point
of view. The data concerning the learning achieved by the Second Trial
students, both as a group and individually, and the more general
observations concerning the advantages and disadvantages of the learning
system per se, are discussed in the context of the whole investigation
in the next chapter. However, the following points might usefully be
noted here:

(a) Frankness on the part of the students when replying to the
Questionnaire was quite apparent; thus their answers were likely to
have considerable reliability and validity (Costin et al., 1971).

(b) Personality was seen to be an important factor governing the
degree of success achieved by an individual student with the system.

(c) Students' previous school backgrounds were also seen to be
important, particularly with respect to their attitudes to having to
work for long periods on their own, e.g., previously 'spoon-fed' students
approached this mode of learning with apprehension but were among the
most appreciative afterwards.

(d) It is suggested in Section 4.4 that at the end of an
'illuminative' investigation, not only the student but the teacher
and the readers of the report should know in considerable detail what
it is like to have taken part in it. The generous response by the
students to my request for full and frank answers to the Questionnaire
certainly gave me, as the 'teacher/manager' considerable insight as to
what it felt like to be at the 'receiving end' of the learning system.
CHAPTER 8

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

As explained in the Introduction, circumstances prevailing at the time of the final preparations of this Investigation meant that the learning system devised was much less ambitious than had been envisaged previously. However, as also explained, it was decided to face up to the limitations imposed and turn the investigation into one where such limitations are an every-day reality, i.e. one where the teacher and pupils involved were working under the normal financial and limited-time constraints in a typical learning situation with no special privileges. The results of such an investigation, it was hoped, would therefore be of interest to the many other teachers working in similar every-day circumstances.

In this Chapter, after collating and discussing the results of the two Trials, I shall look briefly at improvements I would now make in the investigation with hindsight, and speculate on what could be done at another time and in different circumstances.

8.1 Independence or Individualization?

As discussed at some length in Chapter 1, any system of instruction and learning can be at any point on the two-dimensional 'independence-individualization' continuum. The major change in design of the system used in this investigation, which was forced upon it by the circumstances mentioned above, was a considerable swing from individualization to independence. In the event, the system gave the students the experience of working independently of the teacher for several lessons at a time and for about three months overall, so that it has been possible to investigate the presence or otherwise of the anticipated advantages and disadvantages of independent learning, both direct and indirect, as outlined in
Sections 2.21 and 2.22. The main individualization remaining was that of 'breaking the lockstep' (Section 2.142) by allowing self-pacing to a certain degree; the consequences of this have been examined from both the students' and teacher's point of view and are discussed below.

8.2 Rate of Progress

Since the students involved were an A-level examination group, it was important that they should be covering the syllabus at a rate comparable with that achieved by a group being taught in a conventional manner. Therefore, as explained in Section 5.3, I decided to impose some restraint on the degree of self-pacing which would otherwise have been possible; as a result, 10 - 14 days became the length of self-pacing 'runs'. Within these periods, the extent of self-pacing possible was actually quite considerable; a student could work very slowly indeed if he wished, but would then need to make up the lost time at home or in private study.

(a) Individual pacing

The First Trial indicated that students might not take full advantage of even the limited degree of self-pacing allowed them (Section 6.31). However, it was realised that this levelling-out of pace was probably the result of the particular personalities involved, the able students tending to be lazy, and the less-able students being prepared to catch up by hard work.

The Second Trial showed a greater individual variation of pace, with the brighter students capitalising on their ability and tending to move ahead in spurts. It appeared that large gaps could have opened up in a free self-pacing situation.

(b) Group pacing

The First Trial produced a worryingly slow group speed, largely because the group was paced externally at about the speed of the faster
students, and these as explained above were making fairly slow progress. Also, as explained in Section 6.31 (b), there were extenuating circumstances. Nevertheless, the Second Trial also produced a slower group speed than hoped for, particularly for the initial basic revision section which should have been covered quite quickly. However, the probable explanation is that the opportunity to work slowly and thoroughly did in fact expose weaknesses in students' understanding of the basic material which they now had the time to concentrate on and make clear to themselves.

The students' own opinions on self-pacing were interestingly varied (Question 7 (a) of the Questionnaire, Page 176). Those not in favour clearly appreciated the fact that their own chosen speed could easily be too slow or too fast for their own good; the majority felt that the imposed overall speed was about right (Question 7 (b), Page 177). This was very important from the point of view of morale of the students; doing well in their examinations is a top priority for most A-level students and confidence is quickly lost if it is felt that progress is too slow for the syllabus to be covered. Students who want to press-ahead should certainly be allowed to do so; the flexibility of pacing vis-à-vis the Question Sheet deadlines observed in Guide Sheets 2 and 3 of the Second Trial was therefore much to be encouraged.

8.3 Learning Efficiency

Whatever the 'spin-off' advantages of adopting a particular learning system for an examination course, they would pale into insignificance if the learning were inefficient, so that the examination results were less good than would be achieved by another method. For this investigation there were three measures of learning efficiency available:
(a) Pre- and Post-Tests
(b) Question Sheets
(c) College and Public Examination results.

8.31 Pre- and Post-Test Data

The McGuigan Gain Ratio (M.G.R.) was used to estimate the success of the system, with 0.50 suggested as the lowest acceptable value. By this criterion the First Trial barely succeeded (M.G.R. = 0.30) but the Second Trial gave progressively higher values (0.59, 0.60, 0.73) for the three Guide Sheets. As discussed in Section 6.32 (a), I suggest that these are satisfactory figures for one important reason, viz., the questions used for the Pre-/Post-Tests were previous A-level examination questions. They were chosen intentionally so that the students could be given practice in tackling questions at that level. However, such questions are of a difficulty which is intended to discriminate between high and low ability students who have completed the course; thus weak students will always find difficulty with average-standard questions, and this shows up in the M.G.R. values.

Another reason for variation in M.G.R., as also explained in Section 6.32 (a), is the level of pre-knowledge; the lower this is (as for Guide Sheets 2 and 3) the higher is likely to be the M.G.R.

Individually, the Gain Ratio variation was from 0.23 to 0.78 for the First Trial, and 0.25 to 0.91 for the Second. In Sections 6.32 (b) and 7.32 (b) it is made clear that this variation was the result of considerable 'individual differences', not only in the students' abilities (Sections 6.1 and 7.1) but also their personalities, attitudes to work, career aspirations, etc. Only if the system had been much more individualized would one have expected a considerable levelling-up of the Test scores as the weaker students' problems were overcome. (The range would
diminish because there would be much less scope for improvement of the higher scores).

8.32 Question Sheets

In traditional A-level Physics teaching, teachers tend to use questions on the work currently being studied as 'homework', and this is often the only 'independent' learning the student experiences. In this independent learning system under investigation, there was not really any need to set questions for 'homework'; all I had to do was to instruct the group to carry on at home with the reading indicated in the Guide Sheet for the time normally required for 'homework'—say four hours per week for each A-level subject.

However the Question Sheets provided in my system did serve the following functions:

(a) as practice in writing essays and solving problems directly on the reading just done;

(b) as an on-going check for the students that they were understanding their reading. This was most important morale-boosting and provided the motivation to approach the next piece of reading with enthusiasm. These points were borne out by the answers to Question 6 (d) of the Questionnaire.

(c) as an on-going check for the teacher that the students were understanding the reading. Of course, as with traditional homework, these questions were being done with the help of other students, parents, etc., and this was to be encouraged; I have always taken the line that help from any source is very welcome. However, this does mean that marks or grades awarded for 'homework' are not very meaningful as assessments; the only assessments as to progress, ability and likely future performance were provided by the Pre-/Post-Tests which I
insisted should be done without any assistance whatsoever.

(d) as providing points for discussion when their answers were returned. Without these, the teacher would have to ask for suggestions as to what the students wanted to discuss, i.e. the parts of the reading they felt they did not understand. Their answers to the Question Sheets however usually made their difficulties only too clear.

(e) as convenient 'focal' points which it could be insisted the whole group could reach at the same time; thus the degree of self-pacing could be easily controlled.

As indicated in Sections 6.33 and 7.33, the students seemed to appreciate the break from working on their own which discussion of the Question Sheet answers afforded, and the opportunity to check their progress at first hand against that of the others. This was borne out by their answers to Question 8 of the Questionnaire (Section 7.41).

8.33 End-of-Year Examination Results

A useful measure of efficiency of the learning system is a comparison between the Pre-/Post-Test results and the Trial students' performance in the College End-of-Year Physics Examination. Since the latter was done under full Public Examination conditions, good correlation between results in that examination and in the Post-Tests would be a good indication of success of the system as a preparation for the actual Advanced Level examination a year later; thus, for example, the ability of the system to help students actually to memorise the work would be assessed. However, it should be remembered that the system only covered part of the syllabus tested by the End-of-Year examination; thus there was little point in determining the correlation for the First Trial, during which only one eighth of the End-of-Year examination syllabus was covered. For the Second Trial however it was worth determining and, as shown in Section 7.32 (a), was significant on average at the 5% level.
Thus the system was shown to correlate well with traditional teaching and learning for examination purposes.

Note: the correlation between the Pre-/Post-Test results and the actual A-level grades eventually obtained would be of interest but of little significance because the independent learning system only covered about a fifth of the A-level syllabus. (The First Trial students covered only about one fifteenth with the system). However, the End-of-Year examination was quite a good predictor of eventual A-level performance, as shown in Section 7.1 (correlation + 0.75 for the Second Trial students, significance 0.1%).

8.34 Features of the Learning System which affected Learning Efficiency

In Section 2.11 are outlined the factors which determine the learning which is achieved in any situation. However, in the same Section, the point is made that learning is an individual matter, determined by what the individual does and not by what the material does or what the teacher does, (Gagne 1971). Hence the simplification used by school teachers, when writing school reports, of reducing the factors to two, viz., 'ability' and 'effort', and the never-ending attempts by teachers to persuade their pupils to capitalize on their abilities by making the maximum effort. Similarly the design of the learning system under investigation reflected this concern for motivation of the Trial students so that maximum use could be made of ability and previous knowledge and highest possible learning efficiency achieved.

The key motivating features of the learning system are listed below, together with an indication of the amount of motivation achieved and hence the contribution they make to learning efficiency:

(a) Question Sheets: the motivational effect of these has already
been mentioned in Section 8.32 (b) above.

(b) Discussion Periods: the motivational effect of these has also been mentioned above in Section 8.32.

(c) Practical Sessions: apart from the essential practical experience which these sessions afforded, they were motivational in a similar way to the Discussion Periods in that they provided variety, a break from textbook reading when one could relax a little and chat with other students.

(d) Opportunity for Individual Assistance: whenever the students were working on their texts, the intention was that I should be free for consultation by any of them, either individually or in pairs if they were working together, as several tended to do. When their difficulties had been (hopefully) solved, it would be expected that they would resume work with greater confidence and therefore motivation. This happened quite often in the latter part of the Second Trial and quite often the difficulties then became apparent which I could enlarge on to the whole group (7.35 (c)). However, the opportunity was not taken up very often during the First Trial or early on during the Second; shyness was admitted by one student in the answer to Question 4 (d) of the Questionnaire. Others may have been too shy to admit their shyness, or reluctant to admit that they had difficulties. As mentioned in Section 6.35 (e), it was certainly very difficult for me to keep myself obviously available; time was too precious for my doing nothing while waiting for students to approach me to be justified for long. However, that would be the ideal thing if possible. The particular difficulties I expected to be mathematical ones for the non-mathematicians but they didn't materialise to any extent and the results for the First Trial showed that there wasn't in fact any real need for assistance (Section 6.32 (c)). There
were more mathematical difficulties encountered by the Second Trial group however and I was asked about these at intervals.

The above measures seemed to ensure a fairly high level of motivation for most of the students most of the time. Nevertheless, the answers to Question 5 (d) of the Questionnaire indicated that the system did not provide motivation for all of them all of the time, but this could surely not be expected. The answer seems to lie in variety; if frequent changes of resources are not possible, then variety of activity ought to be. The First Trial exposed the lack of flexibility of this learning system in a period of hot weather (Section 6.31) but the different time-tabling of the Second Trial seemed to overcome this difficulty, with the discussion periods and practical sessions providing enough variety.

One of the hypotheses suggested before the First Trial (Section 5.10), was that the 'team spirit' resulting from a group working together and by which members of a group learn from each other would probably be lost if students worked for long periods on their own. After early signs of this danger (Section 6.35 (a) ) the students were encouraged to converse freely and consult each other's notes during 'reading' time as well as the practical sessions; the discussion periods also helped considerably of course, and these were deliberately made as informal as possible to encourage cross-fertilization of ideas.

Two other features of the system which affect learning efficiency are worth mentioning. First the considerable advantage, discussed in 6.35 (d) and 7.35 (b), that if teaching staff or students are absent, the system simply carries on as if they are present; thus staff don't have to set 'fill in' material and students can catch up by simply doing extra work. Of course this advantage is the other side of the coin of
inflexibility of having the readings etc., pre-selected.

Secondly, there is the question of the quality of the resources available, i.e. textbooks, worksheets and information sheets, vis-a-vis what the teacher could provide in the traditional situation. The point is made in Section 2.21 (c) that the quality of teaching provided frequently improved when the teacher stands back and simply 'manages' resources. In this investigation it is very difficult to obtain an objective comparison since the type of resource being used may not be one from which a particular student learns well. However, an attempt was made to compare the quality of the teaching from the student's point of view; the relevant questions in the Questionnaire were nos. 4 (a), 4 (b), 6 (a), 6 (b), 6 (c) and 6 (d). Frankness was particularly requested here and seemed to be forthcoming; however, the answers were roughly equally divided as to the relative qualities of the system resources and my own teaching. Of the two textbooks, the less detailed one was preferred, probably because it was much the easier one from which to take notes; the other resources were generally found to be valuable.

8.4 Indirect Advantages of the Learning System

The literature concerning the 'spin-off' advantages of an independent learning system is surveyed in Section 2.21. Some parts of that discussion were more relevant to my learning system than others; thus 'less discipline and drop out problems' (Section 2.21 (b)) is more relevant to Lower Secondary School form teaching than to the Sixth Form where, at least, the students are studying subjects they have chosen and in which they are therefore quite interested. However, I certainly felt that my personal relationships with the students, especially in the Second Trial, had deepened as a result of the 'tutorial' teaching (one-to-one, or small sub-group) frequently occurring; this may be a 'Hawthorne' effect for me but it was none-the-less true for this investigation.
The question as to whether a higher quality of teaching was provided by the system than by myself was best answered by the students (Questionnaire question 4 (b)); with refreshing frankness they were roughly evenly divided on this (Section 7.41). Whether or not the 'status' of my teaching was raised is more difficult to answer; the other science staff certainly regarded the system with considerable respect.

One of the most convincing reasons for using an independent learning system as far as the students are concerned is that they thereby experience practice in becoming less dependent on their teachers; the literature is discussed in Section 2.21 (e). Several questions in the Questionnaire investigated the students' assessment of the extent to which they had acquired the skills of independent learning. Thus the answers to Questions 2 (b) and 2 (d) referred to the essential ability to take notes; several students had found considerable difficulties in this but felt they had acquired some ability from having to do so. Indeed those who found it most difficult were indirectly confirming the need to practice these skills in a limited way at sixth-form level, before having to use them continuously in Higher Education. Questions 3 (a), 3 (b) and 3 (c) referred to reading skills and nearly all of the students felt that the system had helped them in these. Finally, Question 3 (d) referred to self-organisation of work; again, nearly all of the students felt that they had learned 'a great deal' about the efficient organisation of one's work from the use of the system.

8.5 The Particular Problems of Independent Learning

The literature of these is discussed fully in Section 2.22.

8.5.1 Change of role for the teacher

Basically the teacher stops being the central resource for learning and moves to the sidelines where he 'manages' all the resources available.
As explained in Section 6.35 (d), it was unlikely that I myself would resent this change since the resources being used were my own system of learning; however, I was able to sense vicariously what another teacher might feel if he were using my system elsewhere.

I certainly felt that any teacher who enjoys 'chalk-and-talk' class teaching most of all would feel somewhat deprived; however, the discussion periods provided regular opportunities to 'indulge' in it. There were also compensations in the greater opportunities for teaching 'tutorially', i.e. to one or two students only, something comparatively rare in these days of large classes (even in sixth forms) as a result of greater staffing-ratios. However, the 'management' of such tutorial teaching requires some thought; as mentioned in Section 8.34 (d) above, there is a skill in portraying the right amount of availability so that students don't over-indulge in it, yet take advantage of the teacher's presence when they have genuine problems.

8.52 The Tendency towards De-personalisation

While the students are reading their textbooks and making notes, both teacher and students may feel that the education process has become impersonal; the non-human material resources have come between the human personalities involved (Section 2.22 (b)). However, with this particular system, there are sufficient breaks in that part of the process for these feelings to be quickly overcome by the personal contacts which then take over. From the students' point of view, there is the additional danger that they feel they are 'fodder' for a managerial machine; such feelings are best allayed by an introductory talk.

8.53 Some Practical Problems

The likely practical problems are reviewed in Section 2.22 (c). 'Conflicts with Headteachers' (i.e. my two Sixth Form College Principals)
were minimal; they were mildly interested in the fact that an educational innovation was being experimented with but took the line that it was the end-product that mattered, i.e. the examination results achieved. Since these were reasonable, official blessing was forthcoming. However, no extra time or departmental finance was offered.

The slow speed of syllabus coverage did elicit some comment, especially from the students' parents on 'Open Evening'. Since I had been at Farnborough for nearly twenty years, the parents knew me and, fortunately, trusted my experience to ensure that their offspring wouldn't suffer from this. However, being new to Reigate, I was not trusted so implicitly by the students and parents here; I therefore had to spend some time persuading them that all was well - our being 'behind with the syllabus' was only temporary and that the benefits for the students in lieu were considerable. Unfortunately, some were never entirely convinced.

8.5. The Costs of the System

Even with a system as simple as this one, there are obviously certain financial costs to be met, viz.,

(a) development costs
(b) running costs.

Each of these costs may be further subdivided into those of:

(i) materials
(ii) teacher/manager time.

The material costs for both development and running were simply those of duplicating, i.e. stencils and paper; thus the science departments involved (Farnborough College for the development and First Trial, and Reigate College for the Second Trial) were able to absorb these costs as little more than those of running 'traditional' courses.
Similarly, the cost of my own teacher/manager time, once the system was running, was little more than that for traditional teaching; the extra time was that needed for the marking of the rather lengthy Post-Tests and for 'tutorial' teaching outside Physics periods when occasionally necessitated by the extra demand for personal assistance.

However there was a considerable amount of my teacher-time involved in the initial course development and the later revision of the course. The tendency is not to count the cost of this since it was, as for most teachers developing courses for their own pupils, a 'labour of love' and one could argue that the time involved replaced the time normally spent on lesson preparation. Nevertheless, as Taylor (1972 (b)) points out, the real cost in practice is the help a teacher might otherwise give in extra-curricular activities or pastoral care, or the strain on his marriage or health; we may choose to ignore these costs over a short period but we cannot sensibly do so if the compilation of resources becomes a habit. I certainly felt that the time I gave to the development of the system under discussion approached the limit of 'ignored costs'; I did, however, do everything myself, including all duplicating, so as not to deceive myself as to what was involved. The production of anything much less straightforward would, I suggest, have been a burden on my department, college and family which it would not have been right to disregard.

8.6 Conclusions

This investigation has evaluated the introduction of an independent learning system into a Sixth Form Advanced level Physics course. The main conclusions were:

(a) It was feasible to cover part of the Advanced level syllabus in this way, i.e. the learning efficiency was comparable with that
achieved by traditional teaching, both in terms of the group's examination performance and the correlation between individual performances. It did tend to take a little longer to cover the same syllabus area but this was largely because weaknesses were exposed in students' understanding of basic concepts which would tend to be glossed over by a traditional course.

(b) The system gave students experience of Independent Learning from the resource which they would find, even today, is the commonest to be provided in courses in Higher and Further Education, i.e. the textbook. Thus the 'study skills' required were developed by the practice provided.

(c) The system was individualized in two important respects: (i) by allowing self-pacing, even though I exercised overall control over the group speed; (ii) by allowing for a much greater degree of 'tutorial' instruction during which I could motivate individual students and probe for weaknesses in understanding of the subject-matter.

(d) Although by no means perfect, the system was simple and cheap and it showed what can be done with very limited resources indeed; it should perhaps encourage other science teachers on a limited budget not to be put off by lack of funds. Neither should they be deterred from going ahead because a learning system has obvious defects; nothing would be attempted if it were thought that any innovation had to be perfect. Indeed, a comparison might be made with the use of textbooks; teachers would, of course, prefer to write and use their own but this is impossible except for the few. They therefore accept the imperfections in other authors' work and make the best of it; a similar approach to innovations in educational technology is needed.

(e) The problems of the changes in the teacher's role were considerable but not insuperable. In-service training for management of
independent learning systems would be very beneficial; improvement in such management skills as setting diagnostic tests and handling numbers of small groups would make teachers better teachers anyway (Bausor, 1979).

(f) The system was 'compatible' with the traditional teaching returned to by the students and myself afterwards. The transition was very smooth indeed; it could be said that we 'slipped back' into the old routine. However the fact that the benefits from having taken part in the investigation were not lost was confirmed by the ease with which the Second Trial group later tackled an independent learning 'package' on Atomic Physics.

(g) The Second Trial students gave a general stamp of approval to covering at least part of the A-level course in this way. Their answers to Question 1 of the Questionnaire suggested that, out of a 5-term course, an average figure of 1.5 terms should be spent in Independent Learning.

(h) Highly individual approaches and reactions to the system shown by different students were revealed by observation and the Questionnaire; indeed the exposure of such variety in performance and attitude can fairly be said to be a vindication of the principles of illuminative evaluation. 'Averaged out', the learning achieved by the group could be said to be fairly 'normal' (as witnessed by the good correlation between system performance and End-of-Year examination) and would probably show a 'null' result if taking part in a control group experiment; but a considerable richness of individuality would be concealed by this bare statement.

8.7 Recommendations

Further research into the inclusion of a simple independent
learning system as part of a Sixth Form Physics course could usefully investigate:

(a) the effects of varying the imposed overall pace of the group. For example, the proportion of total course time which should be allocated to any part of the syllabus is known to any experienced A-level Physics teacher; it would be interesting to observe the effect of imposing the group speed on that basis rather than choosing the speed the fastest members of the group naturally adopt.

(b) the best kind of textbook to provide for independent reading. For example, whether it is better to have one which is essentially in note-form or one which is more discursive in style; or again, whether 'programmed' textbooks (if available) might be the most valuable for certain sections of the syllabus.

(c) the provision of 'remedial' and 'enrichment' resources for the least and most able students respectively; how much of each type would be required would depend, of course, on the pace imposed on the group, so that this research would have to be linked to that on pacing.

(d) how 'complicated' the learning system can be before the teacher/manager finds that the task of course development and subsequent management becomes impossible to do efficiently, i.e. without more help (ancillary and financial) than his department ought to allow him via-a-vis the rest of the staff. In this connection, developments in computer-assisted and computer-managed learning (using micro-computers) are likely to be of considerable importance, because they will probably make extremely complex branched learning systems as easy to use and administer as the simple linear one using textbooks which we have been investigating.


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<td>Force.</td>
<td>Types of force: weight, upthrust, friction, tension, normal contact (reaction), lift, etc. Representing forces, vector diagrams.</td>
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<tr>
<td>Newton's laws of motion.</td>
<td>Experimental investigation of $ma = \mathbf{F}$ is expected.</td>
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<tr>
<td>Linear momentum and its conservation.</td>
<td>Experimental investigation is expected.</td>
</tr>
<tr>
<td>Composition and resolution of co-planar vectors.</td>
<td>Especially velocity, force and momentum.</td>
</tr>
<tr>
<td>(18) Moments. Couples. Torques. Work, energy, power. The principle of conservation of energy.</td>
<td>Including (a) mass-energy, the relation $\Delta E = c^2 \Delta m$; (b) internal energy, the relation $\Delta Q = \Delta U + \Delta W$.</td>
</tr>
<tr>
<td>(19) Uniform motion of a particle in a circle.</td>
<td>Examples include satellites and charged particles.</td>
</tr>
<tr>
<td>Rotational motion of a rigid body about a fixed axis:</td>
<td>Derivation of the formula for $I$ in specific cases will not be expected but the factors determining $I$ should be appreciated. $I$ may be introduced from considerations of the energy, momentum or acceleration of a rotating body.</td>
</tr>
<tr>
<td>Significance of moment of inertia.</td>
<td>Experimental investigation is not expected.</td>
</tr>
<tr>
<td>Angular momentum and its conservation.</td>
<td>Problems restricted to simple examples. The solution of the equation of motion may be quoted.</td>
</tr>
<tr>
<td>Angular kinetic energy.</td>
<td>Graphical ideas will be adequate. Amplitude resonance only is required.</td>
</tr>
<tr>
<td>(20) Simple harmonic motion.</td>
<td>The relation between $G$ and $g$ is required but not the determination of $G$.</td>
</tr>
<tr>
<td>Free and forced vibrations.</td>
<td>Including the analogy with electric field and potential.</td>
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<tr>
<td>Resonance.</td>
<td>No mathematical treatment of viscosity is required.</td>
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<tr>
<td>(21) Law of gravitation.</td>
<td></td>
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<td>Gravitational field and potential.</td>
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<tr>
<td>Determination of the acceleration of free fall. Terminal speed.</td>
<td></td>
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</table>

Continued ....
SYLLABUS

(22) Surface tension:
   Angle of contact.
   Pressure difference across a spherical interface.

(23) Stretching of wires and helical springs.
   Stress and strain.
   Force extension graphs.
   Work done in stretching.

NOTES

Simple phenomena. Measurement by capillary rise and Jaeger's method.
Measurement of angle of contact is not required.

Hooke's law.

The Young modulus, including its experimental determination for a metal.
General shape for metals and non-metals, e.g. rubber, related to microscopic behaviour.
Restricted to Hooke's law region.
GENERAL INSTRUCTIONS.

(You will probably need to refer to these instructions fairly frequently during the next few weeks so this paper should be firmly fastened into the front of your file).

It is intended that you should work largely on your own and at your own pace while studying the sections of the syllabus covered by this self-teaching programme (sections 17 - 23 of the A-Level Syllabus). To enable you to do this the syllabus has been divided into sub-units, each of which having a guide-sheet explaining the work to be done and the order in which it should be tackled. These guide-sheets should also be firmly fastened in the front of your file for easy reference.

In each guide-sheet:
Where you see (R) against a piece of work, this means that you must refer to your teacher before starting it.
Where you see (M) against a piece of work: this means that you must have that piece of work marked.
Where you see (T) against a piece of work this means that the teacher will be supervising it directly.
Where you are told to read a section from a book, etc., this means that you first of all read the section, then read it again while preparing a written summary which is then placed in your file. If the work of a section is largely revision, you may be able to get by with a short summary; however, if the work is nearly all new to you, that section will probably need a fairly detailed summary with important definitions, etc., boxed round thus:

'Th' = Thorning's "General Physics and Sound"; 'N' = Nelkon's "Mechanics and Properties of Matter".

Note: The sections of chapters in Thorning are conveniently numbered, but those in Nelkon are not. References in Nelkon, therefore, have to be given by page numbers; unless otherwise indicated a reference such as "pp 8 - 11" means start at the latest section heading to be found on page 8 and finish at the first section heading on page 11. A single page reference refers to a complete section on that page.
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<td>3.</td>
<td>Read Th. Ch. 2 Section 3(c)</td>
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<td>Read N. pp 33 - 35 and p 35.</td>
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<td>Read Th. Ch. 1 Sections 3, 5, 6.</td>
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<td>Read N. pp 1 - 2 and 8 - 11</td>
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<td>5.</td>
<td>Read N. p 1 and pp 2 - 6</td>
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<td>Read N. pp 6 - 8</td>
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<td>Information Sheet 2.</td>
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<td>18.</td>
<td>Question Sheet 3</td>
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<td>19.</td>
<td>Discussion</td>
<td>(T)</td>
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<td>20.</td>
<td>Read Th. Ch. 2 Sections 10, 11, 12.</td>
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<td></td>
<td>Read N. pp 26 - 32</td>
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<td>Read N. pp 112 - 114 and 115 - 117</td>
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<td>29.</td>
<td>Discussion</td>
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<td>30.</td>
<td>Post-Test.</td>
<td>(I)</td>
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</table>
As with Pre-Test I and II, this test contains actual A-level questions and is designed to determine how much of these sections of the syllabus you already know and remember from your A-level work (or your Applied Mathematics course). This test will be repeated as a Post-Test at the end of this section; at intervals you will be set similar questions so that you should be able gradually to improve your mastery of the subject - matter.

1. **State Newton's universal law of gravitation.**
   
   If the earth may be considered to be a sphere of uniform density, explain how you would expect the force of attraction due to gravity on a body (a) at the bottom of a deep mine-shaft, (b) at a point well above the surface of the earth, to differ from its value at sea-level.
   
   An artificial earth satellite describes a circular orbit of radius $7.11 \times 10^3$ km with a period of 100 minutes. Assuming the mass of the earth to be $6.00 \times 10^{24}$ kg, estimate the value of the universal gravitational constant $G$.
   
   The earth has a mass 81 times that of the moon and a radius 3.60 times that of the moon. Assuming the moon to be a uniform sphere find the ratio of the periods of a simple pendulum of given length at the surfaces of the moon and of the earth. 
   
   *(Jan., 1972)*

2. **Given that the radius of the Earth is 6400 km and that the value of the acceleration of free fall at its surface is $9.80 \text{ m s}^{-2}$, calculate a value for the acceleration of free fall at a point 400 km above the surface of the Earth. Although this value is not zero why is an astronaut in orbit at this height in a state of 'weightlessness'?**
   
   *(June, 1972)*

3. **Explain what is meant by the universal gravitational constant $G$.**
   
   Derive the relationship between $G$ and the acceleration of free fall, $g$, at the surface of the earth (neglecting rotation of the earth and assuming that it is spherical)
   
   Explain why the rotation of the earth about its axis affects the value of $g$ at the equator.
   
   Calculate the percentage change in $g$ between the poles and the equator (again assuming that the earth is spherical)
   
   The orbit of the moon is approximately a circle of radius 60 times the equatorial radius of the earth. Calculate the time taken for the moon to complete one orbit, neglecting the rotation of the earth.
   
   *(Acceleration of free fall at the poles of the earth = $9.8 \text{ m s}^{-2}$
   Equatorial radius of the earth = $6.4 \times 10^6 \text{ m.}$
   $1 \text{ day} = 8.6 \times 10^4 \text{ seconds})*
   
   *(June, 1974)*
4. Define tensile stress, tensile strain.
Show in the case of a stretched wire that the product of these quantities gives twice the energy per unit volume stored in the wire.
Describe an experiment to determine the value of Young's modulus for steel in the form of a long wire.
A mass of 10 kg is suspended at the end of a rubber cord of diameter 2.50 mm and unstretched length 80.0 cm. Find the period of small vertical oscillations of the mass.
(Young's modulus for rubber $= 2.00 \times 10^9$ dyn cm$^{-2}$ (2.00 $\times 10^8$ N m$^{-2}$)

5. A spring is extended by 30 mm when a force of 1.5 N is applied to it.
Calculate the energy stored in the spring when hanging vertically supporting a mass of 0.20 kg if the spring was unstretched before applying the mass.
Calculate the loss in potential energy of the mass. Explain why these values differ.
(Jan., 1972)

6. A liquid surface behaves in many ways as though there were a skin stretched over it. Show that this effect can be explained in terms of the forces between molecules.
A drop of mercury is placed on a clean horizontal surface. Discuss how the shape taken up by the mercury drop changes as the volume is increased and explain what combination of factors determines this shape.
Two spherical soap bubbles of radii 20 mm and 60 mm respectively are in contact externally. What is the radius of curvature of the common surface? Is it convex or concave towards the centre of the larger bubble?
(Jan., 1974)

7. Define surface tension and angle of contact. Give an explanation, in terms of the forces between molecules, of the shape of the meniscus formed when the surface of a liquid of angle of contact less than 90° meets a vertical solid surface.
Derive an expression for the pressure difference across a spherical surface of radius $r$ between a liquid and a gas.
A straight capillary tube of internal radius 0.50 mm is held in a vertical position partially immersed in soap solution, of surface tension $71 \times 10^{-3}$ N m$^{-1}$, density $1.0 \times 10^3$ kg m$^{-3}$ and zero angle of contact.
Calculate the position of the meniscus in the tube relative to the liquid outside the tube. A soap film is now formed across the top end of the tube and the pressure in the tube increased, by pumping air into the tube through a side connection, until the pressure reaches a maximum. What will then be the level of the meniscus in the tube? 
(Jan., 1975)
1. A uniform flywheel of diameter 30 cm and mass 150 kg is driven by a motor with a uniform power output of 1.2 kW. Calculate the time required for the flywheel to reach a speed of 1000 r.p.m. \( \omega = \frac{v}{r} \)

The motor is now disconnected from the flywheel, and a brake applied which exercises a uniform torque of 14 N m. Calculate the time required for the flywheel to come to rest. Neglect all frictional and other losses.

What torque is exerted by the motor, when the speed of the flywheel is 10 r.p.m., 100 r.p.m., and 1000 r.p.m. respectively?

2. Six men, all with the same weight, stand at regular intervals around the circumference of a turntable, each being 2.5 m from the axis. The turntable is given a speed of 2 r.p.m. At a signal, all six men simultaneously move inwards, to take up new positions each 0.5 m from the axis. Calculate: (i) the new speed of the turntable; (ii) the ratio of the new to the old energy of the system. Comment on the second result. (Neglect the mass of the turntable, and frictional losses).

3. Find the average angular acceleration of the blades of an electric fan which attains 1200 r.p.m. in 8 sec from rest. If the moment of inertia of the blades and shaft is 1500 gm cm\(^2\), calculate the average power required in the absence of friction.

4. A bicycle wheel, acted upon by a steady tangential force of 500 gram wt., makes its first revolution from rest in 4 sec. Find the angular acceleration; if the force is applied at 20 cm from the centre, calculate the moment of inertia of the wheel.

5. Explain what is meant by the moment of inertia of a body and describe some experimental method of comparing moments of inertia.

A flywheel with a horizontal axle 2 cm in diameter has a cord wound round the axle to the end of which is attached a 5-kilogram weight. The weight is allowed to fall, causing the wheel to rotate. The weight falls from rest a distance of 40 cm in the first 10 sec. What is the moment of inertia of the flywheel? (Assume bearings frictionless).

6. If a constant couple of 500 N m turns a wheel of moment of inertia 100 kg m\(^2\) about an axis through its centre, the angular velocity gained in two seconds is A 5 rad s\(^{-1}\), B 100 m s\(^{-1}\), C 200 m s\(^{-1}\), D 2 m s\(^{-1}\), E 10 rad s\(^{-1}\). Which?

Define the moment of inertia of a body about a given axis. Describe how the mom of inertia of a flywheel can be determined experimentally.

A horizontal disc rotating freely about a vertical axis makes 100 r.p.m. A small piece of wax of mass 10 g falls vertically on to the disc and adheres to it at a distance of 9 cm from the axis. If the number of revolutions per minute is thereby reduced to 90, calculate the moment of inertia of the disc.
Determination of \( g \) by Loaded Spring.

**Apparatus.** Spiral spring with pointer attached at lower end; rigid stand and clamp, metre rule, weight holder and weights, stop watch, fiducial pointer (e.g. needle in clamp)

**Theory.** The graph of extension against applied load for a spiral spring is usually as follows:

\[
\frac{\varepsilon}{F} = k
\]

Graph (i)

The intercept at \( P \) is the load needed initially to separate the turns of the spring (for some springs). For this graph, the gradient is the extension per unit load; let this be \( a \) (in m/kg).

If now a mass \( M \) is loaded on the spring, and the spring is then extended a further distance, \( x \), the restoring force is \( (xg/a) \) (newtons).

Thus the acceleration of the mass back to its equilibrium position is \( (xg/a) \); the motion of the mass is S.F.M. with \( w^2 = g/aM \)

the time period \( T = 2\pi \sqrt{\frac{aM}{g}} \)

Thus the graph of \( T^2 \) against \( M \) will be

Graph (ii)

Let gradient = \( b \)

\[
b = \frac{4\pi^2a}{g}
\]

Turn over.
Thus if gradients \(a\) and \(b\) are measured, \(g\) can be found.

Fiducial Pointer for Obtaining Graph (ii).

Procedure
As indicated by the theory, the experiment consists of two parts:

1. The "static" part in which the spring is loaded, and the extension measured for each load. Thus gradient \(a\) can be found from a graph.

2. The "dynamic" part in which the spring is loaded and the time period of vertical oscillations is measured for each load. Thus gradient \(b\) is found from a graph.

Results Tables

<table>
<thead>
<tr>
<th>Load/kg</th>
<th>Extension/m</th>
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<table>
<thead>
<tr>
<th>Load/kg</th>
<th>(\frac{20}{3}) T/s</th>
<th>T/s</th>
<th>(T^2/m^2)</th>
</tr>
</thead>
</table>

Conclusion

1. From graph (i), the gradient \(a\) was found to be 
   ....... \(m/kg\).

2. From graph (ii), the gradient \(b\) was found to be 
   ....... \(s^2/kg\).

Thus, the acceleration due to gravity was found to be ....... \(m/s^2\).

(N.B. It is not too difficult to estimate the accuracy of this result if the "best" and "worst" lines are drawn for each graph and the resulting probable error used in the calculation for the total error from the equation \(g = \frac{4\pi^2}{T^2}a\).)
(a) Elastic and Non-Elastic.
We have seen that in a collision between bodies travelling in the same straight line, momentum is always conserved. However only in one sort of collision is energy conserved, i.e. total energy of the colliding bodies before collision equals their total energy afterwards; such a collision as this is called 'perfectly elastic' because bodies which conserve energy during collisions are either 'elastic' themselves (with an elastic surface such as a golf ball) or have elastic springs between them which are compressed during the collision. Thus, during a collision deformations occur which are perfectly 'reversible' with no conversion of energy into heat; after the collision the bodies (or the springs) regain their former shapes and move off with new velocities.

A simple example of such an elastic collision is where a moving object strikes a stationary object of the same mass:

\[ m \dot{v}_1 = m \dot{v}_2 + m \dot{u}_2 \quad (i) \]

By conservation of energy, if the collision is elastic:

\[ \frac{1}{2} m v_1^2 = \frac{1}{2} m v_2^2 + \frac{1}{2} u_2^2 \quad (ii) \]

It is easily shown that the solution to these equations is:

\[ v_2 = 0, \quad u_2 = v \]

i.e. the moving body stops dead and the stationary one moves off with the original velocity of the first.

(b) Momentum as a Vector.

Since momentum is proportional to velocity and velocity is a vector, it follows that momentum is a vector and can be resolved into components in any two mutually perpendicular directions. It also follows that since the action and reaction forces occurring during a collision where the bodies involved do not move in the same straight line can also be resolved into components, and since these forces are equal, momentum must be conserved in any pair of mutually perpendicular directions.
For an example see Nelkon pp 22 - 23 (make notes); this shows that if two spheres of equal mass collide obliquely with a perfectly elastic collision, their subsequent velocities are at right angles. This result has an interesting application in atomic physics; cloud chamber photographs of collisions between alpha particles and helium nuclei are found to show these characteristics, thus verifying the equality of their mass.
Attitude Questionnaire

These questions are designed to find out what you as an individual student think about the 'guided Self-teaching' method we have been using to cover part of the A level syllabus. It would be much appreciated if you would think carefully about your answers before writing them in.

Where appropriate, please ring the answer you choose, e.g.

Are you a brilliant physicist? Yes/No

If you wish to emphasise such a Yes/no answer, please add "Very much".

1. How much of the 2 years of the A level course do you think ought to be spent in this way?
   ALL / 5 TERMS / 4 TERMS / 3 TERMS / 2 TERMS / 1 TERM / NONE

2. You may have several reasons for your answer to question 1. In particular:
   (a) Do you think this approach has increased your ability to learn by yourself?
      A LOT / A LITTLE / NOT AT ALL
   (b) Do you think that you learned this part of the syllabus:
      MUCH BETTER / BETTER / NO BETTER / WORSE / MUCH WORSE
      than if a 'traditional' teaching method ('chalk and talk') had been used?
   (c) Did you enjoy this 'guided self-teaching' method of working
      MUCH MORE / MORE / NO MORE / LESS / MUCH LESS
      than being taught in a traditional manner?
   (d) Have you any other reasons for your answer to question 1?
      Please specify.

3. How much was each of the following features of your ability to learn by yourself improved by this course?
   (a) to read a book with concentration:
      A GREAT DEAL / A LITTLE / NOT AT ALL
   (b) to read with discrimination i.e. to pick out the important points.
      A GREAT DEAL / A LITTLE / NOT AT ALL
4. This question lists some of the reasons which could be given for a student being able to learn new work better by this method than by a traditional teaching method. Which of them (if any) apply to you?

(a) You have always found learning from books easier than by listening to someone talking; (YES / NO)

(b) the textbook you have been using put the ideas more clearly than your present teacher (be frank please!); (YES / NO)

(c) You were able to work at your own pace to some extent; (YES / NO)

(d) I was able to give you individual help rather more easily with this method (and also when you needed it); (YES / NO)

(e) having to think about the subject matter and summarise it yourself helped you to understand it and memorise it; (YES / NO)

(f) any other reason? Please specify if you can.

5. On the other hand the following are reasons which might be given for not having learned as well by this method as by a traditional approach. Which, if any, apply to you?

(a) You have always found learning from books more difficult than by listening to someone talking; (YES / NO)

(b) the textbooks you have been using did not put the ideas over as clearly as your present teacher (be frank, please!); (YES / NO)

(c) You don't like being able to work at your own pace; you prefer to go at the same pace as the rest of the class; (YES / NO)

(d) You found doing so much reading boring so that it was often difficult to make yourself work; (YES / NO)

(e) some other reason? Please specify if you can.
6. It would be helpful to have your comments on the materials used in this system. Please comment on them below, using words such as "could be (much?) improved", "satisfactory", "very clear", etc. Specify particular ones if you wish - this will be most useful.

(a) Reading references

(b) Information sheets

(c) Worksheets

(d) Question sheets

7. (a) This learning system has allowed you to work at your own pace (apart from meeting Question Sheet deadlines). Do you approve of such 'self-pacing'? 

YES / NOT SURE / NO

Please explain your answer.

(b) The Question Sheet deadlines did impose an overall speed of working on the group. Comment on this speed as far as you were concerned.

MUCH TOO FAST / A LITTLE TOO FAST / JUST RIGHT / A LITTLE TOO SLOW / MUCH TOO SLOW

8. The discussions after the return of your answers to the Question Sheets were interludes in your self-teaching during which you learned from your fellow-students and from my comments. How useful did you find these discussions?

VERY USEFUL / QUITE USEFUL / NOT MUCH USE

Please explain why.

Thank you for completing this Questionnaire. Criticism or approval will both be valuable in improving the system for future use.
## Student Attitude Profile

Name of Student (or Student Ref. No.)

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**Note:**
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- + = Answer in favour
- o = Equivocal answer
- - = Answer unfavourable
- -- = Answer strongly unfavourable
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