

STUDENT LEARNING AND TEACHER INTERVENTION
IN AN UNDERGRADUATE ENGINEERING LABORATORY

by

Garry John Dearden

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DEDICATION

To my mother
my father
and
my sister

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Summary

A two-term introductory electrical and electronic engineering laboratory programme at the University of Surrey was studied intensively for two successive academic years. The research reported in this thesis represents the outcome of that effort.

Referring to published accounts on laboratory teaching methods, Chapter One argues for investigations of teachers teaching and students studying as these occur naturally in science and engineering laboratories. The suggestion is for a switch in research effort. From inquiries which emphasise what could or should happen in laboratories to the examination of what actually does happen. Methods of inquiry used in educational evaluation and research are reviewed in Chapter Two and the newly emerging anthropological paradigm is identified as most appropriate. A range of theoretical and methodological ideas and concepts used by those pursuing work in this paradigm are adopted and a general research approach suited to the specific setting of an engineering laboratory is proposed. A major concern of this thesis, then, is the ways in which this general stance was able to be translated into practice.

Chapter Three addresses several procedural issues that arise and need attending to when collecting field-work data. Details of who was spoken to or observed, when, where, for how long, and how often, are all included in this chapter.

In Chapter Four the Surrey lab emerges as a learning environment that channels the actions of its students in certain specific directions. Three local customs of conduct are identified (working quickly, preparatory working, working mechanically). To characterise the different features that make up the lab context the concept of a Laboratory Instructional Script and Laboratory Management Framework is introduced. The student act of working mechanically through

experiments is focussed upon in Chapter Five. The way in which this relates to how students learn in the lab and what they learn is subsequently examined. Using twenty years of documentary records, Chapter Six reviews several attempts made to change the Surrey lab programme. The chapter argues that many of the interventions were based on incorrect assumptions about how students respond in the lab and, therefore, resulted in serious unintended as well as intended effects.

Chapter Seven briefly re-considers the method of inquiry used in the thesis and the rationale behind its adoption. The main ideas and concepts developed during the work are drawn together and their generalisability status is discussed. Finally an attempt is made to locate the reported work in the wider arena of educational research.

Each student in the Surrey laboratory proceeds each week through a separate script of experimental instructions. In Appendix I four of the sixteen scripts used in the programme are included (in full) for the reader's perusal.

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CHAPTER ONE

ANALYSING EDUCATIONAL PRACTICE: A SURVEY OF LABORATORY TEACHING

1.1 Introduction

Science and engineering students in the British higher education system have traditionally spent substantial periods of their time engaged in experimental enquiry in a teaching laboratory. A laboratory for physics undergraduates, for instance, was established at University College London as early as 1866. And this was followed by similar programmes⁽¹⁾ at Kings College London in 1868; Oxford in 1872; and Cambridge in 1873, (Aspden and Eardley, 1974).

Patterns were set during this early period that proved remarkably resilient. Once or twice weekly each undergraduate would prepare a piece of apparatus and then proceed through a precisely prescribed written set of measurements. Typically the 'experiment' involved re-determining established physical constants or verifying a well known experimental law or principle (Menzie, 1970).⁽²⁾

(1) Throughout this thesis I refer to that part of a science or engineering course given over to laboratory work as a laboratory programme. The first-year laboratory programme therefore, refers to laboratory work carried out in the first-year course.

(2) A pioneer of this type of laboratory task was the physicist G.F.C. Searle who in the 1890s directed the Cavendish laboratory at Cambridge (Aspden and Eardley, 1974). At the turn of the century he designed many items of apparatus for the specific purpose of teaching the art of experimentation. Several of these experiments such as 'Searle's Bar', 'Torsion Balance', and 'Young's Modulus of Elasticity', are still performed in the first year of many present day science and engineering undergraduate laboratory programmes. All three experiments existed, for instance, in my own first year engineering course in 1970.

In the early 1960s there appeared in British science and engineering education journals several criticisms of this traditional format from teachers (of all disciplines) who had begun to re-design their laboratory programme along different lines. ⁽³⁾ A sample of these accounts can be found in Physics by Gavin (1960); in Electrical Engineering by Collinson (1964); in Mechanical Engineering by Wood (1964); in Chemical Engineering by Johnstone (1961); in Biochemistry by Jepson (1966); in Chemistry by Fuller (1964). The criticisms were similar in many ways, whatever the discipline and I review the common central themes in Section 1.2. Writing at this time one teacher (Plotkin, 1961) summed up the state of affairs in the following way:

"Laboratories have been a source of educational problems for many years. It has been generally recognised that our laboratories have never quite done the job they were supposed to. Students, in particular, have always been rather adamant in their dislike for the electrical engineering laboratory. In the past, the faculty held the view that the reason for the strong criticism was due to the long hours of work required for very little credit with respect to the work involved.

(3) Published disenchantment with the traditional laboratory format did not really emerge until the creation of the 'new' and 'technological' universities. Around this time the number of science and engineering students in Britain rose to unprecedented numbers (the general extent of this increase can be found in the article 'Expansion of the Universities in the 1960s: Problems and Achievements' in (Bell et al. Eds., 1973)). The 'new' universities, though typically without any departments of engineering provided courses in all the sciences and these were designed from scratch. The technological universities had prepared students in science and engineering for many years but the granting of university status for the first time allowed them autonomy and, as in the case of the university highlighted in this thesis, made it easier for the design and content of the undergraduate curriculum to be changed. For an analysis of the general changes that took place during this period see the chapter entitled 'Higher Education Since the War' in the book 'The New Polytechnics' (Robinson, 1968).

In recent years however, a number of institutions have appreciably increased the amount of credit with respect to the work involved and the student protests have continued. Therefore, it might be well to take a closer look at the structure and purposes of our laboratory courses and find out if they can possibly do what they are supposed to."

There is evidence to suggest that similar critical questions were being asked of college lab work in the United States. In 1963, for instance, the American Commission on Engineering Education arranged for a small group of teachers to study the "state-of-the-art" of engineering lab work. The commission believed the lab to be in "serious trouble" and this was borne out when the study group reported four years later:

"It is clear from the findings of the study that there is an intensifying awareness of the critical nature of lab instruction on our engineering campuses and of the need for improvements to overcome the widespread existing problems," (Gosh, 1967).

In 1968 a related American Commission on College Physics as one part of their work, organised a summer workshop in which a large group of teachers met to discuss alternative ways of organising first-year physics laboratories. The rationale behind the conference again revealed a rather depressing climate of opinion surrounding the teaching laboratory:

"There is widespread professional agreement on at least one aspect of the introductory laboratory: it is becoming at most institutions, an increasingly unsatisfactory experience for students and faculty alike. The testimony of this state of affairs probably needs no presentation here, for it is apparent not only in the mail the commission receives, but in the content of various professional conferences held during recent years," (Caplan and Fowler, 1968).

Having set the general theme - dissatisfaction with traditional laboratory teaching - I shall, for the rest of this chapter elaborate on the specific kinds of criticism published by science and engineering laboratory teachers during the last twenty years; identifying general trends while at the same time paying close attention to points of dispute and disagreement. My intention is to construct an overall picture of how published thinking on laboratory teaching methods has evolved, and by doing so identify a set of educational problems deemed problematic and worthy of a sustained research effort.

1.2 Criticisms of the Traditional Laboratory

Scrutiny of published literature - both British and American - reveals that most criticism has focussed upon the allegedly unsatisfactory nature of the "cookbook" laboratory.

The student in a traditional laboratory programme typically proceeds through a carefully constructed, teacher-designed, script of instructions three or four pages in length. The instructions serve as a guide to the experimental tasks he is expected to perform. The student frequently performs a different experiment each week and in an allocated time of three or four hours. The apparatus to be used and the subject matter to be covered usually varies from experiment to experiment but the general procedure rarely alters.

According to suggestions in the script, the student is expected to (1) connect the allocated apparatus to be

investigated; (2) use a range of measurement instruments; (3) tabulate the experimental data; (4) carry out specified mathematical calculations; (5) interpret the findings; and (6) write up the results and conclusions. The principal objective in a cookbook experiment is either to verify a general law such as conservation of energy or electrical resonance; to re-determine an established constant such as the energy to mass ratio of an electron; or, more commonly, to illustrate the theoretical principles of, say, an electrical motor or the stress-strain properties of a material.

Published reactions to this type of laboratory can be best summarised into two distinct groups. The first group of reactions stems from the observation by teachers that their students appear "bored" and "uninvolved". Lack of student enthusiasm is attributed to the poor design of the instructional script. Teachers argue, for instance, that cookbook instructions are so detailed that they rarely allow the student to decide on experimental procedure or indeed exercise any initiative at all (Jenkins, 1968). Other critics have suggested that, in consequence, experiments are transformed by students into a series of mechanical exercises to be completed as quickly as possible and that the student comes to regard "laboratory work as a boring phase through which some misguided people insist that he should pass before they will grant him a diploma" (Sturley, 1967).

Arguing for an alternative, two electrical engineering teachers reflected as follows on the arrangement of the cookbook laboratory they participated in as students:

"typical experiments presented in engineering laboratory manuals began with the words

Object: To study....
To familiarise....
To illustrate....

and other equivalents. Alternatively, some experiments had as their purpose the measurement of the electrical properties of a particular device. The manuals then proceeded to tell us exactly what was to be done, what equipment to use, how many measurements to make, and so forth. Finally, we were instructed to write a report as specified or in conformity with an established pattern," (Kent and Card, 1969).

Another critical engineering professor (Lewis, 1967) summed up his college laboratory experience in the following way:

"I remember quite vividly my first position as a research engineer in a materials laboratory. My first-day indoctrination by my supervisor included these instructions, 'I want you to forget everything you have learned in your college laboratory courses in experimental procedures, techniques, and especially report writing. The training you received was just 'college exercise' with bad habits picked up along the way.' I was shocked by these opening statements.

Succeeding months of retraining were to prove him to be correct. I then reflected on my so-called laboratory education. What I recalled were gigantic machines, unsophisticated instruments, and experiments performed using "cookbook" instructions. There was no basic understanding of the aim of the experiments, no real feel for the equipment, no correct experimental techniques developed, nor any true interrelationship between the experimental and analytical approach shown. Originality and creativity were not fostered."

This university professor was describing a laboratory education he received immediately after the second world-war when cookbook laboratories were firmly established in all years of the undergraduate science and engineering curriculum.

The second group of critical reactions are concerned not so much with the script but with the fact that work performed in the cookbook laboratory is not in fact experimental at all and that a student proceeding through such an exercise cannot therefore develop the necessary skills of experimentation. For instance, should a practising engineer need to know an established constant he would look this up in an appropriate reference book or manual.

The effect on students of carrying out these "unrealistic" tasks was outlined by Eaton (1954) who wrote:

"Students go into the laboratory and check Boyles' Law. Of course millions of students have checked this law and found it to be true. If a student finds the law not to be true we do not rewrite our textbooks but we send him back again and perhaps again, until he proves that Boyle's Law is true. To my way of thinking this is just as far from the experience a real scientific investigator has in his laboratory as it is possible to get. He is drawn to his laboratory because of a certain curiosity - he doesn't know the answer but is anxious to find the answer. If he knew the answer he wouldn't be there. So the experience our student is getting is not only worthless, it is worse than worthless since it gives him a false impression of what goes on in a well-organised laboratory."

And by Plotkin (1961):

"It is a well established fact that for a significant percentage of the time in the lab, the experimental results obtained by the students are not in accordance with the theoretical material presented in the lecture courses. What happens? Is the student shaken in his belief in the lecture material? Not at all; his first reaction is that the test equipment or the components are faulty. The next thought entering the student's head is that perhaps there is some stray pick up or other unforeseen phenomenon present which was inadvertently introduced into the experiment. As a very last notion, the student might concede that there is a slight possibility that he has made an error somewhere. And one thought which absolutely never enters his mind is that the theory is incorrect."

To place the quoted critical comments in context I must state right away that I have only been able to find one article suggesting the total abandonment of traditional laboratory work (Moss et al., 1974). The vast majority of teachers seem to believe that cookbook work should be retained but that it should not be used exclusively throughout the whole three years of a student's education.

1.3 Progressive Destructuring of Laboratory Teaching Methods

A view popularly held in the literature is that there should be a gradual destructuring of laboratory teaching methods over the duration of a student's education: highly prescribed cookbook work early on with experiments becoming more open-ended later in the course until eventually the student is able to carry out individual project work.

"For a student to learn something about scientific laboratory practice, he must at some point have the opportunity to solve an experimental problem in its entirety without specific directions. It would unquestionably be a poor if not futile procedure to turn a (first-year) class free in the laboratory to choose their own methods for solving a given problem but it is quite possible to allow progressively more decisions and planning on the part of the students as they gain maturity," (Kent and Card, 1961).

Planning a student's total laboratory education along these lines has been further explained by Brock, Schinzinger and Tuma (1970):

"Before a student can carry out meaningful experiments, he must be familiar with instruments and methods of measurement. Accordingly there must be some routine...But once he is equipped with such a background he should be experimenting on his own in areas which are new to him. He should design his

experiments, make and record observations, change the experiment as required and take some time to reflect on the outcome."

And by Avtgis (1970) who writes:

"A compromise between too much and too little direction appears to be the optimum laboratory procedure. A sequence of activities should be designed to provide sufficient guidance for efficient use of laboratory facilities yet to allow for the period of uncertainty which precedes understanding."

There appeared in the 1960s and early 1970s, a steady stream of articles identifying a weakness in traditional lab work and advocating the careful introduction of projects to gradually allow the student more freedom of choice. The theme is a common one and apparent in the selected following accounts covering both engineering and science: Blick (1955); Bakker et al. (1964); Dubey (1967); Martin (1969); Holmes (1969); Shonle (1970); Oswald and Sloan (1971); Graetzer (1972).

Surveys carried out by Professor Chambers of Bristol University have indicated that these criticisms have been effective and that progressive destructuring of experimental work has started to be converted into action. In 1964, for instance, Chambers surveyed thirty-six university physics departments and found that five employed individual project work in the final year of their course (Chambers, 1964). In 1970 he repeated the survey and reported that twenty five of the thirty six departments offered final year project work (Chambers, 1972). In 1979 it is now widely accepted that

a project should constitute the whole of the final year laboratory work in most engineering and science undergraduate courses. (4)

In this thesis I concern myself not so much with the total laboratory education of a student but with his first year experience. There is an important reason for this. Briefly, there appears to be less consensus among teachers about the kind of laboratory education that should be provided at first-year level. There is general agreement about a gradual move from directed cookbook work to more open-ended projects but major differences on exactly when project work can be usefully introduced.

In electrical engineering for instance: that changes are taking place at first-year level is apparent, not only from individual accounts by teachers, but also from work carried out by Lee and Carter (1972) who in 1971 surveyed departments of electrical and electronic engineering at nineteen different British universities. The aim was to gather information on the organisation of first-year experiments and specifically the mounting of open-ended investigations. Of the departments surveyed approximately one third had recently introduced projects in the first year. On the other hand, two thirds indicated that there had been no

(4) As far as I know there are no up-to-date figures on precisely how many departments provide project work but the enormous increase in use (and the way in which such work is organised and assessed) is extensively documented in the two articles by Harding (1973 a, b) and in the monograph edited by Goodlad (1975).

substantial change in their pattern of first year work in the recent past (though many of these indicated they had implemented projects in the final year and in some cases in year two).

We learn from Lee and Carter's survey that while two departments who favoured project work issued kits of electronic components and circuit diagrams and left students alone to build a radio or amplifier, four departments did not go so far. In the first term of these latter departments students typically proceeded through a limited number of traditional type experiments, not necessarily for purposes of reinforcing "knowledge to support lectures" but more so that they could learn "how to use a wide range of modern instrument techniques" and understand "the behaviour of a number of electrical and electronic circuits". In one of these departments there was then:

"A transition to a set of design-oriented short projects, each student executing three such projects of approximately six hours duration. The students had already been exposed to some paper design exercises and before each project were given an introductory lecture on the topic of investigation which usually concerned the study of the characteristics of a solid-state electronic device and design, construction and test of a simple circuit containing this device. The final part of the year was spent on a longer more ambitious project in which creative skills were called for in for example, the specification, design, construction and test of a temperature stabilised common emitter amplifier," (Lee and Carter, 1972).

There are therefore marked differences in the experiments provided even by those who advocate project work in the first year (and certainly differences between this group and the two thirds continuing to use cookbook scripts throughout the first year).

Differences in teaching policy were also apparent in two recently published accounts of first-year lab work at the University of Salford and at the University of Hull. Unfortunately neither of the accounts (like the vast majority of other published reports by lab teachers) provide much description of the scripts they use, or even attempt an analysis of the effects of their programme on the participating students. Nevertheless striking differences in departmental policy were certainly evident.

At Salford, following the 1971 survey by Lee and Carter, members of the teaching staff began a series of innovatory changes to the first-year electrical lab programme. Reflecting later on these changes Lee and Carter (1975) reported that prior to innovation (in 1972):

"The laboratory work structure in the first year appeared to follow the traditional pattern comprising 'controlled assignments' with the appropriate 'instruction sheets' provided. The experiments were mostly of a routine nature most properly categorised as providing 'reinforcement and theory' and to a lesser extent 'the attainment of manual skills and the use of specialist equipment.' The laboratory sheets left little or no room for deviation from set procedures and many students appeared fundamentally to be unaware of the significance of what they were doing and the studies they undertook were frequently performed in an unmotivated mechanical manner."

In 1975:

"The laboratory instruction sheets have been comprehensively revised and give detailed instruction to the theory underlying the exercises but do not give full details as to how the experiment should be conducted. The student is thus allowed discretion in determining technique and approach and is encouraged to derive information from staff, other students and literature. The laboratory instruction sheets also pose a series of questions which essentially enable the student to ascertain the extent to which he has understood the theory and the degree to which

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he can extrapolate in some simple exercises of mental transposition. The amount of performance instruction given on the sheets becomes progressively less during the first year of study and toward the end of the year a small amount of open-ended/miniproject work forms the final part of the laboratory course."

The Salford department can therefore be thought of as representing the view that project work can be successfully introduced at first-year level.

In contrast, the electronics department at Hull believes in the exclusive use at first-year level of "directed laboratory work of the traditional type, by which students acquire basic knowledge and skills" (Hodgson et al, 1974). Year two at Hull "forms a carefully calculated transition between the directed work of stage 1 and the open-ended project work carried out in stage 3." Hodgson and colleagues have made clear their general reasons for this arrangement:

"We are not in agreement with those who advocate the early introduction of project work. This approach has the inherent danger of trivialisation since the basic theoretical knowledge remains to be acquired, and the fostering of a superficial understanding of the subject leading to the production of 'green-fingered electronic technicians' rather than professional engineers! Our laboratory plan is intended to transform the naive and bewildered sixth formers, who form our intake, into competent and creative engineers. We achieve this by three stages: the purpose of the first two stages is to lead the students into the acquisition of skills needed to run an independent project (in the third and final year)."

The departments at Salford and Hull believe there should be a gradual destructuring of experiments leading up to an open-ended project. But whereas at Salford the lab was arranged so that students began project work in the first year, students at Hull first prepared for two years.

Unfortunately, the lack of available information makes it possible only to speculate on the origins and background to the disagreement in policy. It could be that the two departments disagree about basic educational aims of their programmes. Alternatively they might agree on the aims to be achieved but disagree on the most suitable teaching methods to attain those aims. It might also be that they disagree on both aims and methods. All I can say, with the information available, is that there is disagreement and this manifests itself in the organisation of the programmes and the design of the scripts. Moreover the disagreements, according to Lee and Carter's survey, appear to be widespread in British departments of electrical and electronic engineering.

Of course, it is not for the educational researcher to deny departments the right to differ in the design of their educational programmes. In my view, his task, if he wishes to make a useful contribution to the study of laboratory teaching and learning, must be to fully understand the nature of the disagreements. Indeed, if thinking about laboratory teaching methods and how students respond is to proceed coherently the teachers themselves must be clear about the issues they disagree upon.

1.4 The Study of Laboratory Work by Educational Researchers

In this section I try to understand better the nature of the disagreements discussed in 1.3 by moving away from accounts by teachers to consider the work of educational researchers who have concentrated on the laboratory.

I refer to the findings of three of the most prominent research studies: those by Lee (1969) on mechanical engineering laboratories; Tremlett (1972) who focussed on chemistry lab programmes; and Boud (1974) who concentrated on physics lab teaching. There are strong resemblances between the approaches used by all three researchers and also between their findings. Taken together, therefore, the three studies represent a tentative paradigm for enquiry into laboratories. Reviewing this work I shall therefore try to make clear the underlying assumptions since they have been influential in setting a pattern (albeit one with a short history) of educational enquiry.

Lee and Tremlett both began their studies with an extensive review of the published literature and together covered most of the articles on lab work published in Britain and American science and engineering education journals between 1955 and 1970.⁽⁵⁾ Both acknowledged widespread criticism of the lab and both offered as their main finding, the disagreements by teachers on what the aims of laboratory work should be. As Lee (1969) put it:

"An attempt to isolate the aims and educational objectives of practical and laboratory work by means of a literature search showed only that the writers' views on its purpose, aims and relevance were legion and disparate."

(5) These two studies can be considered as independent enquiries for although Tremlett reported his work in 1972 he did not seem to be aware of the research carried out three years earlier at Lancaster University by L.S. Lee. This may be because Lee's research was reported as an unpublished research thesis.

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In a similar fashion, Tremlett (1972) reported:

"The literature search has indicated that faculty views not only did not agree on the same laboratory aims for comparable courses in different institutions, but that disagreement existed within the same institution and even between faculty teaching the same laboratory class."

Having failed to gather from the literature an agreed list of lab aims, both Lee and Tremlett felt the need to pursue such a list and consequently carried out their own surveys.

Lee set himself the task of surveying the views of mechanical engineers in "responsible industrial positions" about what the aims of lab work should be. To begin with he constructed a list of sixteen possible objectives of laboratory work (shown below) from an inspection of the literature.

1. stimulate and maintain the student's interest in engineering
2. illustrate, supplement and emphasise material taught in lectures
3. train the student to keep a continuous record of laboratory work in notebook form
4. train the student in the formal reporting of experimental procedures adopted in laboratory practicals and the writing of technical reports
5. give the student training in the interpretation of experimental data
6. train the student to use particular apparatus, test procedures or standard techniques
7. provide closer contact between students and academic staff
8. stimulate the student's interest in 'design'
9. develop the student's skill in problem solving in the multi-solution situation

10. simulate the conditions in research and development laboratories
11. provide the student with a valuable stimulant to independent thinking
12. show the use of 'practicals' as a process of discovery
13. demonstrate the use of experimental work as an alternative to the analytical method of solving engineering problems
14. simulate under controlled and measured conditions certain field conditions so that important variables can be measured and deductions made from the measurements and applied to the field conditions
15. familiarise the student with the need to communicate technical concepts and situations to inform and persuade management to take a certain course of action
16. help the student to bridge the gap between the unreality of the academic situation as compared with the industrial scene with its associated social, economic and other non-scientific restraints.

Having sent the list to a two percent sample of the Corporate membership of the Institution of Mechanical Engineers he asked them (in one of several questions) to rate the aims in order of their importance. The result (based on a response rate of 59%) was that the mechanical engineers favoured the aims of laboratory work in the following order of importance:

1. to provide the student with a valuable stimulant to independent thinking
2. to help the student bridge the gap between the unreality of the academic situation as compared with the industrial scene
3. to familiarise the student with the need to communicate technical concepts and situations, to inform and persuade management to take a certain course of action

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4. to stimulate and maintain the student's interest in engineering.

Lee speculated briefly about the methods by which the four aims could be achieved and for which years of a student's undergraduate course they were most appropriate, but the main finding of the investigation returned to the educational aims of teachers. He concluded:

"This investigation underlines the view that criticisms of practical work in undergraduate mechanical engineering education arise because the aims and objectives of the different procedures are ill-defined and confused in the minds of academic staff... If practicals were planned as a whole to meet a clearly defined range of objectives chosen in the context of the teaching situation to be adopted, then practical work should become more meaningful and enjoyable for the student and the significance of course work assessment would become apparent to to academic staff." (6)

In Tremlett's study the same main points were emphasised. He too decided to carry out his own survey. First, to see "whether previous criticisms and lack of clarity over laboratory aims", highlighted in his literature review, "were still justified". A second, reason was to become aware of the "attitudes of teachers toward laboratory innovation". Aware of the low return rate of nationwide questionnaire surveys he sensibly decided to cover fewer institutions but in more detail. He personally visited chemistry departments in eight different higher education institutions and in doing

(6) Lee appears to subscribe to the view, expounded by the well-known advocate of behavioural objectives Robert Mager (1962): that if teachers do not say where they are going then not only will they not know if they are heading in the right direction but they will not even recognise it if they get there.

so interviewed 30 laboratory teachers and 6 professors or heads of department. Tremlett deliberately chose to cover all years of the three and four year chemistry courses, and talked to those teachers who happened to be available and willing to cooperate on the day of his visit.

The survey showed (not surprisingly) that teachers did indeed hold widely differing views on what the aims of laboratory work for chemistry students should be. Despite the great range of views however, Tremlett endeavoured to construct a list in ranking order of the four most frequently mentioned aims:

1. Develop manipulative, preparative and instrumental skills.
2. Illustrate and amplify the lecture material.
3. Stimulate thought through experimental interpretation.
4. Recognise the precision and limitations of laboratory work.

Tremlett commented that the acquisition of manipulative skills and laboratory techniques was thought necessary to be taught in the first year and emphasised continually until the final year. While, experimental interpretation should be emphasised only in the final year, together with greater emphasis on planning experimental work.

Unlike Lee, Tremlett provided an insight into the student view by interviewing 30 students (at his own university, East Anglia) covering all three years of the chemistry course. From his analysis of these interviews he concluded:

"...the opinion of students on the purpose and aims of laboratory experience differed significantly from those recognised by faculty...the majority of students strongly advocated laboratory work that allowed them to display initiative and originality in tackling chemical problems experimentally. These students sought more opportunities for investigatory laboratory activities rather earlier in the undergraduate course than the customary final-year projects."

From his survey Tremlett also found that the stated aims of a laboratory programme were often couched in very general terms:

"There seemed to have been no attempt to define laboratory objectives in a purposeful way. For such objectives to be meaningful it was considered by the author that they should be expressed in operational terms, to indicate what students should be able to do as a result of their laboratory experience."

Finally, Tremlett concluded:

"It is the author's contention that extensive criticism of undergraduate chemistry laboratory courses has arisen, in the past, because laboratory experience has not been developed under the guidance of clearly operational objectives... Greater clarity is considered by the author to be essential, both with regard to the purpose and the outcomes of laboratory experience. This clarity is necessary for faculty in order to guide the effective design and evaluation of appropriate learning material."

The implication following from both Lee's and Tremlett's investigations are that teachers should spend time defining exactly what they are trying to achieve in the lab; that they should then secure agreement on these aims with their teaching colleagues; and that these aims should be communicated to the students. The role of the educational researcher in all this is to devise ways and means to help the lab teacher better define what he is aiming to do.

In 1974 Boud of Surrey University adopted this role and, building directly on the work of Lee and Tremlett, proceeded to devise "The Laboratory Aims Questionnaire" which, he claimed, could be used to diagnose areas for improvement in science and engineering laboratories. From the published literature Boud (1974) listed 23 possible aims of physics laboratory work (many of them similar to the list of 16 devised by Lee) and submitted this to all physics teachers and first year students at Surrey. Specifically, each person was asked to indicate, for each aim, its importance on a five-point scale: its importance for (1) an ideal first year physics lab programme as they imagined it, and (2) the actual laboratory programme in which they were engaged. Boud's claim was that improvement of lab teaching could take place in two ways as a result of using the questionnaire:

"(1) If there is divergence between the ideal aims of a course as expressed by academic staff and the aims perceived by academic staff in the actual course, then an improvement in the course can be obtained by modifying it so as to bring its aims closer to the ideal aims.

(2) If there is divergence between the ideal aims of a course as expressed by staff and students, and if staff feel that their set of aims is the one to be pursued, then it becomes part of the teaching process to modify the ideal aims of the students so as to bring them into closer agreement with those of the staff."

The following is an example of the sort of result obtained from the questionnaire. For the programme in which the questionnaire was administered it was found that students rated the following aims much higher than did teaching staff:

- (1) to provide closer contacts between students and staff;
- (2) to simulate the conditions in research and development labs;
- (3) to show the use of 'practicals' as a process of discovery.

At the same time staff rated the following aims much higher than did students:

- (1) to train students in writing reports on experiments;
- (2) to familiarise the student with the need to communicate technical concepts and solutions;
- (3) to help the student to bridge the gap between theory and practical.

In the instance cited, one specific inference might be that students appear less prepared to get down to detailed work than staff would have wished. However, the main strength of the aims questionnaire is not in providing remedies to outsiders, but in enabling students and teachers to enter into useful dialogue about their programme.

Lee, Tremlett, and Boud all emphasised the need for teachers to make clear their laboratory aims. In my view this might well prove helpful but by itself will not necessarily lead to lab programme improvement.

Securing agreement among teachers on the aims of a first year lab programme; or closing the gap between ideal and actual aims; or bringing student and staff aims closer together; will not lead to improvement of the programme unless the aims can be successfully translated into practice. If the aims agreed upon cannot be so transformed then it would seem to have little relevance whether there is

substantial agreement or disagreement. I do not say it is a bad thing for teachers to reflect on the purpose of laboratory work rather, that this is unlikely to be sufficient for improving teaching and learning.

That much useful work can be carried out by the educational researcher in the domain of laboratory aims is evident from the work of Lee, Tremlett and Boud, but the three studies are themselves testimonies that there is another equally important research area.

The concentration of Lee, Tremlett, and Boud was with what should happen in laboratories but little was mentioned about what actually did happen in the lab. None of the studies contained any detailed analysis of what students actually did in the lab; the ways in which they proceeded through the instructional scripts; the opportunities that did or did not exist for student-student and student-teacher interaction; and generally the various ways in which students behaved.

1.5 Autonomy and Control: Differing Assumptions About Student Learning in the Laboratory

In one part of each of his interviews with teachers, Tremlett asked whether students undertook any research work. He found that in all eight institutions final year undergraduates were involved in less-directed forms of experimentation and "for many students this represented their first opportunity for a more independent approach." Tremlett pursued this:

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"Several members of faculty indicated that final year students had little idea how to pursue an investigation for themselves, when initially faced with their research project. It was therefore suggested by the author that some earlier experience of less directive laboratory work might help students in the transition from formal set experiments to the research project. In general, faculty considered this proposal reasonable, and appropriate to the students' second-year laboratory course as preparation for the research project."

Tremlett ventured further in his interviews and proposed the idea of including more investigatory work in the first year:

"This was opposed by some senior faculty, on the grounds that most first-year students would not be intellectually or technically ready for a less directive approach to experimentation. Senior faculty considered that the necessary basic laboratory skills should be introduced by formal experimental work before investigatory activities were contemplated. However, a number of junior faculty members supported the author's proposal, and suggested that less emphasis should be placed on learning techniques as ends in themselves."

To better understand the nature of the basic dispute - are students capable of benefitting from project work in the first year - I now examine a series of relevant discussions held in the United States.

In 1968 a four week workshop was organised by the Commission on College Physics (CCP) for teachers of physics laboratory work. The workshop followed in the steps of three previous conferences devoted to physics laboratory teaching (Eaton, 1954; Storrs, 1957; Burch, 1962). Each of these meetings had been critical of laboratory teaching; each group had discussed methods of improvement; and each had concentrated on trying to clarify exactly what the educational aims of the laboratory should be. The CCP organisers

considered that earlier conferences could be improved upon and this was apparent from their statements about the organisation of the workshop:

"No part of the agenda...was assigned to 'a fresh look at the pedagogical objectives of the introductory laboratory.' This was a topic that, on the basis of past experience, we thought it fruitless to approach head on. Yet we did recognise that pedagogical objectives must be implicit in and inseparable from the selection and design of experiments," (Caplan and Fowler, 1968).

This presented the workshop organisers with a dilemma:

"If we sat around discussing objectives, we could expect to end up with a series of philosophical, and perhaps even pontifical, declarations, some of them contradictory, and with no way to act on them. If we ignored the subject in favour of action, we would be avoiding a look at the basis for whatever action we took.

We hoped to resolve this by concerning ourselves not with what we physicists said laboratories were for, but what we seemed to believe they were for, as evidenced by what we said and did in the process of designing them."

Consequently the organisers invited several non-physicists to attend the workshop to "collect data on our objectives, analyse the data, confront us with it, and help us to go on from there." The outcome was a detailed account of the proceedings as seen through the eyes of two educational researchers (Parlett, 1968, Ivany and Parlett, 1968).

There was broad agreement at the conference that the conventional introductory 'cookbook' lab could be improved upon and the main discussion centred around what kind of alternative might take its place.

One of the conference participants had already suggested the "project Lab" as an alternative (King, 1966).

In this lab "students do some sustained experiment work at as nearly a professional level as possible in their field of interest." According to King:

"What counts is not that they (the students) learn specific techniques, or see this or that important principle demonstrated but that they should work on a reasonably extensive experiment in a field that they are enthusiastic about, and that they should get in and out of difficulties using all their faculties and training."

This in turn dictates the sort of experiments most suitable in the Project Lab:

"We feel that the best experiments start simply, yield data early, and develop extensive ramifications. Theoretical predictions and explanations should be possible, but the phenomenon should be sufficiently unfamiliar that neither students nor instructor knows all the answers in advance."

King summed up the student learning experience in a project lab in the following way:

"They have been involved early, with guidance available, in some stringy, chewy problem in their common field of interest. They have experienced in different degree the trials and satisfactions of the experimental physicist."

Although there was broad agreement at the conference to include some project work in the laboratory it was also "clear from people's off-hand remarks and informal comments, that there were variations and differences in emphasis between individuals, and at some point even marked disagreement" (Parlett, 1968). Parlett (the non-physicist observer) chose to concentrate on these disagreements. Analysing comments made during the four week workshop he was able to identify two central and contradictory classes of attitudes

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that were commonly held by the participating teachers.

To make his point Parlett (1968) caricatured both groups - one emphasising "autonomy", the other "control".

The physics lab teacher who emphasised control and favoured traditional lab work:

"...considers students should cover certain necessary and 'fundamental' parts of the syllabus, receiving a 'thorough grounding' in it. The lab should be arranged so that the student is taken through various operations, exercises, and experiences under careful supervision and on schedule. By the end, he should have been 'made to think', he should have learned what the instructor set out for him to learn, and he should have had thoughts and feelings, prescribed as being good for him."

The lab teacher who espoused autonomy and favoured project work:

"...considers that the student is 'best left to his own devices.' The student should come in and get some experience and have some fun.' The instructor's job is to provide stimulation, tools, and a rich environment in which to work. A student essentially organises his own learning, and does what he chooses. If he does not wish to, he does not have to."

In making this distinction, Parlett brings to the surface for discussion an issue which goes right to the heart of the disagreement between teachers about the introduction of open-ended project work. The comments made by teachers (despite the conference organisers' suggested veto) were effectively statements of educational aims. Again there was a distinction between those teachers who emphasised autonomy and those who emphasised control. Some were speaking in terms of the students "developing a feel-and-see vocabulary." Others were wondering how exactly the lab would reinforce learning of concepts presented in lecture

material. Some spoke of "playing around and getting to see" various phenomena, while others emphasised the necessity with experiments to put plenty of "physics into them" (Parlett, 1968).

Not surprisingly the teachers differed as to what educational aims they considered the introductory lab could achieve; they differed also on the most appropriate teaching methods to achieve the same stated aims. But, according to Parlett, the main disagreement was not primarily about either aims or methods, but how the teachers viewed what students were capable of and what they were not capable of in the lab. In other words the views of autonomy and control in teaching method seemed to reflect basic different beliefs that the teachers held about how students learned in the lab.

Further investigations revealed that these beliefs about student learning again split along the lines of control and autonomy:

"(One group of teachers) saw the lab as a means of controlled instruction - learning was thought to follow the lines of the teacher's carefully structured progression in the presentation of his material. Increments of knowledge are learned in an orderly manner: little parcels of knowledge are taken in, unwrapped, and assimilated, as they are delivered."

In contrast another group of teachers emphasised autonomy:

"(These teachers) saw the lab rather as an intellectual playground - learning was regarded as haphazard and ill-defined. Learning 'happens'; some even referred to it as 'learning almost by osmosis'. Another comment: 'They get hold of it, they can't do much with it, but so what? Later they probably will.' A student may or may not understand what

he is doing at any given time in its entirety. They will not understand it completely, but they will see it very clearly."

According to Parlett:

"The more autonomous view of learning was more inclined to emphasise involvement: if the students are having a 'hell of a good time' and are 'turned on' they will learn... 'Questions come out of the student when he gets involved.' Others, representing the more controlled view, were more likely to believe that 'generally it is not enough merely to allow the student to come into contact with phenomena'."

To understand the published literature and how it proceeds, the important point is not so much whether the distinction of autonomy and control precisely captures the different views but that it does exist. It suggests that disputes between lab teachers might stem from fundamental disagreements about the way in which a student derives benefit from a script of instructions. Two teachers who disagreed in fundamental ways about how students assimilated information in the lab, would not surprisingly disagree also about the most appropriate aims and teaching methods. The one follows from the other.

In other words, perhaps the main area of disagreement between teachers is in the differing models they have of how students respond to and benefit from laboratory teaching methods. This is not to say that each laboratory teacher has consciously worked out and can articulate his model of student learning. Nevertheless the models that they inevitably have, manifest themselves in one way or another in action. Indeed a lab programme itself embodies a model (perhaps a collective model) of student learning because the way in

which it is arranged, its organisation and script design, is not haphazard: it is deliberately designed to facilitate student learning.

.6 Analysing Educational Practice in the Laboratory

To sum up, little has been published on student responses in the laboratory. In accounts by teachers the laboratory has usually been described only in the barest details (Harris, 1977, is a striking exception). While articles have invariably been prescriptive, they have typically offered little evidence for the reader to judge the claims made by the author. Reference has rarely been made to what students in the programme think about it, what it demands of them, the opportunities it provides for interaction, etc. Indeed it has rarely been possible even to find out how many students participated in the lab programme described. (7)

This chapter has identified the need for an analysis of teachers teaching and students studying in the lab.

Recently this view has begun to receive encouragement in some circles. It was upheld, for instance, at a three-day meeting of eighteen laboratory teachers convened by the Nuffield Group for Research and Innovation in Higher Education in July 1973. During those discussions there were allegedly

(7) It is unlikely that this lack of analysis is confined simply to laboratory work. Assembling a bibliography in physics education recently Professor Edwin Taylor of MIT was forced to acknowledge "that, while articles treating the subject matter of physics are often helpful, good articles about how to improve the format of courses or how to analyse the context adequately to ensure that an improved format survives are in short supply," (Friedman, et al, 1976).

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many points of disagreement "and those with divergent views remained unconvinced."⁽⁸⁾ But there was concensus on at least one point:

"It was generally agreed tht a great deal more needed to be known about what went on in labs in order to obtain a better understanding of the effects of change...on the system into which they are introduced," (Nuffield, 1974).

One recommendation of the meeting was for several participants (previously involved in laboratory innovation) to prepare detailed case-studies of their work. Eventually the Nuffield Group published a book containing five such studies (Nuffield, 1976 a). Each provided a detailed account of the lab programme, its aims and organisation, and in the case of Brunel, some sample instructional scripts. While two of the studies presented no evaluation whatsoever of their scheme and appeared not to have attempted any, two others included student responses to a detailed questionnaire, and another one (carried out by a Nuffield member) presented a sensitive account of student views culled from several informal discussions and interviews.

This emphasis on investigating and reporting how laboratories actually function was apparent also in a recent study directed by Ogborn of Chelsea College. In 1972 a Higher Education Learning Project (HELP) was set up to examine several aspects of physics teaching and toward the end of the project Ogborn and a team of ten physicists spent a year investigating eight different first and second year

(8) The group first discussed a background paper on the aims of laboratory work; later they split into separate groups to discuss a range of different ways of organising lab work.

teaching laboratories (one member of the team also visited several final-year project labs).

The HELP project represents the most detailed investigation yet of undergraduate laboratory work in the United Kingdom. Throughout the study attention was paid to gathering student perspectives. It is encouraging that Ogborn and his team, reporting in 1977 (three years after the research reported in this thesis was begun), arrived at conclusions similar to those reached in this chapter. For instance, the rationale for their research effort:

"...grew out of the realisation that the problem was not to find or invent new ideas, but to understand better the consequences of various sorts of change. Few (teachers) were wholly satisfied by what they had, whether conventional or novel, so it seemed that a rather deeper study of the workings of laboratories of various kinds in different settings was needed," (Ogborn, 1977).

Briefly, the book of the study contains succinct outside accounts of five different laboratories, and small case-studies prepared by teachers of programmes at eight different universities. The main defect of the book, in my view, is that despite extensive presentation of the student view no overall explanatory framework or guiding concepts are offered in which the reader can place the many interesting issues raised. Even so the book is an important move in the right direction.

All in all the future now seems brighter. The need for more reflective portrayals by teachers, for instance, was recently acknowledged by the appearance of a new education journal "Studies in Higher Education." The journal has deliberately set about encouraging articles by teachers

on their teaching. Commenting in the first volume on papers included by four university teachers the editor R.A. Becher (1976), remarked that:

"Each (are) fairly specific, in that each offers a detailed account of a particular undergraduate course and how it functions. But these contributions are not merely descriptive. Each author is concerned to put the material in a conceptual framework and to present it as a case study which others can use to stimulate their thinking and to sharpen and clarify their teaching ideas. It is this feature which will be particularly welcome in future articles in the same genre. In contrast, purely anecdotal accounts, which offer their readers little scope for extrapolation to their own educational settings, are unlikely to be of sufficiently wide interest to merit publication."

I have argued in this chapter that, such case-study investigations, specifically those that highlight the students' intellectual experience, could usefully feed into the ongoing debate (and perhaps resolve some of the issues) about educational aims and teaching methods in laboratory programmes. At the present time, however, there is a great deal of uncertainty among researchers and teachers about how to proceed with this kind of educational analysis, what kinds of information will result, and how they will be able to use it. It is in this domain that I hope this thesis can break new ground.

CHAPTER TWO

THE APPROPRIATENESS OF AN ANTHROPOLOGICALLY ORIENTATED STUDY OF THE LABORATORY

2.1 Introduction

Following the principle that research problems should dictate the chosen method of inquiry (and not vice versa) I review in this chapter the literature of educational research for specific ways of addressing the research issues identified in Chapter One. Of particular interest is the work of those researchers who like myself have defined their task as wanting to understand educational programmes and gather information for the purpose of aiding programme decision-making.

In an early seminal paper educational psychologist Lee Cronbach (1963) attempted to define a new and rapidly emerging field of curriculum study:

"Evaluation is a fundamental part of curriculum development, not an appendage. Its job is to collect facts the course developer can and will use to do a better job, and facts from which a deeper understanding of the educational process will emerge."

Few would disagree with Cronbach's general description but his statement raises some important questions. How can we know an educational programme? What counts as evidence that a programme is working?

To date there is no agreement on the answers to these questions and this is clearly demonstrated by quoting two

of the most influential people in the development of theory and method in evaluation. According to Bloom (1970):

"Evaluation is concerned with securing evidence on the attainment of specific objectives of instruction."

In contrast, Stake (1969) suggests that:

"As evaluators we should make a record of all of the following: what the author or teacher or school board intends to do, what is provided in the way of an environment, the transactions between teacher and learner, the student progress, the side-effects, and last and most important, the merit and shortcoming seen by persons from divergent viewpoints."

Bloom and Stake differ in the information they seek in order to know an educational programme and not surprisingly they differ in the investigative methods and procedures they use.

In this chapter I critically examine the work of these and other educational evaluators for ways of thinking about how to analyse teaching and learning activity and come to know a laboratory programme. I do not limit myself to evaluation however, instead I draw upon a range of theoretical and methodological ideas and concepts used by investigators who work within what has become known as the anthropological paradigm of educational research.

2.2 The Objectives-Model of Evaluating an Educational Programme

In 1934 Professor Ralph Tyler and his colleagues at Ohio State University, began to devise what was later termed the "objectives model" of evaluation.

The model proposed by Tyler has been discussed many times and at great length but it is not an exaggeration to say that it formed the basis for a large majority of subsequent evaluation studies. Recently the approach has come under attack and is less fashionable, nevertheless it would be a mistake to underestimate its continuing influence. For instance, laboratory teachers who talk of evaluation, if at all, typically associate it with the testing of educational aims and objectives. Therefore, despite the already wide coverage it is important in this chapter - where I discuss alternatives to the objectives model - that there is at least a summary description of that model. According to Tyler (1949):

"The process of evaluation is essentially the process of determining to what extent the educational objectives are actually being realised by the programme of curriculum and instruction. However, since educational objectives are essentially changes in human beings, that is, the objectives aimed at are to produce certain desirable changes in the behaviour patterns of the student, then evaluation is the process for determining the degree to which these changes in behaviour are actually taking place."

Tyler's proposed approach to evaluation was combined with an approach to curriculum development. The combined model essentially required that a development team undertake five main steps:

- (1) Secure agreement on the aims of the educational programme to be studied or developed.
- (2) Express those aims as objectives and in terms of student behaviour that the programme is intended to produce.

- (3) Devise curriculum materials suitable for achieving the intended student behaviour.
- (4) Measure the fit between student performance and stated objectives.
- (5) Modify the curriculum materials until student behaviour matches the objectives.

The principal requirement of the evaluator therefore, was to devise or adapt psychometric tests to assess attainment of pre-specified objectives. However, he also performed other roles because successful performance of No. 4 depended upon the completion of Nos. 1,2 and 3. The evaluator was often expected to assist teachers and other members of the curriculum team, for instance, to translate general statements of intent into precise objectives.⁽¹⁾ In this chapter I concentrate not on the work of the curriculum team but the role of the evaluator.⁽²⁾

An attempt to classify educational objectives was first made by Bloom (1956) and later by Krathwohl, Bloom, and Masia (1964). They identified three separate domains of objectives: cognitive, affective, and psychomotor.⁽³⁾

(1) According to Mager (1962), the characteristics of a behavioural objective are (1) specification of the kind of behaviour which will be accepted as evidence that the learner has achieved the objective; (2) description of the important conditions under which the behaviour will be expected to occur; (3) description of how well the learner must perform to have his behaviour considered acceptable.

(2) For a detailed appraisal of the model as a means of developing curricular see Chapter Five and Chapter Six in Stenhouse (1975). Also see Shipman (1974) for an illuminating case-study of a curriculum development team at work.

(3) Bloom and his colleagues did not produce a handbook for the psychomotor domain. A taxonomy for the psychomotor domain was later proposed by Simpson (1967).

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Subdivisions were then made. The cognitive domain, for instance, was set out in terms of levels of understanding that proceeded from the simplest to the most complex. These were made such that all those using the material could communicate with each other about the specific objective as well as the testing procedures by which achievement could be evaluated.

Briefly, the intention behind the taxonomies was to facilitate exchange of information among teachers and researchers about the specification and evaluation of educational goals and intended outcomes (Beard, 1970). Specifically, the taxonomies drew attention to the possibility of using conventional items to tap a wide array of human behaviours (Taylor and Cowley, 1972 a). They did not escape criticism:

"There is an overlap between the levels and even between the domains; there are gaps; the examples quoted are too few, are usually too vague to be useful...the very format perpetuates the fallacy that cognitive and affective objectives can be attained independently of one another. Nevertheless, as the first attempt to identify some kind of structure and cohesion in a highly flabby area Bloom's taxonomies can still help illuminate curriculum discussions," (Rowntree, 1974).⁽⁴⁾

The taxonomies did not provide criteria for selecting objectives. They did, however, attempt to "provide a useful language for discussing the problem" (Mackenzie, Eraut and Jones, 1970).

⁽⁴⁾ For more extensive critical discussions of the taxonomies see the articles by Sockett (1971) and Pring (1971).

Perhaps the clearest example of what is meant by an objectives-model evaluation can be found in the research monograph by Lindvall and Cox (1970). Here the authors describe an educational programme aimed at individualising instruction in the elementary school. In summary, participating pupils in the IPI programme worked through sequenced units of instruction and in several subject areas. In mathematics, for instance, the pupils proceeded through twelve different units and each of the units were defined by a series of objectives or skills which were specified in such a way that the desired behaviour or change in pupil behaviour could be tested and measured. (5)

(5) Specifically, the IPI programme required that each time a pupil confronted a new unit of instruction, during any part of the school year, the teacher should have information about what that pupil did or did not know so that the student could be placed "in each learning continuum at the point commensurate with his performance level". The pupil was then expected to proceed at his own rate of progress demonstrating "proficiency in each skill prescribed by his particular instructional sequence".

Consequently, pupils were given four different types of test. A Placement Test was administered to all pupils at the beginning of the school year (or any new pupil entering the school). These were intended to provide information about the performance level of the pupil (in each subject) so that the teacher could determine the appropriate units for assignments. Three other tests were continually administered. For each unit there was a criterion-referenced Pre-test of the unit objectives. The results of these tests were intended to help define a pupil's learning needs. Curriculum-embedded tests (ECT) were then administered for diagnosing individual pupil performance and in order to identify the units and the objectives within these units for which instructional activities needed to be prescribed. Pupils then proceeded by working through each assigned skill in a unit attaining proficiency on the CETs for the objectives in his instructional sequence. When satisfactory performance had been achieved on all the objectives in a unit a Post-test was administered to re-assess performance on the unit as a whole. (Lindvall and Cox, 1970).

To sum up, in America in the mid-1950s large sums of money had begun to be invested in curriculum innovation and development. Although questions about the effectiveness of educational programmes had always existed, in the immediate post-Sputnik period of October 1957 these became more urgent because "more money and more people were being involved in the curriculum projects" (Taylor and Cowley, 1972a).⁽⁶⁾ In the United States, local and federal financiers as well as education foundations supporting a range of innovatory programmes were concerned about the return on their investments and all this led to widespread use of the objectives evaluation model; at that time the only such model available. (See Chapter Eight in Hamilton, 1976 a).

2.3 Objections to the Objectives Model

After its use on a national basis the objectives model soon began to receive critical attention. In 1963 Atkin made a plea for evaluators to "question some of the conventional wisdom that has been accepted for decades," and in the same year Cronbach (1963) wrote that "old habits of thought and long established techniques are poor guides to the evaluation required for course improvement."

Jenkins et al (1977) have since drawn together a range of critical attacks of the objectives model and Hamilton

(6) Educational innovation is not our primary concern in this review. For a discussion of the curriculum reform movement in America and Britain see Chapter Two in the book, 'Changing the Curriculum' (Macdonald and Walker, 1976). For a discussion specifically on the outcomes of these reforms see Chapter Five in Silberman (1970).

(1977) has added an historical perspective to these. (7)

It is therefore unnecessary to traverse the same ground and instead, I shall briefly discuss three main deficiencies in the objectives model which make it unsuitable to use as an approach for understanding teaching and learning processes in a laboratory.

(1) The first point centres around the issue of what data an investigator of an educational programme can usefully collect. In 1966 Hasting wrote that the concept of evaluation "must be broadened to include other sorts of venture beside those of collecting and summarising the test scores of students who have undergone a particular curricular treatment." The issue was later highlighted in a seminal paper by Robert Stake (1967) when he addressed the question: What information deserves attention in evaluation studies? Stake argued that the range of information collected by the objectives model evaluator was too narrowly defined and place unreasonable emphasis on student outcomes. According to Stake (1967) the subjective judgements of those participating in an educational programme and also those on the fringe should be considered legitimate data for collection.

The implications of all this for the investigator of a laboratory is that he might include in his research report information about the processes of the programme as well as its measurable products.

(7) In this paper Hamilton attempts to distill the ideas and developments in evaluation during the last 150 years. For another relevant 'historical' paper which examines the evolution of testing methods in evaluation see Hamilton (1974 a).

(2) Reliance of the objectives-model on the behavioural specification of educational objectives reveals a second weakness in the appropriateness of using the model to study a lab programme. A major problem faces the evaluator who attempts to gather a list of agreed programme objectives. Partly because "teachers seem not to take educational objectives seriously" (Eisner, 1967) and partly because even when they try to define their programme intents such specification is difficult. The latter view is highlighted below by an evaluator reflecting on his study of an electrical engineering programme in a department known for its interest in teaching and learning:

In one part of the research I attempted to generate a listing of course objectives. After talking with the staff individually on many occasions and even taking notes, I still found myself uncertain of what I was being told. For a group of people who were usually extremely lucid in communications, I found my notes nearly useless in drawing up the list. At any rate I constructed a list which best captured what I thought had been described to me and submitted it for criticism. Its semantic obscurity and, in some instances trivialism and inutility, was carefully pointed out. I offered another try, after taking almost verbatim notes. These were resubmitted but not acted upon until I urged action. Now my original statements were unwittingly paraphrased as being closer to the core of the objectives, and the list was regarded as clearer but unfortunately, if one were to try to create even a primitive rank ordering in importance, this would be wrong because many of the objectives were practically equivalent in importance and more importantly they were important along different dimensions, i.e. in different ways. Besides, any quantitative results would probably more reflect differences in semantic interpretation than anything else! Even direct quotes from the syllabus written by staff members, were rejected as inappropriate. Finally I wrote a letter to all the staff outlining my difficulties and eliciting their help in constructing the list (in writing); slightly over one-half responded," (Kahne, quoted in Parlett, 1972).

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Getting concensus therefore is a major problem and one that is acute in lab work (see Section 1.4). Specifying behavioural objectives in a way which truly represents actual teaching goals is another problem (see the critiques of behavioural objectives by Atkin (1968), Stenhouse (1970), and MacDonald-Ross (1973)).⁽⁸⁾

(3) There is a third deficiency in the objectives-model which limits its usefulness for adopting in the context of a lab programme. This is its inability to generate information which can aid programme decision-making (see House, 1973 a). Evaluators working within an objectives model have typically claimed to answer questions about what students learn, but have not even addressed questions about how they learn. Consequently such evaluation reports have avoided explanations about student learning which say, a laboratory teacher could use to change his programme. Recently on this issue a group of British evaluators reflecting on evaluation colleagues who tried to apply the objectives model, wrote:

"They soon found that the concerns of decision makers were not restricted to questions about learning outcomes. Teachers, administrators, and sponsors alike sought a better understanding of the...relationship between circumstance, action, and consequence... decision makers looking to implement innovations in specific contexts were not to be satisfied by actuarial generalisations about learning gains across many contexts", (Jenkins et al, 1977).

(8) As Stake (1972) put it: "no statement of programme objectives ever devised has come close to representing the real world intents of people involved in an educational programme...the unspoken objectives - such as safety in the classroom, sharing of work responsibilities, developing a sense of humour, a respect for rules, a tolerance of ambiguity, and so on are left to take care of themselves, at least until a crisis arises. Then these objectives pre-empt all others."

Criticisms of the objectives model just reviewed are neither new nor exhaustive but they do highlight several important reasons that make the model unacceptable for my purpose. There is a need for a suitable alternative.

The search for an alternative was also the concern of J. Thomas Hastings when in 1969 he addressed the National Council on Measurement in Education. His general theme was that:

"educational measurers have tended to be too restrictive in the techniques and points of view which they generally bring to the tasks they are attempting to accomplish in education."

He suggested that evaluators of educational programmes (and he included himself) were caught in a trap in which:

"...(we) having adopted the techniques of psychometrics and experimental design, tend to be more concerned with altering the problem so that it can be tackled by these techniques that we are with adopting and adapting techniques for attack on the complex problems... If our problem is that of getting information about interaction and relevant variables in the classroom or in the school, if we really want to know what is going on in order that value judgments can be made, it would seem that the field methods developed by Bronislaw Malinowski in the early 1900s...would afford an appropriate attack."

This view was to gain increased popularity among the educational research climate generally and evaluators of educational programmes in particular. There emerged what Parlett and Hamilton (1972) later called an "anthropological paradigm" in educational research and in the next two sections I examine the emergence of this paradigm and its relevance to a research study of laboratory work.

4 The Emergence of Anthropological Ideas in Educational Research

Bronislaw Malinowski invented the modern methods of ethnographic field work in the two years he spent on the Trobriand Islands from 1915-16 and from 1917-18. At the heart of the methods are assumptions about the nature of human activity and how best to understand it. In 1932 he wrote:

"The hasty field-worker who relies completely upon the question-and answer method, obtains at best that lifeless body of laws, quotations, morals and conventionalities which ought to be obeyed, but in reality are often only evaded. For in actual life rules are never entirely conformed to, and it remains, as the most difficult but indispensable part of the ethnographers work to ascertain the extent and mechanism of the deviations."

In line with these assumptions Malinowski proposed that investigators should collect three different kinds of data: (1) what people say about what they do; (2) what they actually do; (3) what they think. Behind Malinowski's concern with field methods therefore, was an awareness of the different layers of ethnographic reality and this was perhaps the hallmark of his work (on this point see the excellent discussion in chapter one of Kuper, 1975). Not surprisingly he believed in on-the-spot intensive observation. He was deeply suspicious of second-hand information and, unlike his contemporaries, rarely used professional informants. Right up to "the end of the nineteenth century, most anthropologist wrote from the armchair and relied for their raw data on material recorded by missionaries, explorers, travellers,

government officials, and settlers (Karberry, 1957).⁽⁹⁾

Malinowski challenged this orthodoxy.

In more recent times there has been a very similar challenge (and for similar reasons) to the orthodox methods used to study human activity in educational settings. In 1968 Myron Atkin, a leading American educational innovator, reflected on traditional styles of educational research:

"Let me take a first stab at identifying a major reason for the fact that educational research seems to have had little impact on the classroom... The models of educational research currently in vogue are rooted in "scientific" approaches - inquiry models that are based strongly on empirical, hypothesis-testing techniques... As a direct result of this research bias, we usually find that problems in education that are investigated turn out to be either trivial, or they bear little relevance to classroom practice.

The triviality often results from the strong reliance in much psychological experimentation on "hard" measures of behavioural change. Inasmuch as we have not yet learned to assess behaviourally some of the most important educational changes for which we strive, the sophisticated research models that are used manipulate insignificant variables. The researchers keep refining their procedures, largely but not exclusively statistical procedures, seemingly unaware of where the crucial problems lie. An elaborate research methodology has evolved around the investigation of inconsequential events," (Atkin, 1968 b).

More recently Hamilton and Delamont (1974) commented in the following way about British educational research:

(9) The most famous armchair anthropologist was Sir James Frazer who surprisingly enough was a mentor of Malinowski's (it was the reading of Frazer's 'The Golden Bough' that stimulated the Polish student's interest in anthropology). According to Leach (1974), Frazer was "a man of monumental learning who had no first hand acquaintance with the lives of the primitive people about whom he wrote. He hoped to discover fundamental truths about the nature of human psychology by comparing the details of human culture on a world wide scale." In contrast Malinowski "spent most of his academic life analysing the results of research which he himself had personally conducted...in a single village in far off Melanesia. His aim was to show how this exotic community 'functioned' as a social system and how its individual members passed through their lives from the cradle to the grave."

"Ten years ago Medley and Mitzel (1963) characterised the 'typical' research worker in the field as someone who 'limits himself to the manipulation or study of antecedents and consequences...but never once looks into the classroom to see how the teacher actually teaches or the pupil actually learns.' This characterisation could still have been applied in Britain until the end of the 1960s."

During the last decade however, a shift in emphasis has taken place in educational research. Many investigators have begun to immerse themselves in the educational settings they study and have turned to the methodology of social anthropology for appropriate ways of proceeding (see the literature reviews by Sindell (1969) and Walker (1972)).

A claim most often made by educational researchers who adopted the interviewing and observation techniques of ethnographic field work was that they could gather important information about teachers and students in an educational programme which would be impossible using the more traditional techniques of systematic observation (Flanders, 1970); survey analysis (Maser and Kalton, 1971); controlled experiments (Campbell and Stanley, 1967); and, of course, the objectives model described in Section 2.3.

At the forefront in adopting ethnographic methods and inspired along the way by the work of Jules Henry (1971), have been classroom researchers. Those who had ventured into the classroom to use the systematic observation techniques of Flanders were primarily concerned with the behaviour of teachers and student, with what they did (and said). In contrast, classroom researchers using ethnographic fieldwork though interested in what teachers and students said and did, were equally concerned (following the lead of Malinowski)

with what they thought about their actions. Example classroom studies using interviews and observations in the field can be traced through the work of Hargreaves (1967), Lacey (1970), Smith and Keith (1971), Hamilton (1973), Nash (1973), and the studies included in Stubbs and Delamont (1976).⁽¹⁰⁾

Also prominent among investigators who adopted the methods of ethnographic field work were educational evaluators (Wilson, 1974). Briefly, many evaluators at the beginning of 1970 were fed up with the orthodox methods of the objectives model and sought to collect more comprehensive information about the educational programmes they were charged with evaluating (see Section 2.3). Criticism of the objectives model did not centre exclusively upon methodology of course and there were also objections to it on epistemological grounds (Jenkins et al, 1977). However, what began to emerge (traceable through the contributions of Stake (1967), Scriven (1967), and Eisner (1972)) was what House (1973) later described as a "counter-movement in evaluation."

The year of 1972 was important in the emergence of the countermovement. In that year, for instance, Robert Stake proposed an alternative model of evaluation which he called "responsive" (for a later discussion of this see Stake, 1975), also in that year Parlett and Hamilton suggested "illuminative evalua-

(10) An excellent example of what it means to carry out ethnographic fieldwork in the classroom can be found in the work of Smith and Geoffrey (1968: Smith (the researcher) worked in conjunction with Geoffrey (the teacher). During the long period when they studied the complexities of an urban classroom Geoffrey wrote fieldnotes after teaching every day and Smith wrote continuous records during class time (he was present for eighty percent of one full semester) and then dictated more general summary observations and interpretations after school.

tion," an approach (like Stake's) favouring the methods of ethnographic fieldwork and residing in what they termed the "anthropological paradigm" of educational research. At a meeting convened at Churchill College Cambridge in December 1972 (and funded by the Nuffield Foundation) both approaches were discussed by fourteen participants "chosen for their known reserve about established (evaluation) practice, or because they had suggested or experimented with new approaches" (MacDonald and Parlett, 1973). One major outcome of this meeting was a book of readings on alternative approaches to educational evaluation (Hamilton et al, 1977).

Around the same time, in November 1972, another small group of researchers and teachers (with financial support from the Rockefeller Brothers Fund) met at the University of North Dakota to discuss alternative methods of evaluation (although meeting within one month of each other and for the same main purpose neither gathering, as far as I know, were aware of each other's existence). Consequently, the North Dakota Study Group on Evaluation was formed. This group soon began publishing a series of monographs (see especially 'Alternative Research Paradigm' (Patton, 1975)) and developed an approach they call 'Utilisation Focussed Evaluation' (Patton, 1978). Other 'alternative' approaches were subsequently proposed (see "transactional evaluation" (Rippey, 1973), "goal-free evaluation" (Scriven, 1973), and "democratic evaluation" (MacDonald, 1975)), all utilising ethnographic

fieldwork as a major method of collecting information. (11)

To sum up, ethnographic field techniques of interviewing and observation (traceable back to anthropologist Malinowski) began to be used by a variety of educational investigators and the general methodological rationale, for the first time, assumed some respectability as an appropriate line of inquiry for seeking previously neglected information about teaching and learning activity in educational programmes.

Characterising the Research Approach

In the previous section I lumped together those pursuing investigations in the anthropological paradigm. There is a common thread in their work. They tend to share the "Naturalistic-Ecological Perspective" and the "Qualitative-Phenomenological Hypothesis" quoted by Wilson (1977 a), (12) they are also in broad agreement in their attack on common enemies (for example, the objectives model). At the same time, they have different major concerns (programme evaluators, for instance, are generally less interested in developing educational

(11) For an analysis of the theoretical assumptions underlying both traditional and alternative approaches to evaluation see House (1978).

(12) Wilson (1977 a) has defined these as follows:
(i) The naturalistic-ecological hypothesis: "Human behaviour is complexly influenced by the context in which it occurs. Any research plan which takes the actors out of the naturalistic setting may negate those forces and hence obscure its own understanding."
(ii) The qualitative-phenomenological hypothesis: "Human behaviour often has more meaning than its observable 'facts'. A researcher seeking to understand behaviour must find ways to learn the manifest and latent meanings of the participants, and must also understand the behaviour from the objective outside perspective."

theory than are classroom researchers), and even those evaluators described as belonging to the 'countermovement' differ on important issues such as the degree to which the investigator should interpret data rather than leave it for the reader; the extent to which the investigator should intervene in a programme; and the amount of flexibility that should be built into the design of a study.

In the absence of previous anthropological-type studies of the laboratory, I have borrowed extensively from a range of different sources and it seems appropriate therefore to spell out the key methodological and theoretical ideas and concepts that emerged as I got into the study and guided its development.⁽¹³⁾ The following four main features serve to characterise the adopted research approach:

- (1) Responsive
- (2) Heuristic
- (3) Interpretive
- (4) Holistic

The stance I have taken on these issues is briefly discussed in the following section. The specific ways in which I was able to translate this general stance into practice represents a major part of the thesis and is described throughout the following chapters.

(1) Responsive

To date there is a distinct ~~lack~~ of empirical studies of laboratory teaching and learning. There is no growing body

(13) I can find only one reported investigation of lab work in which the researcher used the methods of fieldwork. This was a one-term study of an electronics project laboratory at the Massachusetts Institute of Technology (Parlett, 1968).

of theory pointing to the salient variables and issues that most need attention. At the present time therefore it seems sensible that investigations of laboratory teaching and learning should be exploratory. If this is so the researcher needs to suspend early judgement about the lab and be guided by what he discovers. In Bob Stake's (1974) terms the study should "orient more directly to programme activities than to programme intents".

In other words the researcher in the lab needs to proceed responsively. The guiding assumption is that if a study of the lab is to be of interest and use to those charged with making decisions about the programme then the researcher must immerse himself in the world of the lab participants and spend his time finding out about their problems, needs, questions, and concerns. ⁽¹⁴⁾ As Bohannan puts it:

"(the researcher)...must be somebody who can learn on the spot - in what is to her a strange situation - with her entire sensing and learning apparatus. Her job is to learn and report what 'they' do and what 'they' say about their way of life, as entire as she can manage it. Learning in an ethnographic situation is not like learning to be a scientist, where there is a body of knowledge to be mastered. She must learn, rather, whatever it is that these people want to teach her. What they want to teach her is the most significant part of her data," (Bohannan et al, 1974).

Proceeding responsively in this way the intention is not to structure the study in order to test, apply, or even develop formal theory in the usual sense; instead the idea is to construct an appropriate "interpretive framework" (Jamieson et al, 1977) in order to make the examined teaching

(14) The Symbolic Interactionists have much to say on this point. See especially Blumer (1966) and also Manis and Meltzer (1967).

and learning issues more comprehensible to those concerned. In other words, the researcher aims to develop a theory of the situation being studied in much the same way as Glaser and Strauss (1967) have described the development of "grounded theory" in sociology.

(2) Heuristic

If the researcher is to respond to the concerns and perceived problems of teachers and students in the lab he requires a research design that is flexible rather than rigid. Consequently the study of laboratory teaching and learning needs to be organised heuristically with the researcher focussing and re-defining the area of inquiry as the study unfolds in the light of accumulating experience and as "significant features" become uncovered (Parlett and Hamilton, 1972).

The notion of progressive focussing is the key concept here:

"In the course of a study, investigators 'focus progressively' on particular areas of concentration. In other words, they select among events, topics, questions, ideologies, and trends being discovered and allocate more attention to these," (Jamieson et al, 1977).

Progressive focussing performs two main functions. First, in a laboratory, as in other social organisations, these are likely to be consequences and implications that are difficult to anticipate beforehand. Unanticipated effects though difficult to plan for are important to address. Proceeding heuristically enables the reseacher to respond to those issues that emerge even near the end of a study and thus allows them to be given due weight in the report. It also serves a

second more pragmatic function in that it helps the researcher cope with the inherent complexity of educational programmes. Beginning with an extensive data base the researcher progressively focusses on the 'emerging issues' and by doing so reduces the problem of data overload by preventing the accumulation of a mass of unanalysed material. Not surprisingly, this facilitates the writing of an intelligible and manageable report. A key feature of progressive focussing, therefore, is progressive distillation of data (Dearden and Laurillard, 1977).

In the explanation of "grounded theory" Glaser and Strauss (1967) have suggested that the "significant features" of the situation being studied emerge very quickly. The danger facing the educational researcher who adopts this concept, is of focussing either too late or too early. Kemmis (1973) draws attention to the latter:

"The choice of a set of observation categories serves to direct attention to a number of features one might regard as important in a situation; but it will also close out other possibilities of observation. And each set will yield a somewhat different picture of the situation."

There are two ways in which this can be avoided. First, observations should proceed responsively in the light of the uniqueness of each situation. Second, the researcher should follow the lead set by his sociologist colleague in the sense of triangulating data (Webb, 1966). In doing this the researcher will use different approaches (interviews, questionnaires and observation) to view the same problem, and will thus be able to check, modify, or redefine, the significant issues.

An example of how researchers working within an anthropological paradigm used the concept of progressive focussing can be found in the article by Smith and Pohland (1974). Throughout their study of Computer Assisted Instruction (CAI) in an American school "the 'particular circumstances' surrounding the CAI project modified the direction of our inquiry." They made a special effort to build flexibility into their research design. Consequently the final product was "only partially a result of the initial problem statement. The problem evolved as events in the real world played themselves out."

(3) Interpretive

Most researchers working within an anthropological paradigm place a high priority on accurate and full descriptions of the educational programmes they study. Consequently the notion of "portrayal" of an educational programme has emerged to support this stance (see Kemmis (1973), Stake (1974), and MacDonald (1976)).

Smith and Pohland (1974) have offered seven reasons why they as investigators of educational programmes emphasise the "descriptive narrative" in their reports. Each I consider to be appropriate to the study of lab work:

"Firstly a careful, thorough-going descriptive account is a prerequisite for grounded theory...the presence of a carefully documented narrative seems to correlate closely with credibility....

Second, the utilisation of theory for the solution of practical problems in education is very important... This requires a fairly intensive descriptive account, particularly since teachers and educational administrators tend to think in situationally specific terms...

Third, (this kind of theory is) a substantive rather than a formal theory...more closely tied to a particular setting and the requisite description of that setting.

Fourth,...when an investigator begins his work, he does not know the full range of theoretically relevant concepts...A concept of theoretic relevance might be only dimly perceived or perceived not at all at the beginning. Again, this suggests the necessity for a detailed descriptive account. Given the choice of an overabundance of data containing much chaff but a potentially dense data base, or a choice of little chaff but a potentially thin data base, we opted for the former.

Fifth, (there is) the possibility of integrating data obtained from one study with that of other studies... The richer the descriptive account of each study, the easier and potentially more fruitful this cumulative effort can become.

Sixth, (teachers in training) go into the kinds of settings that we have been studying. Once again this provokes a need for a more careful view and descriptive account.

Seventh,...in working with a number of students and others who have used and/or wanted to learn the method there is often a good bit of anxiety about the way the method works. The descriptive or narrative job, while difficult to write in an interesting and lucid style, is, at least initially, an easier place to begin. Only after one has struggled a bit with the description and begins to see the possibilities of organizing and abstracting from such concrete materials the broader ideas, concepts, hypotheses, and models can one move freely and well."

Despite the importance placed upon accurate and full description there is, in my opinion, a need for the researcher to go further and offer the decision-maker his interpretation of events. In this respect therefore, I am in disagreement with the "honest broker" role (MacDonald, 1975) in which the investigator gathers participants' definitions of the programme so that each person can find out what others think about it. According to the "democratic" evaluator it is his job to gather these views, not to put them into an interpretive framework.

In this thesis there is a place for attempting to attribute cause to the teaching and learning activity observed in the lab. This is an extremely difficult part of the researchers work but one he should not eschew.

An important assumption underlying the adopted approach is that the reality of a laboratory programme is not all there simply waiting to be located, measured, and rendered as findings. Enough is known from the work of participant observers of classrooms that meaningful relationships have to be discovered (see Bruyn, 1966). In this respect the approach has a commitment to interpretation of data in much the same way as does illuminative evaluation (Parlett and Dearden, 1977), and also functionalist anthropology before it:

"The principles of social organisation, of legal constitution, of economics and religion, have to be constructed by the observer out of a multitude of manifestations of varying significance and relevance. It is these invisible realities, only to be discovered by inductive computation, by selection and construction, that are scientifically important in the study of culture," (Malinowski, 1935).

So it is with a laboratory programme. The invisible realities, I assume, are often some of the most significant for understanding laboratory teaching and learning, and they therefore need to be discerned and drawn out.

(4) Holistic

The adopted approach aims to study educational practice as it occurs naturally in the real life setting of the lab (a stance similar to that previously advocated in sociology by Denzin (1971) and Shatzman and Strauss (1974). Proceeding in this way the researcher attempts to view the educational programme as a whole. No attempt is made to impose artificial conditions or simplified categories. The actions of both teacher and student are investigated in all their natural complexity. The guiding example here is Paulo Friere's methodology of thematic investigation: "When men lack a critical understanding of their reality, apprehending it in fragments which they do not perceive as interacting constituent elements of the whole, they cannot truly know that reality. To truly know it...they would need to have a total vision of the context in order subsequently to separate and isolate its constituent elements and by means of this analysis achieve a clearer perception of the whole," (Friere, 1970).⁽¹⁵⁾

To study teaching and learning holistically, however, also follows directly on from Malinowski's view of cultures as integrated wholes which should not be torn apart for the

(15) In his search for educational knowledge Friere (1970) commits himself not only to holism but also, as I have, to heurism and interpretation. "Equally appropriate for the methodology of thematic investigation and for problem-posing education is this effort to present significant dimensions of an individual's contextual reality, the analysis of which will make it possible for him to recognize the interaction of the various components. Meanwhile, the significant dimensions, which in their turn are constituted of parts in interaction, should be perceived as dimensions of total reality."

purposes of comparative study. According to Leach (1957), the special distinguishing characteristic of Malinowski's field technique "lies in the theoretical assumptions that the total field of data under the observation of the field worker must somehow fit together and make sense." To fragment laboratory teaching and learning activity into variables or operationalise and quantify at all costs, may be regarded as appropriate for many research investigations, but can lead to the investigation becoming divorced from the more down to earth perspectives of practitioner and decision-maker which are essentially and inevitably more holistic (House, 1973a).

In the next chapter I discuss how the adopted approach influenced the way in which I collected data.

CHAPTER THREE

STRATEGIES FOR COLLECTING FIELD DATA

Introduction

In the preceding chapter I identified a general research approach suitable for analysing laboratory teaching and learning. Those who have previously pursued educational research work in the anthropological paradigm have so far been remarkably silent on details about how they proceed on a day-to-day basis in their work.⁽¹⁾ Consequently it has been difficult for newcomers attracted by the general methodological and theoretical rationale of such studies, actually to know how and where to begin.

The chief purpose of this chapter, then, is to de-mystify the collection of fieldwork data for the benefit of researchers, especially those interested in carrying out future laboratory studies.

Ethnographic fieldwork as a method for gathering data has a long tradition in sociology and an even longer one in social anthropology: helpful discussions of the approach in the former (under the name of participant observation) can be found in McCall and Simmons (1969) and Shatzman and Strauss (1973); outstanding in anthropology are Malinowski's opening

(1) The striking exception to this rule is Louis Smith. His reports invariably include large sections which reflect on the methodology used, and attempt to extend and refine what he has called "classroom microethnography". See, for instance Smith and Geoffrey (1968), Smith and Brock (1970), Smith (1973), Smith and Pohland (1974).

methodological chapter in 'Argonauts of the Western Pacific' (1922) and his concluding discussion of field-method in 'Baloma: The Spirits of the Dead' (1916). While these accounts are helpful to the educational researcher, the methods used in sociology and anthropology are directed toward different ends and are therefore not immediately transferable to educational settings. At the present time there are no handbooks for training researchers in anthropological kinds of educational study. However, one solution (attempted here) is for researchers to produce a methodological discussion to accompany their evaluation or research report.

An influential and helpful book by Shatzman and Strauss (1973) ('Field-Research: Strategies for a Natural Sociology') gives advice to the novice field researcher on the impression he should create. Yet even here the guidance is general and difficult to translate into action:

"The researcher is a learner, has patience, is tolerant and sympathetic. He wonders first and judges last: he appears to be that way, and is that way. Furthermore, he generally accepts whatever he sees and hears at face value; he denigrates no motives. He does not visibly take sides on arguments among members no matter how much he may be invited to do so. He is open to the discovery of whatever is not so obvious to others. He is most considerate, polite, but not shy; he is in fact, rather tough in the sense that he cannot be put off for too long, nor shamed or coerced. He cannot be bought off or drawn into private arrangements, even to gain the data he needs. He assumes that the hosts would have it no other way."

That in practice it is not always easy to fulfill these suggestions will be evident in the discussion that follows. The chapter draws on methodological experience gained during

a study of the first year electrical and electronic engineering laboratory at Surrey University and also describes, in part, how the study was carried out.

Background details of the Surrey programme include the following: it is organised into separate three hour weekly sessions. Each student attends sixteen such sessions over two academic terms, working through a different experiment each time. To make best use of the limited available equipment the class of students are split into two groups. One group attends the lab for three hours each Tuesday, the other group each Friday. In each session there are three supervisors available for consultation (two members of the teaching staff and one research student). Students are expected to work through their designated experiment with a partner and each supervisor typically takes responsibility for four groups of two students.

The first year lab programme was studied for two consecutive years. In academic session 1975-76 I acted simply as an outside educational researcher. In 1976-77 the extent of my participation increased and I combined the role of researcher with that of a lab supervisor. Almost all of the raw data included in this thesis derive from the year as full-time researcher. This is a deliberate policy. For purposes of clarification I do not wish to keep switching from year to year, involving stating for each interview extract or related observation which year it relates to. The concepts and theoretical formulations are, of course, a result of continuous thinking throughout the two years work.

A secondary purpose of this chapter, then, is to act as a prelude to the case-study of Chapters Four, Five, and Six, by making clear the procedures used to begin the research and collect conversational and observational data. Three different areas of fieldwork are discussed. These are: (1) Strategy for Entering; (2) Strategy for Getting Organised; (3) Strategy for Recording Observations and Conversations. In each case, specific details of my experience are included and mixed with some general reflections on the methodology of fieldwork.

Strategy for Entering

When an anthropologist begins to study a culture, a major part of his early work is necessarily devoted to learning the indigenous language. One advantage in investigating an electrical and electronic engineering laboratory was that I already knew the jargon. I had studied the subject as an undergraduate and because of this thought I would be more acceptable to lab teachers, in fact this turned out to be the case.

If someone trained as a sociologist or psychologist was studying an electronics lab they would have to understand student talk such as: "getting a DVM to measure the noise in dBs" or "I got stuck when we had to use the AVO on the op-amp". Because I knew the jargon I was able to proceed without too much hinderance in the early stages of the study - a period (see Section 4.4) of enormous influence to the students and therefore of particular significance to the researcher.

While there were some advantages in having a specialised knowledge of the subject there were some disadvantages too. Much of what I saw in the lab seemed all too familiar from my own undergraduate days (though I attended a different university). This was not an insignificant issue because one part of what I wanted to study were the taken-for-granted practices and conventions of the lab.

I took two steps to prevent my 'insider' perspective from closing off too much data. First, simply being aware of the problem kept me on guard. Second, throughout the first term I invited (with the prior permission of the lab supervisors) five fellow research students into the lab, one at a time and in different weeks, and asked them to observe the lab for approximately ten minutes then go away and write down their general impressions. These colleagues came from backgrounds in chemistry, physics, mechanical engineering, mathematics, and linguistics. One of the consequences of these 'outsider' reports was to sensitise me to the lack of interaction between groups of students, a phenomenon I had not noticed, though it stood out to four of the five observers. (2)

(2) For the interested researcher, I include here something about the extent of my experience before embarking on the investigation. In the twelve months prior to the study I spent the majority of my time surveying the literature on laboratory teaching methods (in order to identify a useful research problem) and also the educational research literature (in order to identify an investigative approach appropriate for the problem). Beside attending a part-time MSc course on social research methods the rest of my time was spent investigating a first year physics lab programme at Royal Holloway College, University of London. This programme had just undergone a period of substantial innovation initiated by a teacher at the college and an educational technologist from my own research institute. Both invited me to evaluate their programme, and provided support and encouragement while I gained experience in interviewing, observation, and questionnaires.

At the beginning of the 1975 summer term I made contact with a senior lecturer in the Electrical and Electronic Engineering Department. I outlined to him my background and research interests, explained my interest in investigating a laboratory programme, and asked for suggestions about how best to proceed in arranging such a study. Ten days later he set up a meeting between himself, the directors of the first and second year laboratory programmes, and myself.

Throughout the discussion I emphasised that the purpose of studying the lab programme was not to pass judgement on it (or its participants), rather it was to understand how it worked. I wanted to dispel any notion about me being some sort of spy or inspector. I described the general aim (which remained the same throughout the research) of gathering information suitable for aiding the programme decision-making of teachers of introductory laboratories. I assured them that some sort of feedback procedure for teaching staff would be included. At the same time I probably did not allay all their natural suspicions. (3)

The teachers did not seem to have a high regard for educational research and were skeptical that an investigation could be geared to their concerns and prove useful. At this

(3) At one point in the discussion when the second year lab director finished a five minute's description of the experiments, I asked him what seemed like a good question at the time: "What are the aims of the course?". Straight away I could see I had made him feel uncomfortable. Perhaps he felt I would be wanting to test whether his programme 'outcomes' matched his aims, which of course I did not. Fortunately the teacher recovered to make a light moment out of it, "I suppose my main aim is to get the students to turn up." I was relieved and made a mental note to correct his wrong impression at some later date.

stage, I decided I had gone far enough and should not enter into other questions about confidentiality or access to lab programme documentation etc. It was agreed that I should write an account of the meeting and circulate it to those involved.

In the event, both directors (of the first and second year labs) offered to allow me to study their programmes. I restricted myself to the first year programme and this proved to be a wise decision. I was to find that in qualitative educational research it is easy to bite off more than one can chew (Parlett and Dearden (1977), Chapter Fourteen). To have studied both programmes would have necessarily meant exploring each in less depth and detail.

Strategy for Getting Organised

Before the start of the 1975-76 academic session I had two further meetings with Dr. W. (the first year lab director). He explained about the programme's history, the innovatory assessment scheme, their previous difficulties, and present aspirations. At my request we also resolved to what degree the head of the department should know about my project; that I should take steps to contact the other five prospective lab supervisors to briefly explain the proposed study and my role in it; and that I should introduce myself to the fifty-three students when they met in the first week of term for an introductory talk on lab work.

At this stage I still couched the aims of my proposed study in general terms. I did not want to prejudge the important issues. I did have interests, I was personally

interested in the new system of assessment, but overall my main concern was to find out how the students and teachers who participated in the programme made sense of it. Fortunately, this 'open brief' did not seem to trouble Dr. W. or the other supervisors. In discussions with all the laboratory supervisors I made several points clear, that: (1) my work would involve visiting the laboratory sessions each week; (2) I would be interviewing students in the evening; (3) I would take care not to disturb the work of students in the lab; (4) I would treat the information I received in a way such that it would not be traceable to specific individuals. All these points were agreed upon and it seemed inappropriate for me to write all this down in terms of a formal contract for them to sign. Of course my situation was different from, say, an evaluator carrying out a commissioned study. For a strict evaluation the client would no doubt have designated specific decisions he wanted help with, and specific parts of the programmed to be focussed on. In that case the investigator would need to spend considerable time before the study negotiating boundaries about what he would and would not be willing to get involved in. (4)

Having made clear to the supervisors my intentions I wanted now to speak to the students and toward the end of an introductory lab talk which all students attended (and which is explained in detail in Section 4.2) I went to the

(4) Over the years Parlett has increasingly emphasised the importance of contract setting in evaluation studies. A good example of a study in which such a contract proved useful is described in the article 'A study of two experimental programmes at MIT' (Hamilton et al, 1977).

front of the class and introduced myself. I spent some three or four minutes saying that I was not an electrical engineering teacher but that I had studied the subject and that I was now a post-graduate student studying for an educational research degree:

"What I am interested in are your views of the programme, and what I intend to do - with your permission - is perhaps talk to you briefly during the lab and maybe for longer sometimes outside the lab...I should add that the information you give me will be treated as confidential to me and although it may be used to improve the programme for next year, and perhaps this year, nothing will be reported back to teaching staff in any way that might identify you."

During this early stage of the study I deliberately underwent those student experiences in the three-day departmental induction period that related to lab work. For instance, the morning after the introductory talk when students were taken on a tour of the departmental laboratories, I joined one of the groups and afterwards lunched with two of the students. In the evening I joined two other first year students in the refectory for dinner. Throughout the study I took every opportunity to socialise with the students. The talk during these informal conversations did not always stay on academic matters, nevertheless discussion frequently did touch upon the lab and the course in general and this facilitated broader insights into issues such as the students' worries; their early aspirations toward experimental work; their recollections of school laboratory work; and their reasons for coming to university and studying engineering. Such conversations proved fascinating, enjoyable, informative, and in retrospect invaluable in

helping me get an overall sense of the students social and academic contexts and how they related to those contexts.

On several occasions during the early lab sessions I was at pains to reinforce to supervisors and students my role (as I saw it) of being a non-partisan, objective, non-prescriptive, interested collector of viewpoints. A related difficulty I experienced during this time was to stop myself helping students with problems they asked me about. I had made a deliberate policy decision of not getting involved with experimental problems students posed to me in the lab. This was partly to avoid confusing the role of teacher and researcher. Time spent teaching would be time away from observation. I also felt that if I got involved, other supervisors might feel I was poaching.

When students approached me with some difficulty I reminded them that I was not supervising, however I would then try to help by telling them I would go and get the supervisor for them. Gradually, as the weeks went by, students did not ask me anymore. On one occasion, however, I deviated from my policy and got into trouble. In the morning of the fifth Friday laboratory session a student I was passing asked me about his oscilloscope. He quickly explained about getting one waveform instead of the two he expected. I looked around for the supervisor but he was busy. I could see that the only problem was that the volts/cm switch was set too high causing one of the waveforms to appear too large. I pointed out that I was not supervising but then set about explaining why he had a problem. It became apparent during our conversation

that neither the student nor his partner knew how to use the oscilloscope to measure either voltage or frequency (the basic use of the instrument), yet in the experiment this knowledge was obviously assumed. I later mentioned this incident to the lab technician. He was not as surprised by it as I. Unfortunately, he later mentioned it (in my absence) to the lab supervisor who gained the (wrong) impression that I was complaining about his teaching. The technician and I then had to explain that that was not what I had meant. This sort of mix-up can of course always happen, but in this case it resulted from me being drawn into a role which I had not earlier negotiated and got clearance on.

4 Strategy for Recording Observations and Conversations

Recording Observations

The observation of a functioning educational programme while fascinating, inevitably leads to two separate major problems for the researcher.⁽⁵⁾ He must decide what to observe (see Chapter Four) and how to best go about recording those observations. The two are quite different aspects of the researcher's work and yet dependent upon each other, for whatever is observed will be of little value unless there are adequate means for recording it. Further, the means used to record observations

(5) Unlike the lecture theatre the lab is a particular fruitful setting to observe. Students are actively involved in taking measurements, reading scripts, writing up experiments, asking a supervisor for advice, or discussing with a partner. Students and supervisors in the lab are on view for three hours. I attended thirty seven of the forty lab sessions. My observations almost always began in the queue waiting with the other students for the lab door to be opened, and usually ended when the last student left over three hours later.

can, if badly chosen, turn out to dictate what observations are in fact made. After only a few minutes in any laboratory a researcher is 'threatened' with a crush of observations and interpretations and to exercise maximum control over his experiences he requires an efficient systematic system for recording them. (6)

The recording system I have developed and found appropriate in the context of the Surrey lab programme permitted great investigative flexibility. In the first four or five weeks my observations remained unsystematic. I did not know how I would eventually code or sort out the observations and so I deliberately recorded considerably more than I ever used directly. (I use the word 'directly' with some care. What I mean is that only a few observations recorded in the field notes found their way, in their original written form, into this thesis.) However the recording system described soon became a "constant companion." A set of books composed of factual data; interpretations, reflections, and feelings; and ongoing operational decisions. Throughout the study this account was read and re-read and served as a basis for many of the concepts and formulations that appear in the thesis.

(6) My 'fieldwork' tool kit consisted of one black ink pen and a set of three (red, green, and blue) fibre tipped pens; one 6" x 4" green hard-backed book; one shorthand pad; a ring binder of A4 size loose leaf paper; and a diary. To begin with I carried the shorthand pad around with me in the lab. However, this meant that as I wandered from bench to bench, stopping to talk to a student or supervisor, they always encountered me with pad in hand seemingly ready to pounce. I felt this was restraining them a little, so I changed the shorthand pad for a green book, small enough to fit into the back pocket of my trousers. When I was not recording an event it was out of sight yet was with me ready and waiting.

I was aware that many of the events observed early might well achieve meaning or become significant at some point in the future. Later in the investigation I did use techniques of systematic observation: thus, for instance, I spent two sessions recording the frequency and length of time of a supervisor's interactions with his student; I also carried out five 'shadow-studies' in the second half of the programme, in which I sat at the bench with the students for three hours listening to their dialogue and recording in detail their procedural methods.

My adopted system is a modified version of the model proposed by Shatzman and Strauss (1973). Thus, in the green book I organised my notes into relatively distinct "packages" of material according to whether they constituted Observational Notes (ON), Theoretical Notes (TN), or Methodological Notes (MN). I recorded these observations as near to the actual time they occurred as possible and in my own shorthand. I quickly learnt to include direct quotes of conversations and would put down just sufficient about the people and the event to jog my memory a few hours later. After each session I would transfer the notes into my shorthand pad, making them more intelligible and filling out the details. (7)

(7) A word of warning to other field researchers: after the initial surge of enthusiasm I found that transferring notes from the green book to the shorthand pad required enormous will-power and self-discipline. More often than not I did not feel like making the effort to transfer the notes in the evening. Leaving the job any longer however, say to the following morning, rendered the notes significantly worse. The rewards of this mental effort was a record which never failed to provide, in other black moments, a source of inspiration and excitement.

Shatzman and Strauss have defined these three different types of note as follows:

"Observational Notes (ON) are statements bearing upon events experienced principally through watching and listening. They contain as little interpretation as possible, and are as reliable as the observer can construct them. Each ON represents an event deemed important enough to include in the fund of recorded experience, as a piece of evidence for some proposition yet unborn or as a property of context or situation. An ON is the who, what when, where and how of human activity. It tells who said or did what under certain circumstances.

Theoretical Notes (TN) represent self-conscious, controlled attempts to derive meaning from any one or several observation notes. The observer as recorder thinks about what he has experienced, and makes whatever private declaration of meaning he feels will bear conceptual fruit. He interprets, infers, hypothesises, conjectures; he develops new concepts, links these to older ones, or relates any observation to any other in this presently private effort to create social science.

A Methodological Note (MN) is a statement that reflects an operational act completed or planned: an instruction to oneself, a reminder, a critique of one's own tactics. It notes timing, sequencing, stationing, stage setting, or manoeuvring. Methodological notes might be thought of as observational notes on the researcher himself and upon the chronicle as the recorder finds necessary or fruitful. Were he to plan on writing for later publication about his research tactics, he would take detailed notes; otherwise his MN consists mainly of reminders and instructions to himself."

What follows is a sample extract of field notes taken during a 20-minute period in the second Friday laboratory session:

ON-14.55 hours (just short of one hour into the afternoon session) saw Robert (discussed in FN 17/10) complaining to Dr. K. and Dr. A. I was watching Sammy and Koo wire up transient circuit but could overhear Robert complaining about lack of time to write things down and how, because of this, "it's not possible to show how well you understand the experiment".

ON-Didn't turn around to listen to Robert's conversation. Dr. K. approached me two minutes after the interaction to say "I suggest you talk to" (pointing to Robert who was now back at work). Dr. K. explained that Robert would like to take results he gets in lab home and think about them there. Dr. K. pointed out to Robert that that was what used to happen years before, but that students tended to spend too much time writing up their reports; also many of the students "put the work to one side and left it until just before exams". Dr. K. explained to me (though, I think, not to Robert) that with the "old system" supervisors had problems of marking work that had been done weeks before. And that, if enough students feel the way Robert feels then no doubt they (the teachers) could change the course again, "we are not trying to make them do it this way it is just that we think, all considered, this is the best method."

MN-Make sure to find out where Robert lives and arrange an interview with him soon to go over "Lack of time issue". Make arrangements to talk to Dr. W. about history of the lab programme. Ask him who else to talk to about this. Also inquire about any relevant historical documents. Maybe Mr. M. could help me on this history thing.

ON-Richard and Eddie working at top of lab called out for help with their 'Identification of Components' experiment. I was there and they seemed oblivious of me. Problem seemed to be that they had calculated a d.c. resistance of 70 ohm and then deduced by measurements an a.c. impedance of 60 ohm; this result is impossible and they couldn't see why. Heard Richard saying "leave it, let's get onto the next box". He wanted to carry on. Eddie, in contrast, was trying to figure the thing out "well if we have a low phase angle then the inductance etc. etc." Both began to check the d.c. resistance measurement but encountered trouble with the Avo meter. Dr. K. came over and also tried to measure the resistance. Eventually he went through three different Avos before getting one to work.

TN-What struck me about this interaction was that neither student nor supervisor looked upon the problems with the Avo as something of interest to be investigated and thought about. They appeared to view (at least the students did) the Avo difficulties as something separate from the experimental task; a technical nuisance that was holding them up. This may tie in with earlier observations of student use of scopes (FN 14/10) where scope seemed to be used by students simply as a means to an end. The sort of attitude I'm trying to describe (and I'm not sure I'm right) is a kind of forced disrespect for instrumentation. The scope is adjusted and used only to get a certain waveform and that's all.

Let me go the whole hog and speculate that this sort of attitude doesn't help them get better acquainted with the scope (and how to use it without instruction) but it does get them through the experiment quicker.

MN-Add this point of "instrument not working" to list of other points to be taken up with students in future interviews. Also ask supervisors about it - but, I think, after I've spoken to students.

On-Lab session been going 2 hours 10 minutes. Dr. K. (in contrast to Dr. A and Mr. S.) not sat down since entering the lab. He seemed to be constantly occupied with a different pair of students (he was supervising 6 pairs today). His strategy of intervention was to continually tour the pairs (rather than being called); when there was a problem he stood between the students solved the problem and told them what he was doing as he did it...

On-15.15 hours. Mr. S. had been at coffee for 10 minutes or so and was not yet back. This caused a supervisor problem for two of the three pairs working on 'Variation of Impedence' experiment. What surprised me was that the two pairs neither got together to sort out their problem or asked the third pair who were at a later stage of the experiment.

ON-Correction to above note. Mr. S. came back at 15.17 hours. The only thing holding the two pairs up was that they needed to get their circuit checked by Mr. S."

As well as taking field notes, I regularly wrote two other kinds of report. First, Analytic Memos written on A4 paper and growing out of Theoretical Notes. These allowed me to elaborate upon an inference or tie up several inferences in a more abstract statement. I wrote, on average, two analytic memos per week during the twenty week fieldwork period and these varied from one to four pages long. All memos were dated and placed in a ring binder. I tried to ask myself: What does all this mean in the local lab context?

The second reports were 'State of the Art' notes. Again I wrote these on A4 paper and the aim was to tie up ideas from the analytic memos with my continual reading of published

literature. These were reports in which I tried to ask myself: "What does all this mean in the wider arena of laboratory teaching and learning? What does it mean in terms of educational research theory?" During the study, for instance, I gradually began to see a range of theoretical and methodological connections between what I was trying to do and the functionalist school of social anthropology; also connections with the 'double-bind hypothesis' of Gregory Bateson; and the 'hidden curriculum' concept of Jackson and Snyder (these are discussed more fully in Chapters Four, Five, and Six). These 'state-of the-art' reports (of which I wrote, on average, one per week) in turn affected my interviewing and observation. New theoretical ideas effectively served as hypotheses which influenced future observations - not necessarily "new" ones, but observations made from another perspective. Likewise, it was possible after discovering a concept (e.g. the 'hidden curriculum') to identify events or relationships that had been missed previously because they had seemed unimportant.

In other words, I tried to proceed in ways in which there was a constant interchange between doing fieldwork, recording it, making sense of it, and doing more fieldwork. To do this successfully two things are vital. First, it is imperative to actually analyse the data at the time it is collected; certainly there can be no waiting for weeks before analysis. On this issue Malinowski wrote in 1916:

"...one of the main rules with which I set out in my fieldwork was 'to gather pure facts, to keep the facts and interpretations apart'. This rule is quite correct if under 'interpretations' be understood all

hypothetical speculations about origins, etc., and all hasty generalisations. But there is a form of interpretation of facts without which no scientific observation can possibly be carried on - I mean the interpretation which sees in the endless diversity of facts general laws; which severs the essential from the irrelevant; which classifies and orders phenomena, and puts them into mutual relationship. Without such interpretation all scientific work in the field must degenerate into pure 'collectioneering' of data; at its best it may give odds and ends without inner connection. But it never will be able to lay bare the sociological structure of a people, or to give an organic account of their beliefs, or to render the picture of the world from the native perspective. The often fragmentary, incoherent, non-organic nature of much of the present ethnological material is due to the cult of 'pure fact'. As if it were possible to wrap up in a blanket a certain number of 'facts as you find them' and bring them all back for the home student to generalise upon and to build up his theoretical constructions upon.

But the fact is that such a proceeding is quite impossible. Even if you spoil a district of all its material objects, and bring them home without much bothering about a careful description of their use... such a museum collection will have little scientific value, simply because the ordering, the classifying, and interpreting should be done in the field with reference to the organic whole of native social life." (emphasis added)

Malinowski's statement encouraged me to write analytic memos and helped get me out of an attitude (developed prior to this reported study) of 'collect enough data and at some later date it will speak to you'! This attitude was formed because I did not want to 'prejudge the issues' nor 'introduce personal bias'. These were good reasons but it took me a while to realise they would not be prevented by simply avoiding interpretation and analysis of incoming data.

This brings me to my second vital requirement for the educational field-researcher. To carry out analysis alongside collecting new information the researcher must devise

an efficient and sensitive recording system that allows easy access to what the system contains. In my case, keeping three different types of record facilitated this. (8)

Recording Conversations

Direct observation of teaching and learning activity in the lab is one way of gathering information, another is by interviewing the participating students and lab supervisors. I do not intend to propose here a treatise on 'good' and 'bad' interviewing techniques. My main piece of advice on technique (to get it out of the way) is for the researcher first and foremost to develop an interview style he or she feels most comfortable with. What I want to do in the rest of this section is stick to the facts of who I interviewed, when, and where.

Earlier in this section I discussed informal questioning and how I recorded this in my green book. Important though this is, there comes a time in most ethnographic research when the interview is more appropriate to discuss at length issues that emerge, and to probe for other relevant details. Wilson (1977a) has provided an excellent and rare discussion of ethnographic field interviewing and I do not want to reiterate what he has said

(8) To further ease access I found it useful at the time of writing an analytic memo to indicate in the shorthand pad (using a coloured pen) the theoretical notes the memo had evolved from. For clarification purposes this marking can best be made on the clean page opposite the written page of field notes. Further notes in different colours can then be made on clean pages opposite those that relate to a theoretical idea originating, say, in the published literature such as the double-bind. When the shorthand pad is laid flat there should be one page of black ink field notes and one page directly above it of coloured markings which serve as a quick guide to what the black ink page contains.

(I urge the reader to consult it) except to emphasise the unique kinds of information that can be gathered. The ethnographic field researcher can, for instance, compare the following: "(a) what a subject says in response to a question; (b) what he says to other people; (c) what he says in various situations; (d) what he says at various times; (e) what he actually does; (f) various non-verbal signals about the matter (for example, body postures); and (g) what those who are significant to the person feel, say, and do about the matter." (Wilson, 1977a)

The main point to be underlined is that the field researcher typically has an enormous amount of information on those he interviews and is therefore in a good position to place answers to questions and incidents talked about by participants in their correct context.

I began collecting the names and addresses of students during the second and third laboratory sessions and officially started to interview in the evenings of the third week. I found it useful in the initial interviews to talk to students on their home territory and arranged to see them in their own rooms (at Surrey, almost every first year student lives in a hall of residence on the university campus). No elaborate sampling techniques were used to select the first group of students, I quite simply chose those who appeared most friendly toward me when collecting names.⁽⁹⁾ At this stage of the study I wanted to learn what it was that most

⁽⁹⁾ Nor did I use elaborate sampling later. I did, however, try to interview as many students as possible and often selected them as a result of incidents I observed, or interesting informal conversations in the lab.

concerned the students, what they considered to be important, and therefore, proceeding responsively (see section 2.5), arranged the interview so that the main initiator of issues was the student.

Later in the study I found it useful to interview pairs of students who had worked together in the lab. Invariably the description of an incident by one student would spark the other off, either to reinforce it or add a qualifying remark. Talking to students in this way enabled me to gather a more dynamic and vivid picture of how they proceeded through their lab tasks.

All in all I used six different types of interview during the study. I carried out open-ended interviews with students on an individual basis (OEI) and also in pairs (OEP). In these interviews the students invariably raised the issues to be talked about and I kept in the background. I also carried out semi-structured interviews with individual students (SSI) and pairs (SSP). These constituted the main style of interviewing. The idea behind these discussions was again to let the student raise topics, but during the talk I too would ask about incidents in the lab and themes that had emerged as important from my investigations. In addition, I pursued some focussed interviews with both individuals (FI) and pairs of students (FP). These occurred toward the end of the study and took place usually because I had a specific set of questions I wanted answers to.

By this stage I had already discovered that these related to issues that concerned the student.⁽¹⁰⁾ The table below indicates the student interviews carried out during the study. The numbers refer to students spoken to.

FIRST-YEAR STUDENT INTERVIEWS

WEEK	TYPE OF INTERVIEW					
	OEI	OEP	SSI	SSP	FI	FP
1	1					
2						
3	9					
4	8					
5	1	6		2		
6						
7			1	12		
8						
9			2			
10						
11						
12						
13			2	10		
14			3	10		
15						
16			1			
17					8	4
18					4	4
19			4			
20	6	4				
21						

Table 7.1

(10) In addition, I interviewed four groups of four second-year students (during the latter half of the programme) about their first-year experience. I also spoke on several informal occasions (often for more than one hour) with five final-year

All in all I talked informally in the lab (on at least one occasion) to each of the fifty-three students. I interviewed forty-four students on a more formal basis, interviewed twenty-one of these twice, and talked to a small number of students three and in some cases four times.

Many of the individual interviews were carried out in the students own room in the evening. All but one of the paired interviews took place in my office during the day. These were more difficult to set up, students with an already heavy schedule would forget to turn up until I started handing them 'appointment' slips with the time and place written on. Almost all the interviews lasted between forty minutes and one hour (there were some exceptions that went on for more than two and sometimes three hours). I tape-recorded all interviews except about ten (only once did a student object to being taped).

In addition to the student interviews I talked informally in the lab on many occasions with each of the six supervisors and also the lab technician. I interviewed the lab director, in a relatively open-ended way, twice before the programme started and then again (in a more structured interview) toward the end of the first and second terms. In the first ten weeks of the programme I also interviewed, in a semi-structured fashion, one of the post-graduate supervisors and five teachers who had previously supervised on the programme. In the second half of the programme I completed my interviews of the present-day supervisors. All these discussions took place in the office of the interviewee.

A word of warning to future researchers. A fifty minute tape (even toward to end of the study using a stop-start foot pedal) usually took me three hours to fully transcribe. Only in the final weeks of the programme did I allow myself the luxury of partial transcription. At the end of the study I had constructed a list of general themes that divided into twenty-one different categories as shown:

- (1) Student decisions when proceeding through experiment influenced by assessment.
- (2) Student decisions when proceeding through experiment influenced by time.
- (3) Student decisions when proceeding through experiment influenced by other things.
- (4) Doing experiment correctly does not necessarily mean understanding.
- (5) Models of student learning held by supervisors.
- (6) Importance of getting an overall picture of experiment.
- (7) Laboratory ethos.
- (8) Patterns of student lab activity.
- (9) Cues picked up which form future behaviour in the lab.
- (10) Student desire to finish experiments.
- (11) Preparatory work and its relation to thinking in the lab.
- (12) Relationship of lab programme to lectures and its effect on student understanding in the lab.
- (13) Student experience of working mechanically.
- (14) Reasons for working mechanically.
- (15) Description of working mechanically.
- (16) Type of thinking students engaged in when they work mechanically.
- (17) Type of thinking students engaged in when they do not work mechanically.
- (18) Effects of non-homogeneity of students.
- (19) Conflicts students experience in the lab.
- (20) Supervisor views on assessment.
- (21) General effects on student of allocated lab time.

I found it useful to transcribe the contents of an interview on paper with a large left hand margin. This enabled me to annotate the interview and I indicated in the margin those points that tied in (or did not) with themes raised in informal conversation or by observation, also points that might develop into a new theme. In this way I constructed (along with methodological field notes) a list of issues to be further investigated. At the same time I updated my thematic categories from week to week, abandoning some old themes and including new ones along the way.

The procedural points highlighted in this chapter are, of course, by no means exhaustive. They do represent, however, some of the major issues that arose and had to be resolved.

CHAPTER FOUR

STUDENT ADAPTATION TO THE LABORATORY

Introduction

Chapter One identified the urgent need for studies which would analyse teachers teaching and students studying as these naturally occurred in the Surrey lab. Chapter Two suggested anthropological educational research as an appropriate line of inquiry. Chapter Three was concerned with the down-to-earth, procedural, nuts and bolts problems that arise and need attending to when implementing, the anthropological paradigm in an actual educational setting.

In Chapters Four Five and Six, I introduce a case-study of the adopted approach in action in an undergraduate teaching laboratory. The study is unusual in several important respects and therefore requires some preparatory remarks.

There has recently emerged some new and convincing arguments justifying the use of case-study work in education (see, for instance, MacDonald and Walker (1975), Hamilton (1976b), Stake (1976), Wilson (1977b), Adelman et al. (1976)). At the present time, however, there is little established knowledge about how effectively to carry out such work (partly addressed in Chapter Three).

A major discernable trend is to offer an accurate and full description of the programme under study and deliberately to build in complexity. (see Stake and Gjerde (1974), MacDonald (1976)). I have a lot of sympathy with this stance but I feel it is

inadequate and I have therefore pursued an alternative approach. When working within an anthropological paradigm, the researcher inevitably takes a stance on description versus focus, and complexity versus simplicity. Being too focussed and over simplifying the teaching and learning process is dangerous, because the abstractions that make up the report can end up bearing little resemblance to the complicated transactions and interactions inherent in an educational programme, consequently the report may seriously mislead the decision-maker and lose its utility. There are dangers also in simply describing a programme. Having started where does one stop? A purely descriptive stance leads inevitably to an accumulated mass of complicated details. Utility is again lost because the decision-maker cannot see the wood for the trees.

In his pioneering anthropological work Bronislaw Malinowski searched for an answer to this fundamental dilemma. In 'Coral Gardens and their Magic' he wrote:

"We shall have to follow two lines of approach: on the one hand we must state with as much precision as possible the principles of social organisation... on the other hand we shall try to remain in touch with a living people," (Malinowski, 1935).

In this important respect I have tried to emulate Malinowski. I have aimed for the middle ground between portrayal and focus. At one level the case study is a description of the lab and the events that take place there, at the same time I have quite unashamedly imposed a conceptual structure on laboratory teaching and learning events and tried to create an explanatory

framework which might help teachers and future educational investigators think and act in new ways.

The range of concepts that are offered grew out of the concerns of the participating teachers and students and taken together they illuminate a general theme that emerges in Chapter Four and runs throughout Five and Six. The theme centres upon the relationship between the individual student and the lab system he finds himself in. I examine, for instance, how students adapt to the system and the decisions involved in doing so, also the study strategies and habitual behaviour patterns that are generated. Explanations are then sought in the local lab context within which the behaviour was first established and is maintained.

The concepts and explanatory framework, however, are not presented to the reader to accept without justification. To venture into an interpretive as well as descriptive investigation carries with it its own responsibility, or should do. Consequently, I present and also reflect on the imposed conceptual structure; identifying its separate themes, how they emerged, why I chose to highlight them, and what the theoretical implications are.

The Laboratory Instructional Script and the Laboratory Management Framework

Observing a laboratory session in the Surrey first year programme an outsider might report that, to a large part, some twenty or so students entered the lab, sat together in pairs at separate

benches, and using the relevant allocated electronic instrumentation and measuring equipment proceeded through an associated script of instructions for three hours. This description is correct as far as it goes but it does not go far enough for it tells us little about the details of the student's intellectual experience in between entering and leaving the lab.

Of course, there are an infinite number of ways of describing a lab and what takes place in it. Most teachers, when offering a portrayal of their programme choose to highlight the experiments and the ideas and theoretical material covered in the associated instructional script. This is where I begin.

The instructional script provides the formal⁽¹⁾ way in which a student finds out what he is expected to do in the lab. It typically indicates how to connect the various circuits to be investigated; suggests the measurements to be taken; the measuring instruments to be used; the graphs to draw (if any); and the calculations to carry out. Final interpretation of the data is usually then left to the student.⁽²⁾ The script clearly exercises an important influence on the students, all of whom use it for procedural purposes.

The instructional script is important also to the teacher who has responsibility for its design. Care needs to be given to ensure that, for instance, the level of theoretical knowledge

(1) I use the word formal here to distinguish between this way of finding out what is required from a more informal process explained in section 4.6.

(2) Over a twenty week period students work through sixteen different experiments. Instructional scripts for four of these experiments are included (in full) in Appendix I for inspection by the reader.

it contains is comprehensible to students and that the instructions are appropriately structured and sequenced. Script design would be complicated even for a specific student whose competence and academic background was known, in actual fact all fifty-three participating students were virtually unknown to their teachers at the beginning of the programme.

In the first few weeks, however, the programme director was preoccupied by what can only be described as a managerial role. He had to arrange for each student to be in the right place at the right time with the right person working on the right experiment supervised and assessed by the right teacher each week for twenty weeks. Conceived simply as an exercise in administration the task was clearly complicated.

The specific organisational concerns of the programme director are revealed in the following extract from field notes taken during an introductory lab talk he gave to students in their first week at the university:

"All participating students were gathered together in lecture theatre G on the second day of their three day general departmental introduction. The class were addressed by Dr. W. (the lab programme director) who immediately explained he will 'concentrate on the organisation of lab work'. Such work is an important part of their whole course but he does not intend 'to dwell on that today'. While two booklets were being distributed he informed the class that half of them would begin in the lab Tuesday morning and the other half Friday morning of the next week. One of the booklets contained separate scripts of instruction (each typically four pages long) for 16 different experiments. The second booklet was an advisory document 14 pages in length and entitled 'Notes for students in E1 laboratory work'. The class were advised to read both books carefully when they left... Reading out names from the class register Dr. W. began to allocate a letter and number to each student. Reference was made to the back of the first booklet where all the sixteen experiments were listed - each

designated with a different letter. These letters formed the squares of a rectangular matrix with a vertical axis of numbers 1-8 to identify the student, and a horizontal axis of 1-20 representing weeks of the lab programme. A few minutes were set aside for the students to find their way around the matrix and to work out from their allocated number which experiment in a particular week they were scheduled to work on, and from the letter and class list who their partner would be (the matrix is shown overleaf in Figure 4.1)...The logistics of assessment were briefly explained...students were referred to an assessment sheet and informed that supervisors would use this to grade experimental work at the end of each weekly session. 'There will be no scribbling on the back of envelopes and writing up afterwards'. To record their lab work the class were advised to buy a green hardback book from the university bookshop...(Finally after some explanation of the assessment criteria) several students were picked out at random to see if they could correctly identify which experiment they would first work on and who with. The third student who was asked seemed unsure and the matrix was further explained. Eventually, thirty minutes from the beginning, Dr. W. brought the meeting to a close by asking whether there were any questions. There were none." (Field Notes 2:10:75)

The programme director's apparent emphasis on organisation seemed to reflect his most pressing and immediate concerns. At the time of the talk, the experiments and associated scripts had all been designed (they were essentially the same as for the previous several years), the method used to assess students, and the time allocation of three hours per lab session were also the same as the previous year. The major unknown factor for the lab director (up to one week before the term) was the exact number of participating students and therefore, his most immediate problem was how to split up and administer the work of the class.

The administrative emphasis was also reflected in the programme director's reply to a general question by me about the student tour of the departmental labs scheduled to take

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

E1 LABORATORY - ORDER OF EXPERIMENTS

TERM	AUTUMN								SPRING								SUMMER						
WEEK	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1		
	E	B	+	H	F	+	G	J	S	P		+	V	T	L	+	R1	R2	N1	N2	W		
	B	+	H	F	+	G	J	E	P	+		V	T	L	+	R1	R2	N1	N2	W	S		
	+	H	F	+	G	J	E	B	+	V		T	L	+	R1	R2	N1	N2	W	S	P		
	H	F	+	G	J	E	B	+	V	T		L	+	R1	R2	N1	N2	W	S	P	+	V	
	F	+	G	J	E	B	+	H	F	L		+	R1	R2	N1	N2	W	S	P	+	V	T	
	G	J	E	B	+	H	F	+	R1	R2		R1	R2	N1	N2	W	S	P	+	V	T	L	
	J	E	B	+	H	F	+	G	R1	R2		N1	N2	W	S	P	+	V	T	L	+		

EXAMINATIONS

- B - Use of Instruments
- E - Variation of Impedance with Frequency
- F - Electric Circuit Elements (Black Box)
- G - Equivalent Circuits (Thevenin's Theorem)
- H - Transients
- J - D.C. Machines
- L - Field Plotting
- N1 - Materials 1
- N2 - Materials 2
- P - Combinational Logic
- R1 - Electronics 1
- R2 - Electronics 2
- S - Design of a Simple Filter
- T - A.C. Bridges
- V - Swinburne Test
- W - Three-Phase Circuit

+ denotes private study

Figure 4.1

place the morning after the introductory talk:

"(the students) will be split into seven groups of eight and each group will be led around seven labs by a second year student. In each lab a small demonstration will be put on by a member of staff and after fifteen minutes a whistle will be blown and the students will pass on to another lab."

As well as providing an indication of what was deemed important to get across to new students the included extracts suggest that designing the Surrey lab programme as a whole involved important decisions of a kind quite different from the issues related simply to instructional script construction. In acknowledgement of these 'management' design considerations (so rarely mentioned in discussions about lab work, see Chapter One), I introduce two concepts that allow a more accurate representation of the organisational and design factors that go to make up a lab. The distinction drawn is between what I shall call the Laboratory Instructional Script (LIS) and the Laboratory Management Framework (LMF).

In the Surrey Lab programme the LIS and the LMF can be differentiated as follows.

Lab Instructional Script (LIS).

Each script typically:

- (1) Aims to convey several ideas and concepts related to electrical and electronic engineering.
- (2) Covers a specific subject area i.e. transistor characteristics or direct current machines.
- (3) Includes a section dealing with associated electrical and mathematical theory.

Lab Management Framework (LMF)

Each student:

- (1) Has three hours to work on each experiment.
- (2) Has his work graded (by a supervisor) according to a pre-specified assessment scheme at the end of each three hour session.
- (3) Must work together with another student as a pair.

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(4) Includes an instructional structure and sequence which typically is as follows:

(a) Object Theory (b) Experimental (c) Suggested Preparatory Work (d) Circuit Diagrams (e) Procedure (f) Conclusion.

(4) Must switch to another experiment at the end of each session.

(5) Must carry out eight experiments per term for two terms.

To sum up, the LIS and LMF, taken together, constitute a set of rules of conduct and procedures with which all students are expected to comply and to follow, and which exist both to instruct and manage the affairs of the whole class.

Designing an educational programme equally suitable for each participating student is a problem faced by almost all traditional university courses and is particularly acute at first year level where students have rarely followed an identical course of study. Of the fifty-three students in the Surrey lab programme 19 arrived from overseas (from as many as 10 different countries) a not untypical figure in present day undergraduate engineering courses. A majority of the 53 students had previously followed an A-level course. However, 5 students arrived from an ONC or HNC course and at least 2 years full-time practical experience in industry; 5 students had previously followed an OND course in which a substantial proportion of their time at the college (which they attended full-time) had been spent pursuing experimental work. In contrast, several overseas students began the laboratory programme having had no previous practical experience whatsoever. Each student was required to work through the same 16 experiments and consequently scripts in the Surrey lab were not tailor-made to meet individual needs.

Satisfying a range of individual needs in the Surrey lab arose not only with the script design (LIS) but also the wider laboratory organisation (LMF). One student, for instance, who asked in the first week of the programme if he could work by himself was told that there simply was not enough equipment to cater for his wish. Another student approached Dr. W. at the end of his introductory talk to ask if he might devise his own experiments as well as doing those that were set. The lab director explained that this might not easily fit into the schedule. The student then asked whether he would be allowed to work in the lab during lunch time but was again told that this was not possible because technicians had to be around (for safety reasons) at all times. (3) Later in the term this student reflected on how the laboratory arrangement constrained his natural and preferred style of study:

"If you had more time the way you would work would be different. You'd just sit there and have a play with the equipment first of all. You'd get used to driving the things and see what happens if you move the voltage up say, rather than do what the script tells you. Really you'd have a little play around for an hour to become familiar and get the feel of things."

I shall return to this important issue, however, it was not only the students who were constrained. The teaching staff too, had to work within prescribed guidelines. Organisation of the lab was in fact shaped by a variety of departmental constraints. For example (1) the lab programme had to be fitted into two terms since equipment used in the programme was needed by final year project students in the third term; (2) there were not enough benches for all students to be in the lab at the same time

(3) Not wishing to discourage the student Dr. W. explained to him that since each student was expected to carry out sixteen experiments over twenty weeks, there were four free weeks and that this period might be arranged for extra work of personal interest.

and so half of the class attended on Tuesday morning and the other half on Friday morning; (3) there were not enough sets of apparatus for all students to work on the same experiment in the same week (usually there were six different experiments in operation in any one lab session) it was therefore, administratively difficult to design the lab programme in sequence with on-going lecture courses. Consequently, the undesirable but inevitable situation arose in which a student was frequently obliged to work on an experiment involving theoretical ideas he had not yet covered in lectures; (4) lack of available apparatus also required that students work through their experiments in pairs.

In the case study a major theme is emerging: the channelling of student activity. The Surrey lab is a structured learning environment (tending more toward 'control' than 'autonomy', see section 1.5) in which each individual student is expected to comply with a set of rules and procedures designed for the common good. The inevitable effect of this is to channel student activity in specific prescribed directions as against the many other directions theoretically possible. To simply state this, however, is jumping ahead in the analysis. In the sections that follow I closely examine the adaptation process of students to the lab and explain why I came to focus on this.

Predominant Patterns of Student Activity

Attempting to characterise what students do in the lab although worthwhile is also hopelessly ambitious. There are an infinite

number of different ways it could be done. It could mean describing the ways in which students entered the lab, whether they walked or ran or came in all together or in pairs; it could mean focussing on how students sat in their chair; or how they asked for help from the supervisor; or how they measured transient waveforms using an oscilloscope; or all these things. Indeed, to study a lab programme and somehow "tell-it-like-it-is" is not only unmanageable in research terms but is essentially impossible. Some degree of abstraction is inevitable. (4)

I knew that I had to break the task down in order to make it manageable for a single researcher working alone to document observed laboratory behaviour meaningfully. I also knew that the final representation of student lab activity should not be so simplified as to become trivial, not should it fail to reveal the inevitable complexities of student-teacher and student-student interactions. In other words, I knew in general terms the effect I wanted at the end but I didn't know how to go about getting it.

Ideally the specific issues to be studied should unfold during the investigation and then be progressively focussed upon (see section 2.5) In practice, however, it is not so simple.

Malinowski (1922) faced comparable problems of characterising the activities of the Trobriand Islanders, "the final goal of the ethnographer is to grasp the natives' point of view, his relation to life, to realise his vision of his world." Later he described how the field-worker should take an active role in realising this goal:

(4) Kemmis (1973) touches upon this point in his paper 'Telling It Like It Is: The Problem Of Making A Portrayal Of An Educational Programme'.

"The main achievement of field-work consists, not in a passive registering of facts, but in the constructive drafting of what might be called the charters of native institutions...while making his observations the field-worker must constantly construct: he must place isolated data in relation to one another and study the manner in which they integrate...'Facts' do not exist in sociological anymore than in physical reality; that is they do not dwell in the spatial and temporal continuum open to the untutored eye," (Malinowski, 1935).

What is it that has guided the present-day anthropological educational researchers in their investigations? To answer this is difficult which is why, presumably, researchers have usually avoided the issue altogether. They have been remarkably vague in providing details of how their perceptive/thinking strategies influence the ways in which they proceed. In my own case I tried to follow the general lead of Malinowski, also ethologist Niko Tinbergen. (5)

In 'The Animal in its World: Explorations of an Ethologist' Tinbergen (1972) reminded us that "all observation is selective and this selectiveness is determined from within." He then described how he and fellow ethnologists proceeded in their observational work: "(we) are drawn to study events that seem to contradict what we have been taught to expect on the basis of our knowledge of non-living things. It is this discrepancy between what an animal 'ought to do' and what it is actually seen to do that makes us wonder. Like a stone released in mid-air,

(5) Tinbergen carried out several naturalistic observational studies of animals see, for instance, Tinbergen (1951). Consequently, he was able to show that observations on the behaviour of animals in captivity tell us nothing reliable about their behaviour in a natural setting. Like him, I also chose to observe behaviour as it occurred naturally in the lab and made no attempt to impose artificial experimental conditions.

a bird ought to fall; yet it flies away." (6)

In retrospect - applying the principle of discrepancy - what seemed unusual during the first few weeks of the lab was the almost universal conformity of the class. Although the fifty-three participating students began the lab with widely different experimental experience, and each in turn (I assumed, and later verified) had different interests, expectations, and intentions, what seemed most surprising was not the differences between the ways in which students went about their work, but the remarkable similarities. I did not expect this.

Particularly striking was the urgency with which all students appeared to work. I noticed that a clear majority when entering the lab in the second session proceeded directly to their bench to open the wire drawer, and began immediately to connect the circuits. Frequently I heard casual references to "getting through it" and "being pushed for time." Two related actions also seemed to recur frequently: students would look at their watches and then check the number of pages of the script to be completed; second, there appeared to be designation of responsibilities between two partnering students in order to "save time."

(6) In the preface to 'The Animal in its World' Sir Peter Medawar provides further insights into the work of the ethologists: "Anybody who thinks that Ethology consists of a passive inhibition of the information proffered by nature still has much to learn. The first stage in a behavioural analysis is, of course, to observe and record what is actually going on. This will involve intense and prolonged observation until what an untrained observer might dismiss as a sequence of unrelated behavioural performances is seen to fall into well-defined and functionally connected sequences or behaviour structures. These behaviour structures do not declare themselves in any obvious way. Their identification depends upon an imaginative conjecture on the part of the observer which further observation may or may not uphold. As in other branches of science, this is a creative process in which the imagination must take the initiative."

The question of time, or more specifically the lack of it, in one form or another tended to pervade student discussions about their work and these discussions manifested themselves in action in three distinctive, though not unrelated, ways.

I found that three types of student activity seemed to capture their frequently mentioned concerns with time, these were: (1) to work quickly in the lab; (2) to carry out preparatory work for the experiment beforehand; and (3) often to end up, in the student's words, "working mechanically". All three appeared to be aspects of the students method of lab study that occurred repeatedly from week to week; in other words they could be termed as "customs", defined in the Chambers Twentieth Century dictionary as "a frequent repetition of the same act; any of the distinctive practices and conventions of a people or locality."

In other words the lab, as a highly structured social-organisation with built-in rules of conduct, not only constrained student activity but did so in a way that created distinctive customs of student conduct. (7)

(7) Sociologist Erving Goffman's (1976) observation of the functioning of many different types of social organisations appears to be directly applicable to the Surrey lab: "A rule of conduct may be defined as a guide for action, recommended not because it is pleasant, cheap, or effective, but because it is suitable or just. Infractions characteristically lead to feelings of uneasiness and to negative social sanctions...Attachment to rules leads to a constancy and patterning of behaviour; while this is not the only source of regularity in human affairs, it certainly is an important one. Of course, approved guides to conduct tend to be covertly broken, side-stepped, or followed for unapproved reasons, but these alternatives merely add to the occasions in which rules constrain at least the surface of conduct."

In his article 'Etiquette in the Laboratory' Ogborn (1976) was also taken with the habitual nature of student lab work and talked of students entering "laboratory society" and engaging in a variety of customs such as: making an entry to the lab; the proper manner of discovering the nature of the tasks; the fashion appropriate for regarding the script; correct behaviour in the conduct of the experiment; and the necessities to be observed in recording its outcome.

To sum up, although each student in the lab tended to adapt to the programme in his or her own unique fashion, certain common patterns of activity developed (working quickly, preparatory working, and working mechanically). In the analysis that follows I suggest that taken together they constituted the essential ingredients of a common lab study style practised in the lab social-system as then arranged.

A vitally important methodological consequence of these identified common patterns was that they provided me with a useful and manageable starting point for further investigating lab activity. Focussing on them, as we shall see, allowed me an appropriate lead-in to getting at vital teaching and learning issues. Again there was a similarity with the functionalist school of social anthropology for:

"what Malinowski revealed was that the deepest layers of conduct, feeling, and social relationship, are manifested in custom and are therefore accessible to scientific inquiry without overstepping the bounds of ethnographic methods", (Fortes, 1957)

Malinowski's methodological revelation seemed to hold true in the Surrey lab. For instance, questions posed to students early in the investigation in ways such as 'what did you learn from

the experiment?' or 'what parts of the experiment prevented you learning?' (even though this was one of my main concerns) seemed to leave the student feeling uncomfortable and finding it difficult to answer. On the other hand, students were only too willing to talk, for instance, about the fact that they felt rushed and how this influenced the whole way in which they perceived the experimental task and proceeded through it.

Working Quickly and Preparatory Working

In the remainder of this chapter I examine how "Working Quickly" and "Preparatory Working" relate to the major theme of channelling ("working mechanically" is different in several important respects and the whole of Chapter Five is devoted to an analysis of it). First the students' experience of these two customs, both of which are detectable in the remark of the following student reflecting back on the lab programme and summarising his method of study:

"you know you have to do a lot of preparation beforehand and you know you have to maximise every time-saving process you can in the lab. But after all, this is how engineers behave. They have to find the quickest way to do something."

Although this sort of comment could be frequently heard at the end of the programme, it did not represent student views in the early weeks. As one student put it:

"Well in the first week I didn't know how much effort to put into the three hours and what I could get out of three hours work. Now I know that in the first hour before lunch you have to set up your circuit and take the first few measurements. If you can get that over and done with before lunch you will find you'll be more adventurous in the rest of the experiment."

That students proceeded with speed in the lab was apparent not only from conversation and interviews, but also from direct observation. Especially interesting was the rapidity with which students developed an attitude toward rationing their time. An incident which occurred in the second Friday laboratory session sensitised me to this:

"Immediately after lunch, at 2 o'clock, a student arrived in the lab who had not attended for the hour before lunch nor the previous lab session. He explained to Dr. K. (the supervisor nearest the door he entered) that he had earlier that week transferred from the Civil Engineering course to Electrical Engineering. Under his arm he carried the 'Booklet of Lab Experiments' and the 'Notes for Students'. He had been allocated a number and letter by the lab programme director and told to attend the lab on Friday. Dr. K. explained to him for future reference, that 'the lab begins at 12 o'clock', he then suggested that the student try and find a partner to work with on the experiment he was scheduled to do.

Some five minutes later I observed the 'new' student wandering around seemingly without purpose at the top of the lab. All the supervisors when I looked around were busily involved with other students and so I went to see if I could help him. It turned out that he had found someone who was working by himself (because of there being an odd number of students) but apparently this student (Robert) had indicated to the new student (Bruce) that he couldn't help him. Bruce did not seem to know what to do next and just stood around looking uncomfortable and out of place.

With Bruce, I walked over and explained to Robert that Bruce had been transferred from Civil Engineering and that Dr. K. had suggested that they might work together for the remainder of the day's experiment. Robert's response was 'well I'll show him if I can get extra time'. I was taken aback by this remark and also puzzled by the reception he had given Bruce. I asked Robert, who had continued taking measurements throughout our conversation, whether finishing the experiment was so important. I asked the question out of simple curiosity (with no hidden personal statement) for I had read in the lab booklet that students 'need not necessarily finish the experiment'. He answered 'Yes if you want a good mark'. There was a short pause and I was about to leave, not

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knowing what else to say, when suddenly Robert looked up from the measuring instruments and said 'Well I've almost finished the readings now. If he wants to copy them that's fine'. He then took a quick look at his watch and carried on writing. Bruce approached the bench to sit down and I wandered off to observe other students. I was still puzzled by Robert's actions also surprised at his strong desire to finish the experiment and how he related this with the assessment scheme.

Later in the afternoon I returned to the top end of the lab and noticed that Bruce had left and that Robert was sitting down by himself writing in his lab-log. I was about to pass by without saying anything but he caught my eye and said 'sorry about that', somehow indicating that he would like to have helped Bruce but he had to look after himself. I told him not to worry." (Field Notes 17:10:75) (8)

One student who missed the first lab session (because of a free period) seemed surprised when attending the lab in the following week: "everybody sort of dashed in, went straight to their bench, got the wires out of the right drawers and got on with it. I was still looking for where the wires were kept."

Another student described having to make drastic changes to the style of work he had developed at technical college:

"The sort of labs I'd been used to (at college) - you'd wander in and have a bit of a chat to your mates, write down the results, have a play with the equipment, make a couple of notes then go away and write it up at home."

He soon found out that this was not what was expected at Surrey:

"For a while I was on the same wavelength with this lab (as at college). What tended to happen is I'd get into the lab and tend to think 'right, this is relatively easy' so I'd go at a slow pace and at the

(8) Bruce never attended another laboratory session. A few weeks after this incident I enquired about his whereabouts and was told he had disappeared from the University. Apparently he left without informing either the department of his peers. I was later to learn, from another source, that he had returned home to Greece.

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end I would have to speed up to try and finish. My marks are now getting better. My approach is more methodical; before where I'd tend to play a bit I now get stuck in and get it done. I realise now that three hours is not a lot of time, it goes so quickly. I now start off at a really cracking pace and get a fair bit done by lunchtime...this lab really speeds you up."

Once having perceived the need to work quickly a student would typically develop a series of strategies which allowed him to do this:

"Once you've been there a couple of times there's no messing around. You have to know where to start, you don't sit down, scratch your head and think about it. You go right for the bench drawer and start wiring up the circuit, there's always a circuit to wire up, you know that's the first thing to do. You don't waste too much time, preferably you just get one person to do the wiring."

This student's usual lab partner further explained that:

"We've got it down to a fine art, you spend so much time doing the experiment, so much time writing it up, so much time working calculations."

This is where the second main common pattern of preparatory working comes in. I have mentioned strategies developed inside the lab in order to save time there. Preliminary work, was different, this was work done outside the lab, but again in order to save time inside the lab. According to one student:

"Well, you now roughly from the circuit diagram what apparatus you will be using, so you write that down and it saves you a little time. You draw tables for results and leave space for readings, that will save you time."

Preparatory working, like working quickly, was a technique students seemed to develop early in the programme. One student remembered that:

"In the first one I didn't have the idea of what they call preliminary work, my idea in preliminary work before was a little different - I didn't do it well... Now I do preparation one day before and I usually spend

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all evening working on it...I try to think what could happen because I don't have much time for thinking in the lab if anything unexpected happens."

Early Adaptation to the Laboratory

Two American researchers have briefly touched upon the existence of a general channelling process in educational settings. Jackson (1968), for instance, wrote:

"As he learns to live in school our student learns to subjugate his own desires to the will of the teacher and to subdue his own actions in the interest of the common good. He learns to be passive and to acquiesce to the network of rules, regulations and routines in which he is embedded. He learns to tolerate petty frustrations and accept the plans and policies of higher authorities, even when their rationale is unexplained and their meaning unclear. Like the inhabitants of most other institutions he learns how to shrug and say. 'that's the way the ball bounces'."

Unfortunately there is little we can learn from Jackson about how the channelling process operates, for his comments remain at the level of American schoolchildren and school classrooms in general. Although relevant, Jules Henry (1968) also pitches his discussion at the very general level of the average American schoolchild in the average American classroom.

"Let us grant that American children, being American, come to school on the first day with certain potentialities for experiencing success and failure, for enjoying the success of their mates of taking pleasure in their failure, for competitiveness, for co-operation, for driving to achieve or for coasting along, etc. But school cannot handle variety, for as an institution dealing with masses of children it can manage only on the assumption of a homogeneous mass. Homogeneity is therefore accomplished by defining the children in a certain way and by handling all situations uniformly. In this way no child is directly coerced. It is simply that the child must react in terms of the institutional definitions or he fails. The first two years of school are spent not so much in learning the rudiments of the three Rs, as in learning definitions."

My intention is to be far more specific in addressing the way channelling occurs in the Surrey lab. The indication from section 4.3 is that 'Working Quickly' and 'Preparing Beforehand' are techniques developed extremely early on in the programme. To understand the general process by which they become established, therefore, I examine the initial period when student and lab system first come together. (9)

In the first week students appeared uncertain about what would actually be expected of them. This uncertainty was reflected in many ways. For instance, one student told me that:

"before the first experiment there was a big debate (among students) about how much preparatory work there ought to be done. Everybody was asking 'How much are you supposed to do?' no matter what experiment they were doing."

(9) It is interesting that Smith and Geoffrey (1968) in perhaps the most detailed published case-study of a single classroom, also pay great attention (for similar reasons) to the first few weeks of class. At the end of their year-long study they wrote "What has the book added up to? What is its message?" To us, the message centres on complexity. The beginning of school in the fall is deceptively simple and can be described simply; yet we think the first few weeks have important implications for the implementation of the activity structure (Smith and Geoffrey mean by this the work sheets and other instructional materials) and for the development of the authority structure (achieving classroom control)."

A similar conclusion was reached in a recent study carried out by the Nuffield Group for Research and Innovation in Higher Education (Nuffield, 1976 b). The investigators (who visited 8 universities and 4 polytechnics) concentrated on the first few weeks of term, from the initial induction talks to getting started in the department and concluded that these early weeks were of particular importance in the undergraduate career, perhaps the most "formative", for they constitute "a period of very rapid adaptation and personal change... attitudes and ideas established at this time may become permanent fixtures."

This was backed up by my observation, at the end of Dr. W.'s introductory talk, of several students converging on him to ask specific questions such as "Do we need to write out the method?" "How much preparation will be necessary?" "Are we expected to write all our preparation down?"

One way in which a student was able to find out what was expected was by listening to his supervisor. Throughout the laboratory sessions supervisors were available for advice on such things as interpreting the script instructions, problems of measurements, use of instrumentation, and in the early weeks they were especially busy instilling the general habits of experimentation they required. During the first Tuesday session I recorded some of these student-supervisor interchanges:

"Although they were told not to in the introductory lab talk, almost every student seemed to be writing his experimental results in rough on a separate sheet of paper. Dr. W. observed this and went from bench to bench telling students to record their work directly into the lab-log book." (Field Notes 7:10:75)

In this session I also observed all three supervisors explaining to their students that when recording a measurement they should always specify the approximate level of uncertainty due to instrument and measuring equipment errors. In the second week:

"Dr. W. answered the query of a pair of students and came directly to me smiling: 'two weeks and they're asking about the inaccuracies due to the AVO' (a measuring instrument). It seems they had asked whether it was 3% error at mid-scale or 5%. The point Dr. W. was making and was so pleased about, was that the two students as a matter of course were now taking into consideration the errors due to their AVO meter." (Field Notes 14:10:75)

These early weeks were also used by the supervisors for the purpose of making clear to students the rules surrounding the LMF:

"At 4 o'clock, Mr. C. seemed annoyed and called together all the students under his supervision. It seemed that none of them had finished their experiments and he told them 'You must write everything up as you go along, by 4 o'clock everything should be finished; report, experiment, conclusions, everything'." (Field Notes 10:10:75)

Consequently, students found out what was expected of them by listening to what they are told by their supervisor. Not surprisingly, students also made adjustments to their style of lab study as a result of proceeding through experiments and simply trying to understand what they were doing. For instance, on entering the lab, students soon realised that they had rarely met the topics covered in the experiment they were scheduled to work on. The initial reaction of most students to this was to complain to each other. Several took it up with the supervisors and then later with me in interviews. As one student put it:

"The first thing I found was that I hadn't done the theory of the practicals I was doing, and to a small extent this annoyed me because previously (at school) if I'd done practicals in which I hadn't done the theory it was on a simple enough level to get by without knowing the theory, you know I was doing it from a sheet which gave you an explanation of what to do and you could actually get results without knowing the theory and you could look back and apply the theory later if you wanted to."

For this student and for many of his colleagues, the arrangement they discovered in the lab was unusual, surprising, initially unsatisfactory, and required an adaptive response from them. The common complaint was not that they were unable to work through the experiment, in the sense of following the

suggestions of the script, but that without understanding the underlying theory of the material covered they could not reason out why they were being asked to gather the suggested instrument readings and draw the specified graphs in the first place.

Further adaptive responses were required. It was not possible, for instance, for students to reflect on their experimental results in their own time after the lab (as many had previously done at school). All students were required to produce their work for assessment at the end of each session. To respond to these circumstances a majority of the class found again, that they had to make some major changes to their previous or 'natural' style of lab study. Invariably, the solution adopted by a student faced with this situation, was to concentrate on prior planning and preliminary work to a greater extent than ever before.

One student who had previously been allowed at technical college to take his results home to write a report, asked his supervisor in the second week why this was not the system at Surrey:

"I asked Dr. K. about it and he told me that it was for the student's benefit. That it cuts down the work the student has to do and prevents them just going in taking results and then sweating over them for hours."

For this student the effect of the lab arrangement was to reverse when he did most of his thinking: that is, from after the experiment to before it. Another student explained that with the Surrey arrangement:

"Most of the thinking about the experiments themselves, about the theory of the experiment, is done during the preliminary work. You have to think about what's going on. Really, preparation is the only time you get to think."

Another situational arrangement requiring students to adjust their actions and methods of proceeding was the scheduled time available in the lab. According to one student "you have to find out just how much you can fit into three hours." The initial common response was that three hours was too short and consequently, students had to begin making decisions about the best use of their time given the situation:

"If you don't prepare beforehand you really get stuck for time. What I do is more or less put in all the formulae so that I can just slot in the results. You actually do all the preparation beforehand so it almost mechanically falls out. I draw all the tables and result columns, at least as well as I can, and even put the axes on the graphs I have to draw."

The early adaptive experiences discussed so far arose as a result of students (1) listening to their supervisor; and (2) gaining experience in proceeding through the experiments and making adjustments to understand their work better. A third way in which students developed their style of lab study in the early weeks was as a result of being assessed.

In the period up to three years before this study, a student typically gathered his experimental results during the laboratory session and then took them away to be processed and written up at home. This arrangement, according to the present programme director, was unsatisfactory for several reasons⁽¹⁰⁾ and radical steps were taken in an attempt to devise an assessment scheme

(10) First, students would often procrastinate and be left with several reports to write at the end of the programme. Second, the report when eventually written tended to be too formal and lengthy and students themselves complained about the amount of time they spent in writing them. Third, when reports were received by staff to mark, it was difficult for them to judge the students' general experimental approach and lab behaviour since all they had to go on was a written account of the work.

which would be sensitive to all aspects of a student's work in the lab. Eventually an assessment sheet was developed (and implemented in academic session 1974-1975) in which students would be assessed at the end of the session on both the keeping of a lab-log and experimental performance in the lab.

Briefly, the new scheme required a supervisor to mark each of the students under his supervision on 10 prescribed categories and from 0 to 4 on each category. The highest possible mark a student could therefore obtain was 40. The laboratory sheet used by supervisors to assess the students is shown below in Figure 4.2 .

STUDENT			EXPERIMENT				
PERFORMANCE	TOTAL /20	%	POOR	SATISFACTORY		EXCELLENT	
				DOUBTFUL		GOOD	
			0	1	2	3	4
PLANNING AND PREPARATION							
UNDERSTANDING OF EXPT AND BACKGROUND							
ENTHUSIASM AND EFFORT							
APPROACH TO WORK							
DEGREE OF PROGRESS AND PROGRESS MADE							
LAB LOG	TOTAL /20	%					
			0	1	2	3	4
PLANNING AND LAYOUT (ease of access)							
PRESENTATION AND HANDLING (tables and graphs)							
EXPERIMENTAL NOTES AND OBSERVATIONS							
TREATMENT OF UNCERTAINTIES							
PRESENTATION OF RESULTS AND CONCLUSIONS							
GRAND TOTAL			DATE				

Figure 4.2

The perceived advantages and disadvantages caused by adopting this method of assessment are discussed in detail in Chapter Six. (11)
 At this stage of the analysis I want only to examine the role played by assessment in the early adaptive process of a laboratory student.

The method of assessment enabled students to discover the criteria upon which they were marked and it was not rare for students to actively seek out this information: (12)

"What you do is find out what each supervisor wants... Each supervisor marks three experiments so you go through them three times (in the first term). After the first time you get wise to their methods...you know from observing and listening to them what they like and what they don't like. For instance, if you don't put down any errors he may mark you down on all columns (of the assessment sheet)."

An incident in the second Friday lab session sensitised me to the importance students attached to their lab marks (which, when aggregated at the end of the year, counted as equivalent to two exam courses).

"At 12.00 o'clock the students began to arrive in the lab and without exception gathered around the lower end looking at the class list on the wall. I ventured down and could see that the list contained a set of lab marks. So far only the Tuesday group's marks were filled in. A student who attended on the Tuesday appeared to have got a mark of 29 (it was the highest listed) and I heard other students in the group saying: 'wow 29',

(11) In Chapter Six, using twenty years of documentary records, I trace the history of the Surrey lab programme and this includes analysing the various stages leading up to the present scheme of student assessment. But here I am concerned only with the lab programme as it now exists and how students respond to the present arrangement.

(12) Note the similarity here with the "cue-seeker" students discussed in Chapter Nine of Miller and Parlett (1974). Also on this issue see Becker et al (1968).

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'look somebody got 29', 'who is Smith?' Two or three students then began to refer to their class lists to see if they could find out more about who this Smith was. The marks seemed to be very much the centre of attention and then the student standing next to me said to his partner, rather nervously, 'come on we had better get started'. Soon afterwards the supervisors came into the lab and the crowd began to disperse." (Field Notes 17:10:75)

That the method of assessment can influence a student's developing study style and specifically his decisions on how to proceed through an experiment is illustrated below by separate reports from four other students:

- (i) "At the beginning my marks were very poor. The first one was less than twenty. It was so poor because I was trying to concentrate on the content of the experiment and not on that preparation and things like that. I was really trying to get at the theory of the experiments and why I was doing what I was doing. Then I found out that I shouldn't be doing that sort of thing because I was getting really low marks, my average was less than twenty..."
- (ii) "Usually you are expected to write observations and conclusions for the experiments and things like that. Half the time they are not very necessary - like some experiments just involve at the end saying 'this has worked or it has not worked'. Sometimes it might be an advantage to do away with that and get on with the essential parts of the experiment where you have to take readings or work something out, but the conclusion counts as four marks. Also preparation counts for four marks and various other things. But in certain experiments you might have varying priorities. For instance, in some experiments observations might be more important but it carries the same mark of four, whereas in other experiments there might be no observations."
- (iii) "I now spend about fifty per cent of the time in the lab writing my lab-log. If it was left to me I really wouldn't write anything except the results, but you know the supervisors ask you to report all the important facts that happened during the experiemnt. For instance, if you notice a decay of something you have to write it down just to get the marks."

(iv) "...what changed (as the weeks of the lab programme passed by) was that you began to realise what they were looking for. You found out that although you did lots of preparation and got interested in it, all they did was count how many pages of preparation you did, so for example I'd write out pages from a book then copy out the method and every time they gave me extra marks for writing down the method. Incredible. It was marked very mechanically."

To summarise, the first few weeks in the Surrey lab was a time of uncertainty and tension for most students, a time for re-appraising previous habits of study acquired at school or technical college and adjusting them to a set of new circumstances.

The Student's Experience of Contradictory Demands

A central feature of the early adaptation process was that students frequently encountered conflicting demands. Torn, often, between the official demands of the teachers, as outlined in the laboratory booklet, and the demands embodied in LIS and LMF.

At the beginning of the programme all students were presented with a booklet entitled 'Notes for Students', three of the things they were told in it were:

- (1) Do not go through an experiment following the laboratory sheet line by line. Question each step, the need for it, and the way to perform it. If possible, design your own approach.
- (2) Endeavour to think for yourself, learn as much as possible and try to improve upon the basic format of the laboratory sheet.
- (3) Experimental work should not be a chore, it should be interesting and enjoyable. If the experiment is boring make suggestions for improvement.

Proceeding through their experiments, however, students experienced a tension between the three stated aims and what they were rewarded for.

Trying to adapt to a range of conflicting messages caused students to experience considerable frustration and this was raised time and again by first year students, (and also by sixteen second year students who I interviewed in groups of four in order to gather their retrospective views of the first year programme). To portray these tensions I include an extract from one of the group interviews:

Interviewer (I) Are you saying that getting a high mark and understanding the experiment are incompatible?

(All) Yes. Definitely so.

Student 1 (S1) To get a high mark you must finish the experiment but that doesn't mean you understand it.

(S2) If you do ten pages of preparation even if it's copied out of a textbook and you don't understand a word, and you are really neat and do uncertainties here there and everywhere even if they are wrong, and you draw error bars here there and everywhere even though they are not right, underline all the titles, draw all the graphs, then you are going to get four for everything and you needn't understand a word of it.

(S4) There is only one category (in assessment sheet) on understanding. There should be more marks for this. All there is is four marks out of forty.

Interviewer (I) Were the marks you got in the first year lab representative of how much you had learned?

(All) No!

(S3) A lot depends on who marks you. You could say I know old so and so, he will go mad if I don't put the bench number down. Put the bench number down and it's worth an extra mark to you with that person. You go to another person, he doesn't want the bench number perhaps, but you lose a mark for not noting a meter number.

- (S2) You get to know their preferences.
- (S3) It would be nice if they allowed us to go in on Wednesday afternoon and just play around with the experiment.
- (S4) All the time they say 'Don't stick to the lab notes, if you want to change that capacitor then do it'. But if you do that then it slows you down, you don't get so much covered and lose marks. If you really want to branch out and enjoy yourself you can't.
- (S2) Really the lab is about getting as far as you can even though you don't understand it.
- (S3) Because these two things - what you are getting out of it and the mark you get - because they are worlds apart the majority of people say 'right I'm here for the marks I get; that's important because that's going toward my final exams. The rest I can pick up in experience later on'...You see those marks are going toward my degree and I need every single one.
- (S4) It's disappointing though. OK as you walk out of the lab you think OK another twenty-six marks but you look back and are disappointed when you realise you didn't learn anything.
- (S2) Students want to do practical work but not the type the department serves up...For instance take the transistor experiment. Because of the marking system you stick to what the experiment says. You do everything on the sheet. If you do any extra it doesn't really matter. If you don't do very much it does matter. But you stick to every line. There are lots of things I'd love to do with that transistor rather than what they say on the sheet."

The students probably used the interview to get a lot of 'groans off their chest' and in doing so each was reinforced and spurred on by the others. Consequently, the expressed views carry a lot of feeling and in some cases are undoubtedly extreme.

In the ninth week of the first term, when each student had completed approximately seven of the sixteen experiments, I issued a questionnaire to ask, among other things, about the assessment scheme. The response to three of these questions is shown in Figure 4.3 .

Assessment Sheet

PERFORMANCE	X	Y	Z
Planning and preparation	2	11	0
Understanding of expt and background	5	7	0
Approach to work	13	9	7
Effort and enthusiasm	5	12	6
Rate of progress and progress made	2	8	4
LAB LOG	X	Y	Z
Sectioning and layout (ease of access)	1	1	0
Data presentation and handling (tables and graphs)	2	2	0
Experimental notes and observations	1	2	0
Treatment of uncertainties	3	8	0
Presentation of results and conclusions	1	3	0

Figure 4.3

The three questions are shown below. The numbers included on the sheet represent those students who ticked the box.

- Q1 Please put a tick in column X against any category you do not clearly understand the meaning of.
- Q2 Please put a tick in column Y against any category you feel is marked unfairly.
- Q3 Please put a tick in column Z against any category you feel should not be on the sheet.

Of the fifty-three students who received the questionnaire thirty-nine replied (a response rate of 74%) and of these, three students did not answer this question. The response to the question (presented in the table) indicates, of course, only a

class trend, but as a result of talking to students afterwards about their replies a clearer picture emerged. A discernable trend was that the students were more dissatisfied with the assessment of their performance in the lab than their keeping a lab-log. Indeed, when aggregated, approximately a quarter of those students who replied felt that all the performance categories were marked unfairly. It was not that the students felt that lab performance should not be marked per se, but that it was difficult for supervisors in the time available, to do this accurately. One important consequence of this was that in coping with conflicting demands students were tempted to concentrate on improving their lab-log (the assessment of which they understood) rather than their experimental approach.

Having to proceed with speed in the lab served only to reinforce the experienced conflicts:

"The actual wiring up I now do much quicker and I have more confidence that it will be right...but because of the lack of time you don't get to write conclusions as you go through, you don't have time to think about any sort of conclusions as you go through. You do the experiment in the hope that it will all make sense at the end and this rarely happens. You certainly don't get the chance to try out your own approach as they (the supervisors) suggest. In the first couple of experiments I found myself doing nearly all of the experiment and I had no time to think about it afterwards and I had nothing on paper near enough, and so after a while I got the experiment done as quick as possible and tried to write the work up more fully. But it's just not occurred in the experiments that I've been able to try out my own ideas or to just fiddle around."

To sum up, teaching staff claim they want student to be involved in their experiments "to question each step, the reason for it and the need for it." They tell students: "devise your

own method". While teaching staff officially desired student involvement, it seems more accurate to say what they actually wanted was involvement in some things, but not in others. For instance, lab supervisors did not encourage students to become involved to the point of spending the whole of the scheduled three hours exploring and perhaps developing a new type of instrument to gather the required measurements. Rather, the student was expected - although he was not told this explicitly - to gather his results along standard lines with the instruments provided. The lab programme, as presently arranged, appears to embody certain assumptions about how students will respond and indeed could not cater for the former type of involvement. (13)

The Hidden Curriculum and the Double Bind Hypothesis

In adapting to the Surrey lab programme students were channelled in certain 'desireable' directions. The precise mechanism by which this occurs, however, is complicated. It seems that on the one hand students were officially encouraged to get involved in their experiments and indeed to innovate. At the same time, because of the way in which the laboratory was arranged, not only did they find this difficult actually to do in the time available, but they also felt it was not rewarded. This was a major contradiction facing the laboratory students.

(13) With another educational context Jackson (1968) has touched upon just this point: "if students were allowed to stick within a subject until they grew tired of it on their own, our present curriculum would have to be modified drastically".

Two American researchers have discussed a similar phenomenon in other educational contexts (one characteristic of this thesis is that I have continually tried to draw upon insights, ideas, and methods, from many fields of enquiry to understand better student behaviour discovered in the lab). I refer to the higher education work of Snyder of MIT and the classroom research carried out in primary and secondary schools by Jackson of the University of Chicago. Both have proposed a concept they call the "Hidden curriculum".⁽¹⁴⁾ The hidden curriculum they suggest, constitutes a set of implicit demands - as opposed to the explicit obligations of the "visible curriculum" - that are present in almost every educational setting and which students have to find out about and respond to in order to survive within that setting.

Snyder's (1971) work obviously bears a general resemblance with my own analysis of student behaviour in the lab. He writes:

"When students first come to a college campus as freshman, most are disoriented. Each is busy developing a cognitive map of the campus - finding the appropriate paths to the proper places. In practical terms, students are getting a fix on the requirements - that is, on the formal curriculum. They learn quickly which course options are open to freshman; how to drop introductory English; what specific pre-requisites are needed for the first-year physics course; and how to keep a scholarship. In addition - as part of the formal curriculum - they soon become familiar with the non-academic rules, and with the explicit sanctions for breaking them: for example, the nature of the college's stand on drugs, the penalty for co-eds who fail to sign-out...

Each student figures out what is actually expected as opposed to what is formally required. A professor may explain at the beginning of the term that he requires knowledge and competence and creativity and originality.

(14) Snyder's research began in 1961, an interim published report appeared in 1966 and then in 1971 the book of the concept 'The Hidden Curriculum'. Jackson proposed the same concept in his book 'Life in Classrooms' published in 1968. Surprisingly Snyder does not refer to Jackson; nor in later writings on the same subject does Jackson (1970) refer to Snyder's work.

In many cases, the professor may mean it; or he may believe what he has said but then set the tasks in such a way that rote memory rather than knowledge is rewarded. It takes the class a little time to sort out these messages, to locate the disparity, to interpret the mixed signals created by the presence of both a formal and a hidden curriculum.

There is no simple response to this disjunction between the two curriculums. Some students even fail to recognise that a disjunction exists. But nearly all of them find that they must develop a series of strategems, of ploys and adaptive techniques, to deal with the choices that confront them...They know that they must complete assignments, write papers, pass examinations; that they must organize their time and decide on priorities - whether to explore a question in great detail or to aim for a grade, if time and pressure do not permit both."

Perhaps the major use of the hidden curriculum concept was that it gave a name to a recognisable slice of educational reality and in doing so allowed teachers a lead-in to talking about the related teaching and learning issues. Nevertheless, Snyder's and Jackson's discussion leaves important unanswered questions for the researcher interested in using the concept to understand a specific learning environment such as I wanted to do.

Snyder and Jackson demonstrate that the general nature of student adaptation in an educational setting is to a "double system", but both agree that what is really crucial is not so much the presence of formal rules and informal responses, but the kinds of dissonance created by the distance between the two. According to Jackson (1968) the student "must develop strategies for dealing with the conflict that frequently arises between his natural desire and interests on the one hand and institutional expectations on the other."

The concept of a hidden and visible curriculum calls attention to the points of conflict between "institutional conformity and intellectual development" that I too discovered in the lab. In recognition of future work Jackson ended his discussion with some serious questions and a plea for further research:

"Can both (curricula) be mastered by the same person? How incompatible are the two sets of demands?... Unfortunately, no-one seems to know how the above balances are maintained, nor even how to establish them in the first place. But even more unfortunate is the fact that few if any school people are giving the matter serious thought." (Jackson, 1968) (15)

Snyder is vague on how observed student study strategies arise, he never gets around to attributing cause and yet this is surely crucial information for the teacher (or any other decision-maker) to know if he is to do anything about changing his teaching or the design of his course. All that Snyder says on this is that:

"The faculty is not playing a duplicitous game, but the processes that the system has created tend to work against the ends desired by the professors, the students, and the university. It is these processes - and not malice or sadism on the part of teachers - that help perpetuate the gap between the two curricula."

Related to the concept of a hidden curriculum but of more practical use in helping explain the student's experience of contradictory demands in the lab, is the "double-bind hypothesis" pioneered by Gregory Bateson (surprisingly, neither Snyder or Jackson refer to the work of Bateson).

(15) Judging from these remarks it is not surprising that in a subsequent book Jackson (1970) coins another and perhaps more informative phrase for the concept. He calls it the "Unstudied Curriculum".

Historically speaking, the hypothesis is traceable back to Bateson's anthropological fieldwork in New Guinea during the early 1930s. In the book of that study ('Naven') Bateson (1936) introduced the notion of "schismogenesis": basically a rule that opposites are continually and dialectically heightened once begun. As a result of subsequent anthropological studies in Bali, Bateson was able to show how Balinese culture exploited schismogenesis as a means of training 'proper' detached, uninvolved, uncompetitive, Balinese adults. The Balinese mother, he showed, alternately attracted and ignored her child - i.e. gave it mixed signals - teasing it by the promise, and then the unexplained and unexpected denial of affection (see Kuper's foreword in Bateson (1973)). This, Bateson claimed, blunted the child's basic human tendency to involve itself in sequences of cumulative interaction.

Years later Bateson incorporated certain of these ideas into the double-bind theory of schizophrenia. The first account of this was published in 1956 and provided a framework for the formal description of schizophrenic symptoms and the experience of the schizophrenic in his family (Bateson et al, 1956). In essence, Bateson's double-bind hypothesis suggested that the schizophrenic personality was likely to develop in a person who was regularly placed in a situation where he or she was forced to obey conflicting rules. (16)

(16) The hypothesis is explained more fully in a later paper entitled 'Minimal Requirements for A Theory of Schizophrenia' (Bateson, 1960).

There are certain specific requirements for a double-bind to be said to exist that relate to the context within which a person operates. Bateson spells out these conditions in detail and the same conditions are also discernable in the Surrey Lab. (1) the first precondition was that learning occurred always in some definable context which had "formal characteristics" such as a cause/effect, correct response/reward sequence. In the case of the lab we may think of the student working through an experiment guided by the designed instructional script. (2) Next, the hypothesis depended upon the idea that "the structured context also occurred within a wider context - a meta-context if you will - and that this sequence of contexts was an open, and conceivably infinite series," (Bateson, 1960). Thus, we can think of the lab experiment as part of a lab programme, which itself is embedded within the first year course, which in turn is part of the Electrical Engineering Department, which is part of the University of Surrey, which is part of the British higher educational system, etc. (3) The hypothesis also assumed that what occurred within the narrow context (the experiment) would be affected by the wider context (lab social-system) within which the smaller one had its being, and that there may be an incongruence or conflict between context and meta-context. For instance, to think out a new experimental approach might be encouraged in the primary context but

'punished' by a poor assessment mark in the metacontext.

This is the double-bind, so called. (17)

Of perhaps the most interest (methodologically) in elucidating what happens to people subjected to conflicting messages is the work of the psychiatrist R.D. Laing. More than most he led the way in developing Bateson's ideas. For instance, he has reported (18) over one hundred studies of the circumstances surrounding persons regarded as schizophrenic. His thesis: that "without exception the experience and behaviour that gets labelled schizophrenic is a special strategy that the person invents in order to live in an unlivable situation" (Laing, 1967b). Of special importance to my own study is Laing's view on the origins of this observed behaviour and his procedure for looking for its causes.

According to Laing, if an investigator set out to examine the experience and behaviour of schizophrenics without reference to family interactions (as traditional psychiatric inquiry tended to suggest) then the individuals' actions would appear comparatively socially senseless. However, if the investigator examined the same experience and behaviour in their original family context, the schizophrenic's behaviour was more likely to make sense:

(17) Of course, there are major differences between the experience of students in a lab programme and a diagnosed schizophrenic in a family context. What is common is that each is subject to and must learn to cope with contradictory demands, however the laboratory student is not placed daily in this situation (at least not in the laboratory).

(18) Eleven of these cases are documented in the book 'Sanity, Madness and the Family' (Laing and Esterson, 1970).

"(the person labelled schizophrenic) cannot make a move, or make no move, without being beset by contradictory and paradoxical pressures and demands, pushes and pulls, both internally, from himself and externally from those around him. He is as it were in a position of checkmate.

This state of affairs may not be perceived as such by any of the people in it. The man at the bottom of the heap may be being crushed and suffocated to death without anyone noticing, much less intending it. The situation here described is impossible to see by studying the different people in it singly. The social system, not single individuals extrapolated from it, must be the object of the study". (emphasis added) (Laing, 1967b)

What Laing is saying is essentially very simple: that to understand schizophrenic behaviour the investigator must take care to locate the behaviour in its correct context; the reason being that the same human act in a different context would not necessarily have the same meaning.

This is about as far as I can usefully take the work of Laing. The idea of locating behaviour in its correct context however is one that obviously needs to be seriously considered.

Conclusion

Educational psychologists and others interested in the student learning process have, by and large, been more interested than teachers in context-free explanations of student behaviour (see, for instance, Gagne (1970)). From their standpoint the reason why a student decides to, say, work quickly through his experimental task, is because of his previous experience, his own personal interests, or other individual preferences.

The analysis of Chapter Four suggests something quite different. Students in the Surrey lab of course reacted to the programme in their own fashion but many of their adaptive responses overlapped and formed common patterns which were largely channelled by local situational demands. In other words, student activity in the lab seemed to be influenced not so much by personal desires and preferences, but by the organisational and administrative arrangement of the LIS and LMF.

The decision made in this chapter to conceptualise the lab in terms of a social system made up of both an LIS and LMF seems like a good first stab for setting the context and understanding the events that takes place there.⁽¹⁹⁾ However, the teacher who reads a description of student learning experiences in the lab and in the light of this decides he would like to change some aspect of the programme would presumably find it useful to know not only about the general channelling mechanism by which student activity takes shape but specifically why it was that way, and therefore where he could go about most effectively making organisational and instructional interventions. In the next chapter, therefore, I consider the third predominant pattern of student activity (working

(19) In a general sense the lab can also be compared to what Goffman calls an "instrumental formal organisation". He defines this as a "system of purposely co-ordinated activities designed to produce some overall explicit ends". Goffman found it useful, when trying to understand the activity of mental patients, to define the mental hospital as such an organisation. Doing so allowed him to show that seemingly unintelligible behaviour could make quite ordinary human sense. He managed to do this by describing such behaviour not as 'in' mental hospital patients, but 'within the context of' the system in which it took place, (Goffman, 1968b).

mechanically), relate this to how students learn in the lab, and attempt to seek out the various local reasons for why working mechanically occurred in the Surrey programme.

CHAPTER FIVE

WORKING MECHANICALLY IN THE LABORATORY

1 Introduction

In 1968 in his book 'Life in Classrooms' Jackson wrote that "despite a half century of research and the development of several sophisticated theories, the teacher's classroom activities have been relatively unaffected by what the learning theorist has to say." (See also, Cronbach, 1975)

The reasons for this are no doubt complex but an increasingly popular view suggests that researchers of student learning have sought answers to questions that the teacher is unconcerned about (McKeachie, 1974).⁽¹⁾ Indeed, this point was recently acknowledged in an editorial of the British Journal of Educational Psychology (1976):

"Since the pioneer work of Barlett (1932) on remembering there has been a tendency to trivalise human learning in experiments designed to discover fundamental general principles... Conventional approaches to the study of learning have created a mental set of 'frame' which has limited views on learning to rather narrow horizons."

To understand the process of student learning in the lab therefore I adopt an unconventional approach and attempt to unravel an issue of major concern to both teacher and student.

(1)

Kitwood (1976) has recently gone the whole hog and suggested that the findings of educational researchers in general have failed to appear "convincing or relevant to those who are directly involved in education".

Clearly the early adaptative process of students in the lab constitutes a time of taking in important new information. In Chapter Four I identified three patterns of student lab activity and subsequently examined two of these: "Working Quickly" and "Preparatory Working". Students call the third kind of study behaviour "Working Mechanically". This way of proceeding in the lab was frequently mentioned by students as having a profound effect on what they learned in the lab; indeed students claimed that when working in this way they learned nothing.

As a way into understanding the general process of student learning in the lab I concentrate on this theme of students working mechanically, a theme of undoubted significance to teachers and acknowledged as such in the published literature.

Published View and Assumptions about Working Mechanically

There are many recorded accounts (as we saw in Chapter One) of how students in the engineering and science lab often seem "bored" and "uninvolved" and appear to carry out their work "blindly" or in an "unthinking" fashion. Indeed, the syndrome seems to have been the main motive behind many of the proposed innovations in laboratory work.

In the Department of Electrical and Electronic Engineering at Salford University, for instance, an investigation of the first year lab revealed that real involvement was restricted to a small minority of students, and that the vast

majority "performed the (lab) exercise presented by the lecturer without understanding the need for such performance nor the contextual relevance to their course or future aspiration" (Lee and Carter, 1975).⁽²⁾

It seems rather strange that the problem of working mechanically is so widespread (and continues, for instance, to be discussed at conferences year after year) for there appears to be equally widespread agreement on its cause. In the Department of Electronics at Southampton University, for instance, Beynon and Bailey (1971) have suggested that above all a first year lab should "encourage students to develop a confidence in their own experimental ability". In the opinion of these two teachers, most programmes fail to do this because of the designed scripts:

"Too often...formal experiments have reduced the student to a 'knob twiddler' where, having been supplied with a 'black box', he has had no option but to follow blindly the detailed instructions of the experiment. Such an approach does nothing to make a student think for himself," (emphasis added).

Lee and Carter also attributed the cause for mechanical work to the "routine nature" of the experiments and the associated scripts which "leave little or no room for deviation from set procedures".

(2) According to Lee and Carter, most of the students they spoke to appeared "to be unaware of the significance of what they were doing" and "experiments were frequently performed in an unmotivated mechanical manner" (emphasis added). In their earlier survey of first year lab programmes in nineteen British electrical and electronic engineering university departments, Lee and Carter (1972) found that students' working "mechanically" through set lab experiments was a widely recognised, and unresolved, problem.

For teachers the unambiguous message is that they should concentrate on changing their script design - perhaps the sequence or structure of the instructions, or the content area covered, or even the experimental equipment to be used. (See the discussion about innovation in the Salford lab in section 1.3.)

This model of laboratory intervention is apparent in the handbook by Scott and Lyon (1973) called "A Course in Practical Physics". Interestingly, they begin their book with an anecdote about a student carrying out his lab work "unthinkingly":

"Some years ago we were watching a student 'performing' Searle's well-known experiment to find the thermal conductivity of copper. He had been sitting staring at the apparatus for half an hour or more waiting for the temperatures to become steady. We asked him why the bar was bedded in felt. 'To keep the heat in'. 'Why?' 'I don't know'. At that point it was time, according to his instructions, to change over the thermometers. The student did so and was asked the reason. But his patience was exhausted and exasperated, he replied 'You know, I am only doing this experiment - I don't understand it'."

Explaining the rationale behind their book Scott and Lyon make the incontestable point that any student who approaches lab work in the way outlined above is unlikely to find it either "interesting" or "profitable". But they then propose, not as an hypothesis but as a taken-for-granted axiom, that scripts of instruction if designed properly could avoid the situation arising. They assert that, for instance, scripts should "include questions to help (the student) to think why (he is) doing certain things in a certain order". Their

book, following on from this general rationale, sets about providing self-contained, ready-to-use, instructional scripts for just over ninety different experiments.

The underlying assumption of this published literature is that observed "unthinking" student behaviour is connected in a cause-effect relationship with the nature of the instructional script. It also follows therefore that educational researchers interested in explaining such student behaviour should look toward the instructional script for its root cause.

The argument may appear convincing on the surface but it does not fit with the evidence presented in Chapter Four. There I showed that the way in which students proceeded in the lab was influenced by far more than just the script. The casual assumptions in the published literature are therefore too restrictive and it seems reasonable to search for other influencing factors.

Definition and Analysis of Working Mechanically

Students used many words to refer to the mechanical ways in which they proceeded in the lab. They talked of working "blindly", "automatically", or "parrot fashion": almost always they claimed that they "learned nothing". Three different students expressed this in the following way:

- (i) "Take the filter experiment. We didn't have any idea of filters...to prepare for it I had to read through three different books but at the end I still didn't know what they were on about...(in the lab) we did exactly what they told us; read it (the script) line by line and carried out the instructions. We

took the results but we didn't know what they meant. Even when we finished the experiment we didn't understand what had happened. To tell you the truth I don't even understand it now."

- (ii) "When you do it mechanically you know you haven't done a worthwhile afternoon, you haven't done things that might have taught you something."
- (iii) "It's just annoying really because for three hours you just follow the instructions blindly. You do the experiment and go out at the end without feeling you have accomplished anything."

These remarks seemed broadly representative of many others making the same point and to test this out I issued a questionnaire to students in the ninth week of the programme when most of them had completed six or seven experiments. The questionnaire touched upon several issues raised during previous interviews and observation, one of these was working mechanically and the question is shown below:

Question

Several students have remarked to me that there is sometimes a tendency to 'switch-off'. That is: to follow the instructions from the sheet without really understanding, for instance, why you are taking the measurements and what they actually mean.

Please put a tick in Table 1 against any experiments in which you felt you 'switched-off' either for all or most of the time (Table 1 consisted of a list of the programme's experiments).

Twenty three of the 39 students who responded claimed to have worked this way for 3 or more experiments; all 39 claimed to have worked this way for at least 1 experiment; and 4 students reported that they had worked mechanically in all 6 of their experiments.

Implied in the claim by students that they learned nothing when proceeding mechanically are assumptions, of course, about what they felt they ought and ought not to be learning. These assumptions may differ from the intentions of the teachers but what can be safely said at this stage is that the students were expressing in their own terms a serious problem.

I found that in the Surrey lab there were three main constituents that characterised the specific study style of working mechanically. The student who proceeded through an experiment in this way was (1) unlikely to have understood the underlying mathematical and electrical theory and consequently the rationale behind the experimental procedure; (2) likely to perceive a lack of available time; (3) probably spending most of his time thinking about the mechanics of simply getting through the script and "doing" the experiment. I address each of these separately and in turn although they usually occur in conjunction and are not orthogonal.

(1) First constituent: To examine working mechanically in detail requires an important distinction to be made right away between on the one hand knowing how to work through the script in the way laid down, and on the other hand knowing why to proceed in the ways suggested.

I talked to several students who were able to "do" an experiment in the sense of correctly completing what was formally asked, without understanding (on their own terms) the ideas behind what they had done and the rationale for

the experiment. Thus, a student who was able to wire up the required circuits, take the required measurements, draw the required graphs, carry out the required measurements, and gather the required results, might also be unaware of why he was doing any of these things and what the experimental results meant. As one student put it:

"When you're following something parrot fashion you can't really write any conclusions because it (the script) says 'object: to find the characteristics of a transistor' OK you get the graph but if you have no idea of what the characteristics should look like then all you can conclude is that these are the characteristics. You don't know whether they are good, bad, or indifferent."

Not surprisingly, students encountered difficulties when working through experiments in which they did not understand the underlying theory and therefore the rationale behind the various stages of the script:

- (i) "They ask you to do things without explaining why. They say 'take such and such a reading, take such and such a reading, and plot this against that'. So you do the plot and get a nice curve and the supervisor comes up and says 'oh, yes, very nice' and you still don't know what the curve means so you don't really get anything out of the experiment."
- (ii) "Well, you start off the practical quite simply by taking readings. Usually it's fairly obvious the readings you take. It's not until you have to deduce something from the readings: there is always something you have to do and you have to derive equations to do that; if you don't understand the theory you don't have an earthly chance of understanding it all."
- (iii) "If you can get an overall picture of what is going on it makes life a lot easier. If you have an overall picture of what should happen then you know what you're looking for and you can understand it."

Getting an "overall" picture of the experiment was judged very important by these students and was one of the main ways in which they contrasted those experiments in which they worked mechanically with those in which they did not.

As one of the three students put it:

"I liked this experiment because I had an overall knowledge of what I was doing. Most of them you don't know what you're doing, you're just working through, you're not quite sure of the overall thing; you're working through it and you're not quite sure what kind of thing you should get at the end."

If a student did not manage to get an overall picture - both the 'how' and the 'why' - of the experiment there was a tendency for him to 'switch off' and simply proceed mechanically through the script suggestions. (3)

(3) It is worth quoting at length a relevant anecdotal account by the American observer of school children, John Holt (1970):

"Perhaps I can make more clear what I mean by the wholeness of learning...At school I was always a fairly good math student. It bored me, but it didn't scare me. With any work at all I could get my B. But after many years I knew that although I could do most of the problems and proofs and remember the theorems and formulas, I really didn't have the slightest idea what it was all about...I didn't see how it related to anything...what it was for, what one might ever do with it... (years later) I came across a series of books, written to help people with little or no math training understand some of the new and large ideas in mathematics.

The books were very well done (the authors)...understood how easily and quickly a learner, moving into new territory, is frightened by uncertainty, contradiction, or logical steps that cover too much ground. So they were very careful to define their terms in words the learner would understand, to move ahead slowly and patiently, taking time to illustrate their points and to reassure the reader...

But at the end of the books, though I had enjoyed being able to follow (the authors)...on their journey, and liked the feeling of knowing something I hadn't known before, I was still uneasy, dissatisfied...I had been able to follow them, step by step, to the end of the book. But at the end I felt as if I had been blindfolded and then led along a carefully prepared path. 'Now put your foot here, easy now, that foot there...' I didn't stumble, but I wanted to take the blindfold off and say, 'Where are we anyway? How did we get here? Where are we going?'"

(2) Second Constituent: In the process of working through the experiment a student customarily found there was little time in the lab to set about understanding the theory, even if it was comprehensible to him. He was obliged to work quickly (a common pattern discussed in Chapter Four). Four different students explained some of the consequences:

- (i) "Often Chris says to me 'Oh let's do that again' or 'let's do something else again' and I say 'no, let's get the next bit done first, let's get it finished'."
- (ii) "...You haven't really got time to think about it (the experiment). You sort of get the measurements and then grasp around for a few things and see what you can make of them."
- (iii) "...You only have three hours to work in, so immediately there is a time pressure on you. So you work quite quickly but when you're working quickly you can't really think about what you're doing."
- (iv) "The thing about the lab is you're working to a time limit...you have to get all the uncertainties (of the measurements) down mucking about with all that, and reading off the different instrument numbers that takes another half hour, and then you work through the experiment and the bloke you're doing it with says 'well this isn't very good, should we do this bit again?' So you perhaps do it but you find when you get through the lab that you have nothing worked out, nothing written down except the results..."

When both conditions (1) and (2) existed - i.e. the student did not fully understand the rationale before he started on the experiment and he also perceived there to be a shortage of time then he was typically forced into the position of thinking only about "doing the experiment" and "getting through the instructions".

(3) Third Constituent: Thinking about "doing" is a consequence of (1) and (2) and refers to the primary thinking process that students seemed to be engaged in. They were thinking about how to do the different stages of the experiment (connect up the circuit and take the measurements) rather than about how those stages came to be in that order or even why they were included at all. Consequently students often failed to appreciate the emerging experimental results of each stage and what they meant:

"Well, you do it automatically in that you've got it all jotted down in your book, all written out in the preliminary (preparatory work) and you sort of refer to that. You do things as they say: just put the numbers into nice equations and you get the results but you don't really think about what it is you're doing. It's just a case of actually writing it down."

"I remember the three phase circuits experiment. I didn't know what was going on so I followed what we were supposed to do: take measurements OK, we took all the measurements and then we asked, 'what are we supposed to do with the measurements?' and we were given a sort of indication (from the script) that we were supposed to work out certain formulae which was just a matter of substituting your experiment values into a derived formula. Well that doesn't help at all, it's just like doing something mechanically. I was just substituting the figures, working everything out - push a few buttons on your calculator and you get the answers...In one part (of the experiment) you have to find a phase angle. You might know what you are doing to find the phase angle but you don't know why you want the phase angle in the first place..."

In Chapter Four I discussed the general channelling process by which customs of conduct were generated in the Surrey lab. I now want to take this major theme of mechanical work further and, in order to help teachers who may wish to intervene and change their programme, seek out the specific factors

that influence a student to work this way. In other words, to take a first stab at the inevitably difficult task of attributing cause.

One of the factors that influenced a student to proceed with speed was the method by which he was assessed (a major feature of the LMF). As one student put it:

"(if I wasn't assessed) I would take more time over what I was doing, make sure I fully understood each step before moving on to the next one. But we've all got into a marks syndrome where everything centres around marks."

Students were assessed immediately after they finished their work, and by and large (as shown in Chapter Four) they believed the best way to get a good mark was to complete as much of the script as possible and to fully document this in the lab-log as they proceeded.

Another LMF factor influencing the students perceived need to rush was the time schedule. From time to time I asked several students: "Suppose you were given six hours to do the same experiment, would you proceed in a different manner?" The answer was invariably the same and the essence of the replies was captured by one student who explained:

"Yes. I think for each part of the experiment I would take more time and try to understand what's happening, because if time is short then at the same time as thinking I have to write. If the time is enough I will have the time to just sit and see what's happening in front of me, think about it and then go to my lab-log book and write."

There is another way to understand the 'perceived lack of available time' in the lab. It could equally be argued

that the amount of material included in the script was too much for the students to cover (an LIS factor). This, in fact, was the way the following student explained it:

"With slightly less set work to do you would probably get more from it. You would try and think, well, what is actually happening? What am I actually investigating? Rather than just noting down the results and not thinking what is going on."

A teacher wishing to re-design the lab programme to give students enough time to reflect is faced therefore, with the problem of whether to change the method of assessment and keep the amount of script material and scheduled time the same or, alternatively, change the scheduled time or, perhaps the amount of material to be covered by the student. I return to these important questions of intervening in the programme more fully in Chapter Six. The features of the lab programme that contributed to students perceived lack of time also reduced the chances of him understanding the underlying rationale of the experiment. The connection was explained to me when I asked whether it was possible to understand the rationale during the actual process of carrying out the work:

"Well, that's the problem of the time limit. I have found, with some experiments, that did happen to me, but when I really started thinking about it I didn't have much time. There were certain parts of the experiment that when I started thinking about it I began to grasp what the experiment was about so I tried to take other readings to see if I was correct. But the time factor didn't allow for that and so I had to push on and finish it within the time. So even if you realise half way through what you are actually doing, it usually doesn't help very much - you only have three hours."

One way in which students gained an overall picture of the assigned task was to spend time before going into the lab studying the script:

"If it's an experiment where you've done the preparation and you know exactly why you're doing the experiment, how you're going to do it and what each step is leading to, you're not just following instructions parrot fashion."

A major job at the preparatory stage was for the student to understand the electrical and mathematical theory included in the script:

"It gives you a feeling of confidence, when you know what you are doing - exactly what you are doing - when you fix up the circuit you know exactly what is going to come out, or if something is wrong you know what the error should be or where you can trace it back to. In some other experiments when you don't know the theory behind it, if you get some readings that don't match up to what you are supposed to get, you don't know where to start to discover the errors. It's really very frustrating - sometimes you just tend to give up."

To grasp the theory associated with their assigned experiments the students were clearly influenced by the actual theoretical content covered in the script (an LIS factor). This was sometimes pitched at a level which was too difficult for the student to appreciate even with further reading. In contrast, it sometimes covered ground that the student had previously encountered in 'A' levels. Consequently, related to all this, and therefore another influence (from the LMF) was the fact that (for organisational reasons) the lab programme was not sequenced with any specific on-going lecture course.

The following diagram summarises the interrelationship between the different influences that act upon a laboratory student and result in him adopting a study style termed working mechanically. Of course everything is connected to everything else, however, the main influences and relationships discussed in this section are highlighted.

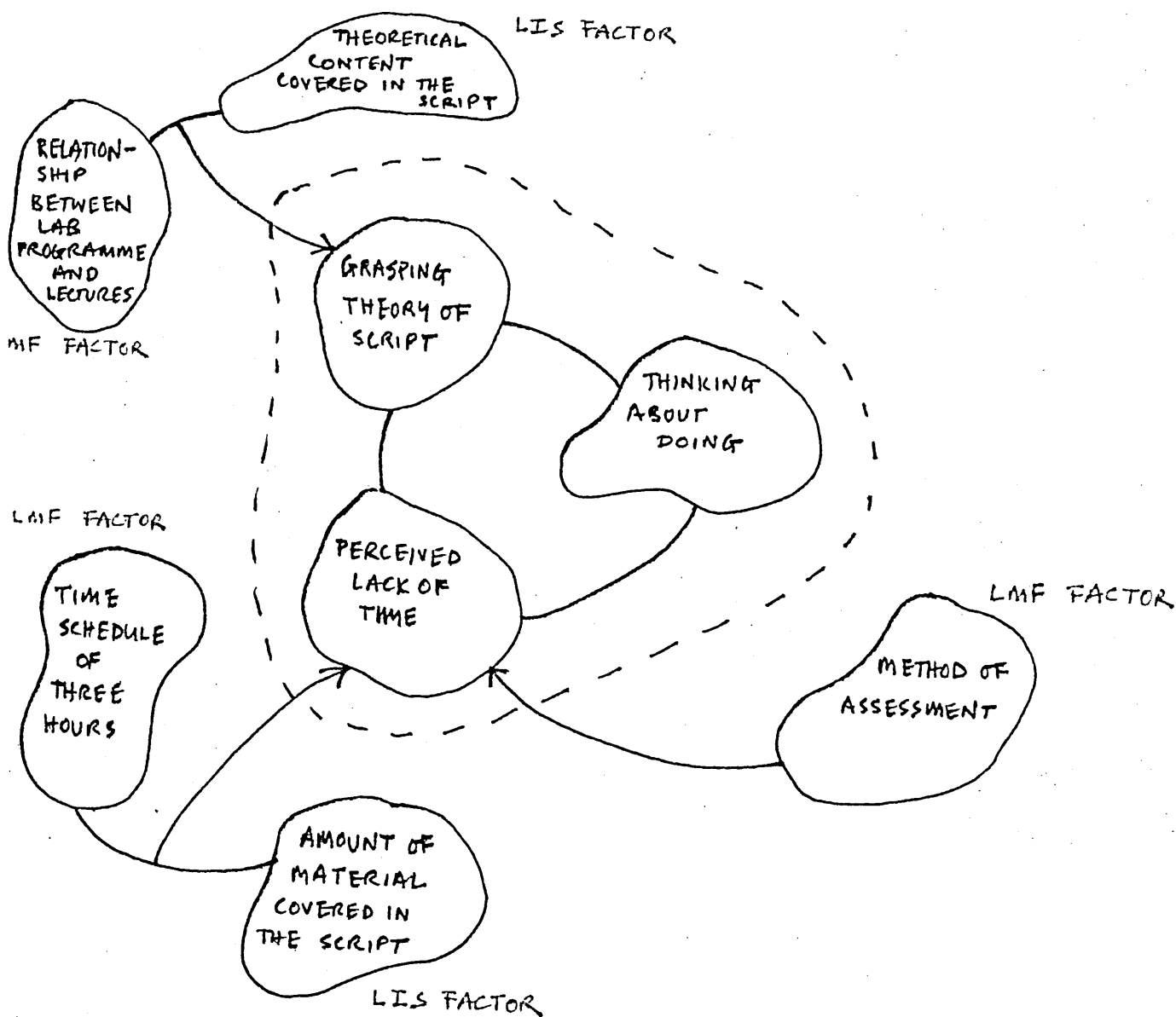


Figure 5.1

Two Myths about Working Mechanically

It now seems appropriate to correct two myths which seem always to have surrounded the phenomenon of working mechanically.

First, such a style of lab study has often been referred to in the literature as "unthinking", and caused by following "blindly", or word for word, the experimental instructions. This is true up to a point but is superficial. The fact is that working mechanically does require students to think: this was particularly apparent when they talked of the strain they experienced. Several students, for instance, maintained that the first thing they did after the lab was go to bed for a rest. (4) As one student put it:

"...it takes it out of you. Usually I don't do anything afterward. The lab is really a hard day. I usually come back, lie on my bed and then go out for something to eat and a pint. It's quite mentally exerting. You may be doing something mechanically but you have to think about it, you're racking your brain as to how you're going to write it up and how to get the errors done etc. - it's much harder to do the lab than do an exam. Really, you're concentrating solid for three hours...its quite a brain strain."

Another student expressed it in the following way:

"Tuesday is the one day that I don't really work in the evening. I just take it easy because the lab really does take it out of you. It's not that it's really hard work or anything, it's just that you're concentrating solid for three hours...even when you end up doing it parrot fashion you're thinking the whole time and having to concentrate."

(4) Of the fifty three first-year students I talked to during the year, thirteen mentioned (without specific prompting) that in the evening following their lab work, unlike the other four academic days, they usually had a 'nap', 'a lie down', or generally 'took it easy'.

A third student commented:

"The thing is that you're having to think about it and work quickly at the same time and it's bloody tiring...you're sat down like this and writing, and then reaching over to take an instrument reading, rearrange some formulae and write it down, take some more readings and check that they're accurate. And you're doing all this at speed and maybe something happens and you have to ask yourself 'why is there a difference of phase on the oscilloscope?'..."

It is not the case, then, that students who work mechanically are switching into an "automatic-pilot" mode in which they freewheel without exerting themselves. Students did think: they thought about "doing" the experiment. The important point is that this did not, in their terms, help them understand the ideas and concepts of the experiments they worked on.

The second myth to dispel is that working mechanically arises because students are following instructions word for word. Consider the following student talking about his "best experiment":

"I suppose it was the Integrator and Differentiator Circuits (experiment). In this one I understood what they were asking us to do. I knew all about the circuits and what to expect...I knew what I wanted at the end. I was only doing things as they tell you but I knew what I was doing the experiment for and I knew why I was doing the experiment that way." (emphasis added)

The act of 'simply following the instructional script' therefore is a necessary but not sufficient condition for saying that a student is working mechanically. A student

who follows the script exactly as it is laid out maybe unaware of why he is taking a particular set of measurements or wiring up a specific circuit, but alternatively, he might be fully aware of the rationale behind these different stages of the experiment. If so he is unlikely to proceed mechanically in the sense described here.

A Portrayal of one Student's Laboratory Learning Experience

So far I have discussed working mechanically as a general phenomenon, which it is. Its main features are common to all students in the lab. However, a danger of general or theoretical discussions is that one can lose sight of what all this means for the individual student. This must be prevented. A guiding principle of this thesis has been that theory about student learning should grow out of their phenomenological experience of the lab and that such abstractions should continue to relate to the world of the student rather than become removed.

To complement the earlier analysis therefore, I now portray one student's laboratory learning experience. While the account is slightly repetitive it also enables us to appreciate better how all the influencing factors converge

on a single student to affect his pattern of work.⁽⁵⁾

The portrayal will also prepare the ground for a general statement about student learning in the Surrey lab.

First, a brief note about Simon. Aged eighteen, he came to Surrey directly from Comprehensive School in Kent where he took A' levels in mathematics, physics, and chemistry. In addition, Simon studied engineering science at A' level and in the course of this was able to spend several hours each ~~per~~ week in the well-equipped laboratories of the local technical college thereby acquainting himself with a wide range of electrical and electronic instrumentation.⁽⁶⁾

(5) Uses of portrayals in this way are rare. However, examples can be found in "The Divided Self" (Laing, 1964); here Laing portrays "Julie", "David", and "Peter" and in doing so is able to effectively illustrate several of his general theoretical points. The anthropologist Oscar Lewis uses a similar approach for the whole of his book 'The Children of Sanchez' (Lewis, 1963). More recently the approach has been used by Jamieson Parlett and Pocklington (1977). In their illuminative study of blind and partially sighted school children they devote a chapter (for reasons similar to my own) to the experiences of four separate children: "we have sought in this research to unravel complexity. But readers should also encounter complexity first hand, how the various questions interlock. We can think of no better way of doing this than by presenting detailed information about four individual partially sighted children and their ordinary schooling."

(6) Like most students Simon had responded to my questionnaire and I had spoken with him on several occasions. However, glancing back over my data before choosing to portray him, I noted he was one of seven students I had interviewed three times. Moreover, it so happened he was one of three students who had featured in two of my close-up 'shadow studies' (see section 3.4). Consequently I had more information about Simon than most students (though not all). He wasn't chosen as a 'typical' student because I do not consider there to be such a student. Nevertheless Simon is representative in the sense that he expresses the common teaching and learning experiences discussed earlier in the chapter. The final choice therefore was made on the grounds (that of the students I had most data on) he was perhaps the most articulate. Simon is not quoted anywhere else in the thesis.

In the process of carrying out an experiment there are many times when a student has to make a study decision on how to proceed. This is where I begin. Simon described the sort of decision which occurred frequently:

"Sometimes you'd like to go a bit further into a part (of the experiment) but you think 'oh, no, I'd better do the next bit' and you keep going."

According to Simon there were two primary reasons for arriving at this decision. One related to the amount of time he had and the other to how he would be assessed:

"Perhaps you should be able to spend a day (instead of the allotted three hours) on each experiment and then you could sit down work through it and get each individual bit under your belt. At the moment to get the experiment done you just have to do what they say in the book (instructional script). You haven't really got time to think about it. You sort of get the measurements and then grasp around for a few things see what you can make of them. If you could get all the measurements and then go through the experiment afterwards using the measurements that you took, that's fine. You could go away and probably write up a good lab report that way. But they want to mark it as soon as you finish so you just don't have time you know, there's a man standing there with a pen and assessment sheet who says 'I'll see you at four o'clock'."

Early in the lab programme Simon had to learn what it was possible to do in three hours and decide on priorities:

"There was a point last week (second experiment) when we were arguing with the supervisor because we didn't agree with the method which he put before us. We thought 'well I don't really think that's right' so in the end we went up and started arguing with him but it was taking so long this argument

that we just had to accept what he was saying in the end because you couldn't get through the experiment if you just stood there."

"Getting through" the experiment was important to Simon and this represented an early lesson for him on how to distribute his time and energy. The laboratory handbook outlines what is officially expected: "Do not go through...the laboratory sheet line by line. Question each step...Design your own approach...Think for yourself, etc." Simon was thus encouraged to be inquisitive. On the other hand, he frequently received quite different messages:

"The postgraduate demonstrator never gives any leeway. It's either right or wrong. There's no in-between like 'Oh you've done it that way but it might have been easier this way...' This was very noticeable last week. I was doing a certain thing and I was taking a lot of values and he said you know, 'you just take one average value', well that's another way of doing it but my way would have worked."

After completing three experiments Simon talked to me about not really having "time to think about" the experiment and how in his desire to rush ahead he frequently got into difficult positions:

"You're doing something and you think 'now, why is that resistance connected there?' and you say to yourself 'Oh, let's just accept it and go on to the next part...Let's get the other values down then maybe we can come back to it'."

Proceeding through the experiment in this way is associated with a specific type of study decision: a decision to work mechanically. As Simon explained it: "you follow your nose and just do what it (the script) tells you."

Simon revealed how 'following his nose' required him to think in a very special way about the experiment. To illustrate he gave an example of what working through an experiment was normally like:

"...you have lots of little things to think about like, $V=IXR$ therefore $I=V/R$ and, we want X_c and $X_c=1/2\pi fC$. You're just constantly thinking of things like that, and you have to know it and write it down; (beside) thinking of uncertainties (of measurements) and formulae to rearrange in your head - you're trying to tie things together, so you're going backwards and forwards in your lab book to see previous results or whether you've written down a formula you now need. You also have to worry about whether your work is right."

What Simon seemed to mean when he said there was no "time to think about the experiment" was that there was no time to think about some things but there was time to think about some other things. Even when 'following his nose' Simon was engaged in detailed thinking and effort. For instance, how to wire up the various circuits, plot the appropriate graphs, take all the measurements, compute the readings, tabulate the results, and write it all up. At times this sort of detailed thinking caused him to experience considerable strain and this seemed to be most acute when he was proceeding mechanically:

"Sometimes it's really bad. You come out with a headache and you feel grotty. It really takes it out of you, three hours of trying to do something you're not quite sure of, so you are under constant strain. Sometimes I come out with really bad headaches so it's obvious that I try and think hard all the time."

At these times the collaborative relationship between Simon and his partner becomes especially important and that too became strained:

"I enjoy working with most of my group but there's one I don't like working with and I do my best to avoid him...You see I'm quite a fast worker but when you get someone who's a slow worker and they go 'wait a minute, can I see if...', well you're being dragged down, you're waiting again and that's even more tiring...Now normally I can do the stuff and the other chap is saying, 'now, why is that...?' One week someone kept asking me questions. I said, 'for God's sake get off my back and do it yourself'. It's when you are trying to do something and you're thinking of four problems in your head and someone says 'why?' and you try and get back into your own train of thought and he says 'what about...', and you get so annoyed. You're thinking hard, straining yourself and he breaks into your concentration and you have to start it all again."

To understand the ideas covered in an experiment depends upon the correct interpretation of the data that is gathered at each stage. The problem, Simon pointed out, was that it took him all his time simply to get through the mechanics of setting up a measuring instrument and gathering the results and he often missed subtle intended guides in the script instructions that might have tied together and made sense of the experimental findings. He talked of the tendency "to get lost in all the figures".

Like other students, Simon prepared for experiments in his own time before going to the lab. He regularly spent at least one hour per week on this preliminary work:

"I see what you actually have to do and read through that lot. If they tell you (in the script) to prepare anything, I do that and then read a few background books."

Simon placed considerable importance on this preliminary stage. He saw it as a time for vital thinking and explained the rationale behind it saying "If you haven't done the prep properly you just get lost in the lab". For example: "The reasons (for working mechanically) are either because you've prepared wrongly or you didn't prepare at all because you couldn't find anything. So you go into the lab and you've got this time constant of three hours in which to finish it all by."

Doing this work outside the lab allowed him more time inside the lab. He referred to an early experiment which made a major impression:

"The Use of Instruments experiment was a bad one. Well the preparation I did was wrong. At the start of the lab the supervisor crossed it out and said 'no that's wrong'. All my systematic errors were wrong. So I had to try and do it again and there I was trying to think it all out again on the spot and at the same time as doing other things. This is one of the ones where I came out feeling really dead."

Further comments by Simon revealed how working mechanically was not caused simply by shortage of time. It also had to do with whether, in the preparatory stage, it was possible to comprehend the theory to be covered in the experiment, and why each part of the task has to be done in the way prescribed:

"The lack of time would be OK if you knew exactly what you were doing. If you knew what you were doing and you had an overall outlook on it, you'd go 'ah! it's easy' you know, and you'd work through it then - even if you were short of time. You'd know what you were doing."

I asked Simon to describe an experiment which, in his opinion, stood out as a good one:

"Combinational logic. In this one I'd covered it partially at A-level and knew all about the terms they were using and all the circuits...At one point the supervisor came up to me and said 'there's a better way of connecting this part of the circuit'. I disagreed and said 'count the gates in yours then in mine' and then he found out I was right. I had that much confidence. You see I knew what I was doing beforehand."

In this experiment Simon finished with one hour to spare and received his highest mark: "I just messed about all the way through and really enjoyed it."

Referring to another experiment, he described how following instructions exactly as specified did not necessarily mean he was 'following his nose':

"Take the Transistor experiment which I was able to plan for...In this one I knew what I was doing the experiment for, and I knew why I was doing the experiment that way."

Here, Simon had an overall sense of the direction of the experiment. He contrasted experiments where "you see it as a whole" with those where you follow your nose and "do the individual bits". With the latter type:

"Usually I come out with headaches, go back to my room, lie down and thank God it's over...But I was looking forward to combinational logic and the transistor because I knew what I was going to do... At the end I was pleased, it was fun...I just played about with the experiment; just sheer pleasure."

When Simon completed an experiment and went home, usually tired and with a headache, he was immediately subjected to pressures from eight other courses: he had to meet deadlines, finish tutorial sheets, and write reports. It is not surprising then that lab work quickly got forgotten. He explained how sometimes other students in the programme asked him about an experiment he had done and which they were about to do; by spending time going through it and trying to explain to someone else "I then understood it, but I hadn't until then". Normally Simon found little time to sit back afterwards and reflect on the implications of what was done in the lab.

It might be argued that the best time for reflection and assimilation of an experiment is outside rather than inside the lab. The former practice was in fact that students wrote their experimental report at home and handed it in at a later date. With this sort of organisation there might have been more time to "take in" the work but as Simon honestly reported: "In A-levels we had to write reports after the lab and I never used to get around to doing them." A lecture course sometimes provided the necessary

spark for further reflection afterwards but the reason it often did not was because of its lack of co-ordination with the lab programme topics.

At the end of the programme I asked Simon if he saw in his style of lab work any differences between the first few weeks and the last few weeks:

"My marks have got better for one thing, my average is now about twenty seven. I now do as much preparation as I can and I make sure I work very quickly in the experiments. Before I would think 'Oh, I'll do this, write it down nicely'. Now I just scribble it down. If you look at my book you can see the difference in neatness. It's all down there but perhaps not as neat as it used to be. Maybe I know my work better now and more about what I'm supposed to do. You get the idea of how to prepare work. Before I came I'd never prepared labs as such, not to this degree anyway...I've become more methodical in the way I work. The way I write the stuff down is easier to understand, less essay type and more lab-log. I now write the bare minimum, get the answers and it seems to be working."

This summarising statement neatly captures the adjustments Simon has made to his style of work in the Surrey lab and some of the regular features that make up his style, it also serves as a balance to the rest of his account by reminding us of the positive consequences of the adaptations.

6 Conclusion

It is now time to review what is learned by students in the lab. One central point which the analysis serves to underline is that students are learning things all the time. Even when they proceed mechanically through their set task they are learning (though what they learn may differ from what is officially expected or intended). (7)

There are two separate but equally important issues. What is it that a student learns in the lab? And what is it that affects what a student learns in the lab? I want to focus on these two issues by drawing together several general trends which were introduced and highlighted in Chapters Four and Five and became manifest in the portrayal of Simon. Drawing upon this portrayal (and other observational data) it is possible to construct a summary of some of the specific learnings that Simon had in the lab. One of the things Simon learned was:

- to proceed through a script of instruction, the overall meaning of which he did not understand;
- to study relevant textbooks in advance and answer preparatory questions;
- to record only the most relevant information in the lab-log;

(7)

Not only do students in the lab learn all the time, they also learn more than one thing at any one time. This point has been cogently argued in general terms by Jules Henry (1968) in 'Culture Against Man': "much of what I have to say...pivots on the inordinate capacity of a human being to learn more than one thing at a time. Although it is true that all the higher orders of animals can learn several things at a time, this capacity for polyphasic learning reaches unparalleled developments in man".

- to spend a minimum amount of time on visual presentation of the lab-log;
- to optimise time spent following up seemingly unusual experimental phenomena;
- to develop modes of relating to his partner (e.g. division of labour) and his supervisor (e.g. not to spend time arguing) to enable him to complete the laboratory task;
- to appreciate the differences between electrical theory and experimental practice;
- to realise that activities such as questioning the appropriateness of the measuring instruments supplied, are not rewarded;
- to arrive on time;
- to manage the after-lab period to take account of his feeling of extreme tiredness and strain;
- to search out the meaning of unfamiliar engineering technical terms;
- to regulate his eating patterns at lunch (on the day of the lab) according to the amount of experimental work he has still to complete;
- to draw inferences about what was 'good conduct' from the way he was assessed;
- to interpret experimental results obtained in terms of general electrical theory;
- to assess errors of measurements made with instruments provided;
- to tabulate experimental findings in an acceptable manner;
- to use a range of electrical and electronic measuring instruments to gather required data.

This list is not exhaustive of course. In addition, Simon also learned a whole range of specific electrical and electronic ideas and concepts related to the subject matter covered in each of the sixteen experiments.

However, the list clearly demonstrates that a student in the lab learns about much more than just the subject matter included in the script. Furthermore, some of the 'other' things the student learns (e.g. not to spend time following up seemingly unusual experimental phenomena) might severely limit his learning about the material covered in the experiment. For example, a student's decision about whether to take more voltage measurements of a circuit than are requested in the script will perhaps depend upon his perception of how accurate the measurements need to be, which in turn depends upon, for instance, whether the data will be used later in the experiment in another circuit design. If the student feels accuracy in this instance is called for, he might then decide to set up a more sophisticated measuring instrument but consequently run out of allocated time and be unable to proceed to the next stage of the script. The possibility of such an outcome would likely influence his decision as would the likelihood of getting a higher assessment mark for fully completing the script instructions, say, than for devising a new method of measurement.

Variations of the simple example outlined above may occur several times during a single experiment. The strategy a student decides upon each time will obviously influence the information he derives from the experiment for it dictates to what depth he will explore particular problems and questions that arise in the script. This is not to suggest that a student agonises over conflicting and difficult alternatives several times in an experiment. As I have shown, he

develops habitual behaviour patterns which automatically resolve the decision and which reflect his early stance on these issues of priority.

To understand the learning process of students in the lab I focused upon their actions and specifically the act of working mechanically. To summarise the analysis I propose a principle of context which is intended to be useful to both teachers and researchers. The principle can be expressed as follows:

The Principle of Context

The study decisions a student makes when proceeding through instructional task X in the laboratory are influenced not only by the nature of task X but also by the arrangement of the local context Y within which task X is organised.

Two immediate points need to be made. First, the boundaries of X and Y are necessarily artificial and need to be stated as precisely as possible in each context in which the principle is used. In my case I take task X to represent a single instructional script, what I earlier defined as the LIS. Context Y, I take to be the LMF.

In fact the principle holds across the board. Individual experiments X exist in lab context Y which in turns fits into course context Z. In other words, the study decisions a student makes about lab Y are influenced not only by the nature of lab Y but also by the arrangement of the first year

electrical engineering course Z. Now course Z is in turn part of departmental context W, which itself is part of university context V and so on. The principle equally holds true going the other way. For instance, the study decisions a student makes about section X_1 of script X are influenced by both the nature of X_1 and X.

The rationale behind defining in this case task X as the LIS and context Y as the LMF is that much of what happens in context Y is under the decision-making control of the lab programme director. The director also has some wider departmental and institutional influence of course, but this influence is much smaller. The boundary is therefore chosen on the grounds of utility. It is important, however, for the educational researcher using the principle to be aware of these artificial boundaries when making claims for the research, and to realise that what is studied is just one slice (hopefully not a trivial one) of an extremely large cake.

Second, it follows from the principle of context that what students learn about task X is significantly related to study decisions they make about how to proceed through it. For if a student decides not to spent time exploring, say, a seemingly unusual set of measurements but instead decides to carry on through the script in order to finish, then this could seem likely to affect the kinds of benefit he derives from working through the experiment.

It is not new to claim that students in an educational setting learn more than just the subject matter and that they

are affected by the immediate environment within which they are placed. It is surprisingly rare however for researchers to take either point seriously and to study the context of learning systematically. As Jackson (1970) puts it:

Some of us, even on distant reflection, can attribute to our experience in school ways of looking at the world, which, though not directly related to the material we were taught, are yet among the most valuable consequences of our having been there. Given the obvious importance of changes such as these, it is puzzling to find them being referred to in some quarters as mere "side effects" or "incidental outcomes" of instruction, and, consequently, treated quite casually or overlooked completely in discussions of our educational priorities. One would think that such matters, regardless of the labels attached to them, would be taken more seriously than they typically are by all who are interested in education."

My analysis of the lab has shown that teachers need not necessarily feel powerless to control these effects of the context nor should researchers feel powerless to study them. As postulated, the principle of context appears simple straightforward and common-sensical. (8) Adoption of it however demands a deep change in attitude, specifically it requires both the educational researcher and the teacher to forego the importance both of them have previously attached to the script as the major influence on student lab behaviour.

Students in the lab clearly learn about both delivered educational content and the surrounding context. Moreover, future educational researchers when attempting to attribute cause to the adopted study styles of laboratory students need

(8) Comfort can be found in Ogborn's (1977) comment: "True remarks about any laboratory tend to be blindingly obvious once stated. But from the inside, it is not always so easy to see their truth, or their consequences in action."

to be aware of the contextual influencing factors as well as the experiment. For the teacher, the straightforward but far reaching implication is that relatively little may be changed in the students' intellectual response by manipulation of the laboratory task itself, considered in isolation from the context of the task.

With the principle of context in mind I examine in Chapter Six how teachers have intervened in order to change the Surrey lab programme during the last twenty years, and what effects these interventions have had.

CHAPTER SIX

TEACHER INTERVENTION IN THE LABORATORY

Introduction

I ended Chapter Five by proposing a principle of context and briefly discussing its methodological implications for future researchers who wish to investigate how students learn in the lab. The principle also has important implications for teachers who wish to intervene and influence the work of their students. Briefly, the Surrey lab as it is presently arranged (with an LIS and LMF) elicits distinctive common patterns of student lab activity (working quickly, preparatory working, working mechanically). However, according to the principle of context a student does not decide to, say, work mechanically through an experiment in response to any one single feature of the LIS or LMF.

Being aware of this principle, therefore, would likely help supervisors to understand better the origins of everyday student behaviour they observe in the lab. At least it might put them on the right track. It might, for instance, get them to think in terms of designing, say, a new script on logic circuits in conjunction with, rather than in isolation of, the existing assessment system, such that the two might then exert complementary rather than contradictory demands on the student. It is not possible to prove this rule of intervention in the strict sense of the word. However, to confirm it I carried out a detailed examination of how the

laboratory programme had been changed in years gone by and what the effects of these changes had been. The account is again a mixture of description and interpretation and provides an example of how existing documentary records can be utilised in an anthropological educational study.

There are clearly dangers in trying to piece together what actually took place in an educational programme years before. In this case I was lucky to be permitted access to all documentation relating to the first year programme for the last twenty years. College memoranda; relevant departmental memoranda; lab programme memoranda; scripts of instruction for years gone by; internal reports on the lab; guidance notes for students; guidance notes for supervisors; relevant notes of staff-student meetings; and even hand written introductory lab talks were all made available to me. At the same time I was in a fortunate position of not having to rely too much on this 'documented' data, for I not only interviewed all six supervisors presently teaching on the lab programme

but five others who were involved years ago and lived through or initiated many earlier innovations. (1)

The Battersea College Laboratory

Documentary evidence suggests that the act of students proceeding through their laboratory tasks in (what I have called) a mechanical fashion has long been an unresolved problem in the Surrey programme. In 1971, for instance, a departmental discussion paper reviewed the years of the lab programme 1958-1967⁽²⁾ and the author of the paper (a lab supervisor throughout those years) suggested that during that ten-year period:

(1) I was thus able to get over the inevitable problem neatly outlined by the narrator in C.P. Snow's 'Corridors of Power'. There, the narrator, a senior civil servant involved in disarmament, reflected on what history would make of the British stance on nuclear weapons: "Once or twice during the next few months, I found myself wondering whether Roger (a cabinet minister) and his associates would qualify for a footnote in history. If so, what would the professionals make of them? I did not envy the historians the job. Of course there would be documents. There would be only too many documents. A good many of them I wrote myself. There were memoranda, minutes of meetings, official files, 'appreciations', notes of verbal discussions. None of these was faked. And yet they gave no idea, in many respects were actually misleading, of what had really been done, and, even more, of what had really been intended. That was true of any documentary record of events that I had seen. I supposed that a few historians might make a strong guess as to what Roger was like. But how was a historian going to reach the motives of people who were just names on the file, Douglas Osbaldiston, Hector Rose, the scientists, the backbench MPs? There would be no evidence left. But those were the men who were taking part in the decisions and we had to be aware of their motives every day of our lives...", (Snow, 1966).

(2) The University of Surrey grew out of Battersea College of Technology in 1966. The period in question covers the final years of the College during which the curricula for the new University were being planned. During this period students at the College read for external degrees of London University.

"We ignored a rule of great importance...that it is rather easy to ensure that onerous and boring chores are performed, but very difficult to ensure that they are performed intelligently...The student must do his lab work, perform his calculations, draw his graphs and write his log and reports; no matter how well the experiments are designed these tasks are boring. Therefore the temptation to perform them without thinking is very great. To take the measurements for, do the calculations for, and then draw six graphs is a long business; to read, study and think so as to understand the graphs is also a long business. If it is possible for a student to do the measurements, calculations and graphs without doing the thinking and studying, then there is a high probability he will do so," (McVey, 1971).

I have examined this discussion paper carefully and talked to its author. I have also interviewed four other teachers who supervised in the latter years of this decade, and referred to various other written records produced at the time. In the event a period of radical innovation followed distribution of the McVey report in 1971, in this section I examine several earlier attempts to influence the study habits of students in the lab.

Up to 1967 arrangement of the Battersea Lab was significantly influenced by official rules laid down by the University of London. Regulations issued by London gave guidance on, for instance, the number of experiments to be performed by students in the lab and how they should record those experiments. One such entry in the schedule of course work for the BSc. examination (dated 1963) stated for a course in Electrical Theory and Measurements:

"The following topics are not intended to be restrictive and it is desirable that experiments should be developed illustrating the fundamental principles concerned (there followed a list of topics for experimental work). For all experiments performed, records should be entered into log books at the time of performing the experiment. About ten experiments representative of the sections listed should be performed. Six of these experiments should be written up in a formal manner giving an adequate, concise but not unduly elaborate account of the experiments."

Between 1958 and 1967 a first year student studied four subjects that involved experimental work: electrical engineering, thermodynamics, applied mechanics, and physics. In each of these, thirty percent of the total mark was awarded for laboratory work and students were expected to pass in this and in the written annual examinations considered separately. Marks awarded for work in the lab were based on both the student's laboratory performance and his associated written records of the work.

These records were classified into two parts. The lab-log was intended to be a diary in which a complete on-the-spot record of the experiment was to be compiled as the tasks were performed. At the end of the session it was expected that the log would require only the completion of calculations and the addition of interpretive comments and conclusions in the students own time. The second type of record comprised of "formal reports" which were intended to be lengthier and more detailed technical documents. All experiments were

recorded in the log and several of these were to be reported formally, (Departmental Instructions, 1960).⁽³⁾

In sessions 1961-62, Professor Lovering (then Head of Electrical and Electronic Engineering) along with several of the lab teaching staff identified specific deficiencies in the study habits that students were practising in the lab. Consequently he initiated a series of changes to be made to the programme.

Prior to 1961, for instance, the written work required of a first year lab student (for all subjects) was twenty four formal reports and forty lab-logs. Professor Lovering considered this to be excessive and that it got in the way of the principal aim of going into the lab to concentrate on an experimental investigation.

London regulations for the first year electrical lab which read "of which six are to be written formally", had previously (and correctly) been taken to mean that six reports, each on a single experiment, were to be written. In 1961 Professor Lovering suggested that this be re-interpreted as meaning that less than six formal reports might be written, provided six experiments were dealt with. New requirements

(3) In the final weeks of the lab, shortly before the annual examinations in early June, students handed their formal reports and associated lab-log records to the lab supervisor who proceeded to award each report a mark out of ten. These records were then sent to the University of London Examination Hall and on the appointed day the external examiners of the subject scrutinised the work. After negotiation with the supervisor the list of marks were returned to the department and then to the students.

were subsequently issued for each electrical laboratory subject (not more than three formal reports, on six experiments) this device cut by half the number of formal electrical engineering lab reports to be written by a first year student. (4)

Measures were also taken to improve the way in which students recorded and presented their experimental work. As one teacher who supervised at the time put it "experiments which were not to be formally written (and therefore not externally examined) were ignored when the lab class ended." Keeping an adequate up-to-date record of experimental work was considered an important study habit to instill and in a note on 'Procedure in the Laboratory' (dated 1960) Lovering wrote "wherever possible, a graph must be plotted as the experiment proceeds, so that obvious errors may be corrected and unnecessary observations avoided".

Getting a student to record a log of his work was one problem, presentation of the lab-log, when kept, was another - though not one exclusive to Battersea College. A 1964 general circular from London University to its associated colleges stated:

(4) The reason behind this departmental change was later appreciated by the University of London, for soon afterwards it began to revise its requirements in a like manner. A university circular, dated November 1964, stated: "For each electrical subject, candidates will be required to submit a log and one or two formal reports."

"The lab-logs submitted are often unsatisfactory. The records may be either (a) so fragmentary, incoherent and untidy as to defeat the preparation from them of a formal report; or (b) so careful and detailed as to constitute formal reports in themselves. In (a) the object of the present procedure is missed, while in (b) the further preparation of formal reports is redundant."

Professor Lovering arranged for the writing of exemplar formal reports and lab-logs. These were distributed to students and in a departmental instruction supervisors were asked to ensure that lab-logs be recorded according to the specimens and at the actual time of the experimental work.

Ironically, the Lovering reforms did not substantially decrease the overall amount of writing required of a student. What they did was decrease (previously emphasised) formal written work and increase (previously neglected) work on the lab-log.

These, then, were the extent of the interventions made in the decade prior to 1967. Throughout this time the instructional scripts remained unchanged. One supervisor (McVey, 1971) described the lab experiments during this period as follows:

"Under the old dispensation, excessive emphasis on routine appeared not only in the reports but also in the experimental work itself. The normal experiment, in all the subjects and all the years I knew of required:

The connection of a specified circuit.

The connection of meters in specified positions.

The taking of specified readings.

The performance of specified calculations, and the plotting of specified graphs."

There are strong indications that the interventions did not all meet with success. For instance, dissatisfaction with the lab programme was apparent at a staff-student meeting convened in 1967. Students were reported as having three main complaints:

- "(1) They were unable to start writing formal reports until the end of January because the relevant experiments were not done until then.
- (2) They received different instructions from different supervisors (and occasionally different instructions from the same supervisor at different times).
- (3) There was too little feedback; by the middle of February (i.e. after 12 weeks in the laboratory) hardly any logs in certain experiments had been marked and returned."

By the end of this period two teaching staff, supervising at the time, reported that most students were still unwilling to keep an up-to-date log of their work. McVey (1971) later wrote of this ten year period:

"That students of engineering should carry out laboratory work and report on it seems neither unreasonable to demand nor difficult to ensure. Yet arrangements to secure this, though designed and implemented by intelligent men, have gone sadly awry."

More radical interventions were to follow.

.3 The Rationale for Programme Change

Arrangement of the lab remained largely unchanged as Battersea College became the University of Surrey.⁽⁵⁾ However, in 1972 the programme underwent a series of major changes, again aimed at influencing the style of study students adopted in the lab.

In the event, the laboratory assessment scheme was chosen as the main agent for change. To be clear about the rationale behind this intervention I examine in this section an internal departmental discussion paper distributed to teaching staff in 1971 and mentioned in section 6.2. I have already used some of the material included in this paper, here I want to concentrate on the conclusions of the document for these were clearly intended to shape future policy on programme design.

The final concluding paragraph hinted at the sort of attitude needed among supervisors, and the changes considered necessary "in order to avoid errors of the past":

"...We must be clear what we intend; we must sink our differences and implement whole-heartedly what is agreed; we must take care to devise a sensible marking scheme; and above all we must accept the need for the conscientious, painstaking and intelligent performance of a great deal of damned hard, boring work," (McVey, 1971).

(5) In 1968 students continued to attend a two term electrical lab in which they worked through sixteen experiments in sessions of three hours per week. However, instead of attending three other similar courses, as before, they were simply expected to attend a one-term combined lab of physics and applied mechanics in which no formal reports were required.

The report acknowledged the existence of some form of mechanical work by students (as illustrated by the quote at the beginning of section 6.2) and went on to propose that the way to change the lab programme in general, and specifically to prevent students proceeding mechanically, was to re-think the method of student assessment:

"We neglected the examination law: 'That which is not examined is not done'. This law does not assume that students are inherently wicked; merely that they are human, and will therefore try to meet the specification as they see it. If they see that, in the marking of course work, great weight is given to long reports and proliferous copying, while none is given to intelligent performance in the lab, then they will devote their efforts to long reports and copying and will not strive to act intelligently in the lab. Hence, it is not sufficient that a good specification be made; it is necessary that teachers make clear, by their actions, their words and their marks, that the specification means what it says," (McVey, 1971).

There is a great deal of common sense in the two statements but also some apparent misconceptions. The statements seem to assume that (1) it is necessarily boring for a student to follow the suggestions of the instructional script as laid down; (2) that if the student follows the script as requested he will inevitably do so unthinkingly; (3) that there is a great "temptation" for the student to work in this way.

The analysis of Chapter Five has shown that on the contrary, following the suggestions of the script is not necessarily boring but becomes so if the student is unable to grasp why he is being asked to proceed in the way suggested. Moreover a student never proceeds through an experiment

without thinking. Furthermore, a student will try to avoid working mechanically if it is at all possible because to proceed in such a way not only causes great strain but does not aid understanding of the ideas covered in the experiment.

To summarise briefly, the rationale behind the proposed change correctly assumed that students in the lab could be influenced by the way in which they were assessed. The danger however, and it is implied in the statements, is in thinking that students are influenced only by the method of assessment.

Changing Laboratory Assessment

The programme director devised a new assessment scheme in 1972 to prevent students working mechanically and to instill a range of study habits deemed desirable.

First, the lab supervisors wished to emphasise the importance they attached to the 'doing' of experiment work.

As one supervisor put it:

"In the old days students used to come in (without having looked at the script), do the experiment and leave. They would then write it up at home and present you with a book to mark. By the time the books came back to us it was very difficult to discriminate between who understood it and who didn't."

In the new assessment scheme a student's preparatory work was to be inspected immediately on entering the lab and the whole lab-log was to be examined at the end of each session while his experimental competence was fresh in the

mind of the supervisor. Consequently, supervisors were instructed to award two separate marks to each student: a mark out of five for lab performance and a mark out of five for the lab-log.

Second, it was assumed that with the new arrangement students would be forced to prepare and keep an adequate lab-log. In the past, these had always been difficult rules to enforce. There had been a long history of reluctance by students to present their log as anything but a well written neatly laid out account with ruled tables of results (possibly only by a student spending considerable time at home afterwards). Consequently, in the introductory lab talk of 1972, students were told: "Ultra-neatness is not the main requirement (of the lab-log) and some crossing out is not penalised."⁽⁶⁾

A third reason for changing the assessment was to improve feedback of information to both student and supervisor about the formers experimental work. Previously, students received little feedback until late in the programme. In the new

⁽⁶⁾ The reason for wanting students "to write up as they go along" was explained by a present day supervisor by saying that in the d.c. machine experiment it was possible for a student to make a mistake and get an impossibly high motor efficiency of over 90 per cent. However, because students did not draw the relevant graphs as they proceeded but only collected the data, they would invariably discover their 'impossible value' later at home and have to fake a result or copy someone elses. Under the new arrangement, the student was expected to find out and puzzle about his experimental results at the time of doing the work.

system it was intended that they would get instant critical comments on their work and consequently be able to improve from week to week.

The lab director also hoped that the new method of assessment would promote more uniformity of marking. In the past:

Students completed their work as best they might according to the often conflicting instructions of individual teachers. Arid comments by myself, such as: "Don't put so much damned arithmetic in", were countered by: 'But Mr...says that all calculations must be shown in full'," (McVey, 1971).

Guidance notes were therefore prepared in 1972 (primarily for students, but also distributed to supervisors) to specify the requirements for lab work. Typical notes read:

Lab Performance

"It is essential that students have some idea of how to approach the experiment and what is involved before commencing the class."

"Laboratory sheets (instructional scripts) should be taken as a rough guide. Students should decide, and be able to justify how they are going to perform the experiment, i.e. if a graph is required; what parts can be omitted if time is short, etc."

"It is not essential to follow exactly what is written on the sheet. Good marks can be obtained for an intelligent approach, even if the experiment is not completed in time."

Lab Log

Brief notes were included on the use and presentation of graphs, experimental observations, diagrams, experimental measurement errors, and conclusions. On the presentation of experimental results, for instance, the notes read: "Results should be tabulated at the end with estimation of uncertainty if possible and appropriate experimental details; e.g. ambient temperature. The number of significant figures should be consistent with the uncertainty."

The sixteen experiments which students completed in 1972 were essentially the same that had been used in the earlier Battersea days and those experiments continued to be used in 1973. The only change a year on was that a set of notes on marking were issued to students and supervisors:

Lab Performance

Marks will be awarded for:

- Preparation
- Understanding the purpose of an experiment
- General ability
- Interest and enthusiasm
- Well reasoned decisions on method
- Originality of approach
- Additional material
- Prompt, intelligent data handling

Lab-Log

Marks will be deducted for:

- Logs not keeping up with the experiment
- Lack of experimental observations
- Over elaborate description of method
- Poor general layout, poorly laid out tables and poorly labelled graphs
- Insufficient experimental data and equipment numbers
- No consideration of errors

Students were reminded that "...The last period in the afternoon has been left free to enable supervisors to complete the marking of laboratory notebooks" and that "...all work should be written in the laboratory notebook. Scraps of paper should not be used."

Further modifications were made in the assessment scheme in 1974. In that year, as in previous years, other aspects of the LIS and LMF remained unchanged. (7) On this

(7) Except for small 'preliminary work' sections (written by the programme director) added to several of the scripts. These sections posed specific questions or asked for equations to be derived by the student and were included to help the student carry out appropriate preparation.

modification the programme director later reflected, "One of the big troubles was that different markers were still looking for different things." He emphasised the importance of not just "marking as you fancy" but being able to "tell the student what is wrong and where he can improve." The re-designed assessment sheet is shown below (use of the sheet by supervisors has already been described in section 4.4).

DENT		EXPERIMENT					
PERFORMANCE	TOTAL	%	POOR	SATISFACTORY		EXCELLENT	
	/20			DOUBTFUL	GOOD		
			0	1	2	3	4
PLANNING AND PREPARATION							
UNDERSTANDING OF EXPT AND BACKGROUND							
ENTHUSIASM AND EFFORT							
APPROACH TO WORK							
EVALUATION OF PROGRESS AND PROGRESS MADE							
LAB LOG	TOTAL	%					
	/20		0	1	2	3	4
PLANNING AND LAYOUT (ease of access)							
PRESENTATION AND HANDLING (tables and graphs)							
EXPERIMENTAL NOTES AND OBSERVATIONS							
TREATMENT OF UNCERTAINTIES							
PRESENTATION OF RESULTS AND CONCLUSIONS							
GRAND TOTAL			DATE				

Figure 6.1

To further reinforce earlier educational intents a new set of "Notes for Supervisors" were written in 1974. One

part of these seemed to refer to working mechanically and asked supervisors to:

"Decide whether a student's approach to the work is:

- (a) Original, full of ideas, questioning each step.
- (b) Standard method, questioning steps.
- (c) Standard method.
- (d) Standard method, but not knowing why (partner makes decisions).
- (e) Not contributing at all, no ideas."

New guidance notes also reflected the continuing concern to get students to prepare and to keep a lab-log:

"We ask the student to prepare in advance for the laboratory class. Check that he has done some work as soon as possible after he arrives. It is convenient to initial his preparatory work when he arrives and check it later. A brief discussion at the beginning is important in order to assess the student's preliminary work and planning."

"Also check that students are keeping an up-to-date record of events, mistakes, decisions and problems."

After these changes in assessment the lab continued essentially unchanged up to the time of writing (1979), and the data for this case-study were collected during the academic year 1975-76.

Conclusion

Particularly interesting about this evolutionary account of the lab programme is that attempts at changing the study activity of students were not (as is usual) initiated by changing the instructional script. To change the LIS is a strategy which has been popular in the published literature

but which I have shown in Chapter Five, is usually based on several misconceptions about how students actually act in the lab and what they are influenced by.

Teachers in the Surrey lab pursued an alternative intervention strategy, and it is clear from the analysis that changing the LMF can indeed have considerable effects on the study styles and habits students adopt in the lab. Changing the method of assessment, for instance, had the effect of getting students to regularly prepare for their work in the lab and also to maintain a relevant lab-log. Both of these experimental habits had been deemed desirable by teaching staff (prior to 1972) but both had been previously difficult to achieve.

However, beside achieving some intended effects, changing the method of assessment also caused some unexpected outcomes. Prior to 1972, for instance, students used the lab (although unofficially) simply as a place to collect raw data, they would then prepare their log at home in their own time. After 1972, however, students were marked at the end of each lab session and they were therefore required to collect the raw data (as before), but also write up their log and at the same time draw some conclusions. Since the amount of material to be covered in the instructional scripts and the length of time allocated to each session remained the same, the student was required to do more work. To cope with this they (as shown in Chapter Four) typically proceeded through the scripts with speed. Working quickly, though not

deemed undesirable in itself by teaching staff, had the unfortunate and unintended effect of promoting mechanical working. Changing the method of assessment, therefore, had the desirable effect of getting students to prepare for the lab (a pattern of activity tending to prevent working mechanically) and the undesirable effect of getting students to work quickly (a pattern of activity tending to promote working mechanically). The overall effect, shown in Chapter Five, is that working mechanically continues to exist as it has done for over ten years.

A clue to why this is so can be found by examining the rationale behind the recent innovatory measures. The guiding assumption of teaching staff (as indicated in section 6.3) was that the method of assessment could be changed in isolation of everything else to promote desired student lab activity. This assumption fails to recognise that assessment is only one element of an interconnected social system made up of several different elements.

In fact, the mix of the LIS and LMF produces a unique organisational pattern. Changing one of them or an element of one of them changes this mix and, following from the analysis of this chapter, can profoundly influence the student response though not by itself, rather by changing the overall pattern of pressures and demands that ^{on} converge on the student. It would seem, therefore, that the following rule might usefully be followed by teachers trying to promote a desired student response in the lab:

The Rule of Intervention

Although all elements of the LIS and LMF influence student activity not all of them need necessarily be changed in a successful intervention, rather an element should be changed in the knowledge that it will then relate differently to other elements and it is to the new total elemental pattern that the student will respond not just the single changed element.

Implicit in the principle of context, therefore, and illustrated by this evolutionary account of lab interventions and their effects, is a new way of thinking about lab programme decision-making.

CHAPTER SEVEN

CONCLUSION: THE RESEARCH STUDY RE-CONSIDERED

Each of the three chapters that make up the case study, ended with a concluding discussion and I shall not take up space here trying to re-work those remarks. Instead I will briefly reconsider the research as a whole.

A major purpose of this work was to construct a set of working ideas suitable for helping teachers and researchers make sense of every day student practices and ways of proceeding that occur in first year electrical engineering laboratories. As an important addition to this concluding chapter I show how the different ideas fit together to form a coherent explanatory framework. I also discuss the generalisability of the main research findings and illustrate how these findings are confirmed by visits, made in association with the main investigation, to two other first year electrical and electronic laboratories.

I have tried to find out what happens to students who attend a first year engineering laboratory programme. For instance: What is the nature of the students' week-by-week academic experience? What does sixteen consecutive weeks in a laboratory do to a class of students? How do the students make sense of all that is going on?

At first sight these might seem insulting and irrelevant questions to raise with teachers already interested in their students and who spend time supervising them in the lab, and

yet there exists in the Surrey lab a 'hidden curriculum' (see section 4.6 and 4.7) that tends to prevent teachers getting to know their students (and vice versa). Indeed, this hidden curriculum depends for its very existence on there being a breakdown in dialogue between teacher and student. Nevertheless, the decision to concentrate in this study on the learning experiences of laboratory students -- the 'receiving' rather than the 'transmitting' end of the teaching and learning process -- was influenced primarily by, and chiefly in response to, the persistent neglect of this important perspective by laboratory teachers and researchers formally reporting their work (see Chapter One). The professional education journals of the last twenty years, for example, have included a considerable number of articles by teachers speculating about how laboratories should and could be organised. There has been less debate (but some) about the benefits that students should or could derive from attending such programmes, but almost no analysis at all of how students actually carry out their work in the lab and what they think about it. Educational researchers have contributed to the debate (by and large) by trying to clear up exactly what the laboratory is there for and have spent their time getting teachers to state and be specific about their programme aims and objectives.

A different line of inquiry is presented in this thesis. I spoke to participating students, and to a lesser extent, teachers, in one engineering laboratory about what they considered should or could happen. But the main focus was to

observe what actually did happen and to get teacher and taught to reflect aloud on their actions and the motives behind their actions. Associated with this stance is an assumption that if we do not in our research investigations study the students views of their own experience and come to see their work as they do, it is unlikely that we will ever understand their approaches to academic work. In other words, the general ways of proceeding and the study strategies students adopt will remain largely a mystery, and the teacher interested in a student's approach to work will continue to find difficulty in taking steps to influence it as he would like.

This work represents, therefore, an attempt to stake out a largely neglected area of research. This should not be taken to mean that inquiries of this kind will replace ongoing 'mainstream' research. The idea is that they will provide a complementary perspective. In the absence of such in-depth studies of laboratory settings the theoretical and methodological rationale for an appropriate way of proceeding is offered as an example in Chapter Two. This research approach is then tested out in the Surrey first year electrical and electronic engineering laboratory.

A major strength of the proposed case-study approach is that the researcher is able to take account of the idiosyncratic nature of the educational setting being studied (the case). He respects the uniqueness of the setting and grounds his study in the particular events that take place there. Consequently, important local concerns can be addressed and dealt

with. Clearly, a case-study approach is not inherently better as a way of proceeding than, say, large-scale survey work. Quite simply, a different kind of information is gathered. Having elected to study a single programme the researcher can more easily move up close to the world of the student and grapple first hand with a wide variety of human issues. At the same time the single case-study presents some new and tricky questions. For example, the Surrey lab is only one of over forty introductory electrical and electronic engineering lab programmes in British universities, in the light of this what can be said about the generalisability of the findings of the thesis?

First of all, to begin to answer this point on generalisation, the recent emergence of the anthropological paradigm and associated case-study inquiries has meant that the conventional notion of generalisability in educational research has begun to be questioned (see Walker, 1974). Some of the latest thinking has been proposed by MacDonald (1976) and I quote his argument at length:

"It is a mistake to assume that evaluators who choose to portray educational instances have abandoned the hope of generalisation. On the contrary. The portrayal evaluator has only shifted the locus of responsibility for generalisation and reduced the size of the sample upon which generalisations will be based. After all, it is an axiom of sample-based generalisation that the sample must be adequately described in terms of all its relevant characteristics. And it is a 'finding' from our experience...that educational cases are behaviourally unique. It is a small step from these premises to the conclusion that, if we hold to the axiom, we must first seek adequate descriptions of individual cases, their characteristics and interactive effects. This will not enable us to prescribe action to others...If, however, we shift the burden of responsibility for generalising from the

outsider to the insider, from the evaluator to the practitioner, and if we restrict the task to that of generalising from one fully described case to another that is fully known (i.e. to the one in which he lives) then we can argue that portrayal of a single case may still fulfill the function of generalisation, though it calls for re-distribution of responsibilities with respect to the evaluation process."

MacDonald is surely correct in suggesting that all educational settings are unique. Every first year laboratory (to some extent) is organised and arranged differently and (as shown in Chapter One) there have not yet been enough studies of laboratory programmes to enable a researcher confidently to predict the most salient features to be investigated. Certainly there are few detailed descriptions of how students proceed through laboratory assignments. Consequently, MacDonald's statement represents an important way of re-thinking the meaning of generalisation in human affairs and one that is appropriate in the study of single laboratory programmes.

MacDonald's argument, however, depends upon the teacher generalising from "one fully described case" (the researchers) to one that is "fully known" (his own). The assumption is that there is such a thing as a "fully described case" and that because of this the researcher need play no part in the process of generalisation. On this non-trivial point I disagree. The Surrey lab as presented in this thesis is not "fully described" nor (as argued in Section 4.3) could it ever be. Whether the researcher likes it or not, he inevitably emphasises some events at the expense of some other events.

The different ways in which this work was guided by local practices, concerns, and circumstances at Surrey, has already

been discussed in detail throughout this thesis. The related search for those concepts and ideas that might have wider applicability, however, was not mentioned. In retrospect this search was influenced not only by local concerns but also by the knowledge that while the Surrey lab is of course unique, it is also, in some important respects, closely similar to every other first year electrical and electronic engineering laboratory. For example, students in a first year electrical lab programme, by and large:

- (1) Proceed through a script of instructions.
- (2) Have their work assessed by a lab supervisor.
- (3) Attend the lab for a fixed chunk of time each week.
- (4) Work in pairs.
- (5) Attend the lab involuntarily. Lack of attendance in the lab usually means failing the whole first year course.

These five features are, to my knowledge, common to all forty odd first year laboratories even though the arrangement of each will differ from programme to programme.

To sum up, even the researcher studying a single educational programme can take steps to make his analysis applicable to settings other than the one he studies. This being so he should not, in my view, then stand back and place all responsibilities for the generalisation process onto the teacher. Ultimately of course the findings of research studies such as the one presented here will be judged by practitioners from a variety of lab programmes and will be accepted or dismissed as they see fit. That is how it should be.

Having said something about the unconventional interpretation of generalisation that is appropriate in studies such as this one, I turn now to consider the actual research findings. A continuing concern throughout the course of the work was to construct an explanatory framework for helping teachers think about and make sense of the customs of student conduct and general practices that take place in first year electrical and electronic engineering laboratories. It therefore seems appropriate at this point to re-state the main working ideas and rules that make up the framework and to show how they fit together to form a coherent whole. The framework can be applied to all similar lab settings and is thus, in that sense, generalisable.

Laboratory Instructional Script and Laboratory Management Framework: Working Idea Number One

In Chapter Four I included a full and accurate description of the administrative, organisational, and physical setting of the Surrey lab so that the reader would know the kind of programme investigated and how it was similar to or different from the laboratory he taught in or intended to investigate as a research worker.

Later in the chapter I reduced this full description to include only those environmental features that seemed to most influence the academic work of the students. For example, there were three doors in the laboratory and these were all painted blue, as the analysis proceeded however, these facts

seemed less important to include than the nature of the instructional script design, or the system by which students were assessed. The latter seemed to impinge far more upon the educational experience of the student. Out of all this I proposed the concept of an LIS and LMF; a reduced description that characterises important aspects of the context which influence student activity in the lab. Briefly, the present Surrey LIS and LMF is arranged so that:

- (1) Students work together in pairs.
- (2) Laboratory sessions last for three hours.
- (3) Each student must complete sixteen experiments. They must move onto a different experiment at the end of each session and are not allowed into the laboratory during unscheduled hours.
- (4) Each student proceeds each week through an instructional script sequence of Theory, Object, Method, Procedure, Conclusion.
- (5) The lab programme is not sequenced with any lecture course.
- (6) The work of each student is marked according to a special type of categorised assessment scheme at the end of each lab session.

As an educational environment the Surrey programme clearly provides a range of possibilities and opportunities for its students. It also, simultaneously, constrains and limits what they can and cannot do. This should not be taken to mean that the Surrey lab has a precisely prescribed set of educational goals that it pursues relentlessly at the expense of all others. Rather, different teachers in the lab pursue different ends. Some of their intentions may overlap with their colleagues while others may not. In other words, a variety of different

aims and objectives of different types (from encouraging creative circuit design, to developing an awareness of personal safety with electrical apparatus) are pursued in a single programme, frequently at the same time. Whatever the educational goals, they must be achieved within the administrative and organisational context of the lab and be in the range of what that context makes possible. To an outsider, a description of the LIS and LMF helps reveals what those possibilities are.

The generalisability of the explanatory framework largely depends upon being able to conceptualise laboratory programmes in terms of an LIS and LMF. Consequently, to test this Working Idea, I visited first year electrical and electronic laboratories at Southampton University, and Queen Mary College at the University of London. In the event, the arrangement of each laboratory fell naturally into the LIS and LMF format previously formulated at Surrey. The descriptions that follow allow the reader to compare and contrast all three laboratory programmes.

At Queen Mary College:

- (1) Students work through experiments in pairs.
- (2) Each student attends the lab for three hours each week for ten weeks. There is a student intake of fifty six and the class is split into one group of twenty four and another of twenty two. Two supervisors attend each session.
- (3) Each student must complete ten experiments. They must move onto a different experiment at the end of each session but are allowed into the laboratory for further unsupervised work on any afternoon convenient to them.

- (4) Students are issued two handbooks of scripts and associated theory for all experiments. One handbook is entitled Basic Electric Circuits (BEC), the other Electric Fields and Materials (EFM). The BEC handbook includes ten experiments and students choose the five they wish to attempt. The five EFM experiments are compulsory.
- (5) Associated with the laboratory programme is an ongoing course of lectures on Basic Electric Circuits and another course on Electric Fields and Materials. Each course is taught by the designer of the respective laboratory experiments.
- (6) Students are expected to collect 'raw' data in the lab and write an informal account of the experiment in their own time at home. These reports are inspected from time to time by supervisors to ensure that they are of respectable standard. Students submit formal reports of two BEC experiments and two EFM experiments towards the end of the programme. These reports are examined by the respective teacher responsible for the experiments and marked according to a five point scale: Outstanding, Good, Average, Poor, and Unacceptable. Each student is allowed to submit a report twice in order to increase his mark. In each lecture course (BEC and EFM), 25% of the total mark is awarded for performance in the lab.

At Southampton University:

- (1) Students work through experiments in pairs.
- (2) Each student attends the lab for three hours each week for five weeks, and four times for six hours. There is a student intake of one hundred and the class is split into five groups of twenty. Two supervisors attend each session.
- (3) Each student must complete nine experiments. Five experiments are scheduled for three hours, four experiments are scheduled for six hours. Students need not move onto a different experiment at the end of a session. Moreover, they are allowed into the laboratory to work, unsupervised, on a spare side-bench on any afternoon convenient to them.
- (4) Students are issued separate scripts of instruction for all nine experiments. In any one session all students are scheduled to work on the same experiment.

- (5) The laboratory is not sequenced with any ongoing lecture course. Students are issued a separate fifty-five page handbook on the theory of electrical measurements. Each student is expected to read this in advance of doing an experiment, the scripts indicate the relevant sections of the handbook.
- (6) The first four laboratory experiments are written in a programmed-learning format and require students to fill in 'result-boxes' in the script. Other than the plotting of graphs no other writing is required. In the five remaining experiments students have to write an informal account of their work as it proceeds. Students are further required to write a formal report of one of the latter experiments. There is no formal assessment of the student. The course is organised on a pass or fail basis and from week to week, during the lab sessions, supervisors check that the work of each student is 'up-to-scratch'. Only two students have ever failed the programme in its present format (covering five years). The lab programme counts for no examination credit.

To sum up, the LIS and LMF arrangement is, in some important respects, clearly the same in all three programmes and, as previously mentioned, this increases the chances of a single case-study being widely applicable. There are revealing variations however. To examine a description of an LIS and LMF is to take the first step toward understanding some important shared educational assumptions that govern that particular laboratory programme.

Early Student Adaptation: Working Idea Number Two

Students in the Surrey laboratory are largely told what it is they must do, how they should do it, the time available to do it in, and what constitutes success and failure. A glance at the make up of the LIS and LMF shows this to be so.

With this state of organised affairs the student has very little control over his time in the lab. Programme decision-making power resides unambiguously with the teachers and the university authorities. Of course there are regular departmental student/staff meetings in which students can voice their complaints and these will likely be listened to, but should substantial changes result from this (and they have at Surrey) they are unlikely to be implemented in time to benefit the protesting student. Students know this and it no doubt has the effect of reducing the number who offer formal suggestions for re-designing the lab.

It is not unusual in an educational environment for teachers to have a monopoly on the power to make decisions and it is easy to see how this pattern has developed. Teachers are usually more knowledgeable about the subject matter than their students and have accumulated years of experience in trying to communicate it in a comprehensible manner. It is not the purpose here to suggest an appropriate emphasis, merely to point out that students in the Surrey lab have little power or opportunity to re-design the programme. Students have to fit in or leave. Typically they elect to fit in.

Adaptation is a word used throughout the thesis as a way of referring to the method by which students fit in and adjust their ways of studying to the demands of the laboratory. It is a rough and ready general description of a major social-psychological process in which students are engaged.

This thesis has highlighted the speed with which adaptation takes shape (see Chapter Four). As a working principle teachers should take special care in their first few weeks of supervision for this period can have profound long-term effects. Certainly future researchers could usefully consider this early adjustment period as a starting point for fruitful investigations.

Customs of Student Conduct: Working Idea Number Three

It is not really surprising that students in the Surrey lab develop regular ways of proceeding through their assigned work. The LIS and LMF provides the main influence on student activity, it is the LIS and LMF arrangement that they adapt to, and as the programme unfolds, this arrangement remains largely unaltered -- the only changing element from week to week is the subject matter covered in the script. Of course individual students react to the same environment in different ways. But in a highly coercive setting like Surrey where the conditions affecting all students are largely alike, common patterns of collective activity tend to emerge. Typically, students adjust to the requirements of the LIS and LMF in the first few lab sessions, develop successful strategies for overcoming these demands, and in the unchanging conditions continue to use these strategies week after week.

These adaptive strategies I have called customs of conduct and three were identified in the Surrey lab: Preparatory Working, Working Quickly and, Working Mechanically. I have

already mentioned that the generalisability of the Surrey analysis is problematic. The three customs identified at Surrey may or may not occur in other lab programmes (see Working Idea Number Four). That there will be collective patterns of activity, largely influenced by the particular nature of the LIS and LMF, is highly likely. For instance, one of the patterns of student activity analysed in detail in this thesis (the act of proceeding mechanically through experiments) has been frequently mentioned in published literature as an unwanted and widespread phenomenon.

The important point for the general reader turning to this framework for help, perhaps, is not so much the particular customs of student conduct that emerged at Surrey, but that in lab settings such customs do occur. The idea of adapting to and LIS and LMF provides a clue to how they occur but the next two Working Ideas go further and suggest a way of conceptualising how students act in the lab and then, building on this, how one might go about trying to intervene and make appropriate changes to the lab context.

Principle of Context: Working Idea Number Four

The Principle of Context, proposed in Chapter Five, states that the study decisions a student makes when proceeding through the laboratory instructional script are influenced not only by the nature of that script but also by the arrangement of the laboratory management framework (the method of assessment etc.).

My visits to Southampton and Queen Mary College, though brief, proved sufficient to confirm the existence of an LIS and LMF at both places. At QMC I also got the chance to venture beyond informal conversation and interviewed eight students (picked at random) about their laboratory work. Although many of the details raised by students were different than Surrey (as we would expect), it was interesting to note that their general ways of proceeding through experiments -- as outlined in the Principle of Context -- were the same. Moreover, each student mentioned, to a greater or lesser extent, that they frequently worked quickly (a pattern discerned at Surrey). I include a long extract from one of the interviews because it provides a rich and detailed description of a student at work in a laboratory setting other than Surrey, it also, better than anything I know, gets across the real meaning of the Principle of Context:

Student (S): You want to know about EFM experiments (Electric Fields and Materials) and Basic Electric Circuits (BEC)?

Interviewer (I): Yes, what your general feelings are.

(S): Well the EFM I would say are great, not bad at all, no trouble. The Basic Electric Circuits I would say the experiments are just too long. The one today I didn't complete.

(I): Which one did you do today?

(S): Transformer. You've seen that one have you (nod by interviewer)? Well the bit I didn't do was about matching the loudspeakers and I profess to be pretty competent at handling mathematical equations and I reckon I can fluke some results for it. That's it. You said nothing will be going back to the teachers didn't you (further nods from interviewer)? I reckon I can fluke some results for that and quite simply make it look as though I've done the experiment...in the filter circuit two weeks ago I didn't even start that.

(I): Why?

(S): Time ran out...

(I): Have you been rushed with all the Basic Electric Circuit experiments?

(S): Every one. Every one. You see the fellow who sets them, I reckons, he reckons, he sets ones that he would be able to do in the time. At least that's my opinion.

(I): Does the lack of time affect how much you can get out of the experiment?

(S): Yes. I can't learn a thing from it. The EFM you can absorb the theory. With BEC my mate and myself have come around to the thing of looking (he begins to go over the kinds of thing they say in the lab) 'right got to do something here, let's get that done, take it down.' Then we take it home. We still haven't completed the experiment today doing that. Today, everytime it said investigate or do this, we did it. Anything that said, it can be shown, we ignored. And we still didn't complete it. So I would say the experiments are too long...

(I): When you do the Electric Fields experiments do you feel you get more out of them?

(S): Yes, in a sense.

(I): In what sense?

(S): Well I can absorb the theory as well as the practical. For instance, in the radio one playing around with the ariel, you could read why you were doing the experiment as you were getting on with it.

(I): Because you had time?

(S): Because we had time. The experiments are too long in BEC.

(I): When did you first find out you couldn't finish the BEC experiments?

(S): The first week.

(I): And you developed ways to cope?

(S): Yes, we tried it this week and got the furthest we have ever got but still didn't finish.

(I): Can you tell me a bit more about your strategy, Roger?

(S): Well I'll choose one I haven't done yet and show you. (He looks through the instructional scripts at his side.) Supposing I was doing this one. Tuned circuits. (He begins to read through the script and talk about how he would proceed.) Look through the list of apparatus, quickly belt round and get it. Introduction, not really worried about that. Quite simply, off we go, I might read it but I won't look at it in there. Using the Sig. Gen (variable voltage/frequency generator) set it to ten kilohertz. Set Sig Gen to 10 milivolts. Circuit Diagram. Belt the old Sig Gen round until you get an output, measure L and C on a bridge, quickly belt round get a bridge if I haven't already got one, flash down the figures in the book.

There are no sentences in there (pointing to his lab book), all I've got are things like, Capacitance = 3.01 microfarad. In fact I have a hell of a job sorting out what they all mean when I get back home.

Set up the tuned circuit using a ten milihenry inductor. Set that up. Find the resonant frequency. Right quickly put it on the scope, belt the old generator round while the old output goes up. Put it down in the book. Never mind taking measurements on the time base to see how accurate things are, read it off the Genny and put it down.

It's the only way to get through his experiments. You can make up the readings for the scope afterwards because let's face it, it's not important, the results. What's important is the theory.

(I): What do you mean?

(S): Well let's face it, what difference does it make if it resonates at one K, or one K one hertz. If the generator says one K I might put down one K one to make it look as though I measured it on the scope. (He carries on reading the script). It can be shown, right skip that paragraph. You've got to look for something that tells you what to do. You see what I mean, this is what we've been doing today.

Connect up the circuit. This confirms, you don't want to do that, it's maths, quite simply it's maths, leave it alone, do that when you get home, it's maths.

Now this would be a good experiment to do. I might do this one next time. What, I've only done four measurements so far, the rest is waffle.

(I): Do you choose which experiments to do after consulting your partner beforehand?

- (S): In theory yes, in practice no. You get with your partner at the start of the lab and pick the one that looks like it's only got a few pages in it. It's the only way for BEC. Now with EFM if we were given a choice we would look through and find one that looked interesting, because EFM are quicker.
- (I): Has Dr. X stipulated that you must finish the experiments?
- (S): No. He has said that he is going to mark them not on how much you have done but on how well you have done what you have done, if you follow. In other words it doesn't matter if you only do 20%. But if you only do a couple of words, if you just wrote 'Jesus Wept', you're not going to get any marks for it are you? You've got to do a good percentage of it obviously. Let's face it if you only get a third of the way through you are going to miss about three quarters of the marks...
- (I): What do you write when you are in the lab?
- (S): In BEC I get the results and very little else. Look I'll get my two lab books and you'll see won't you. Look this is what I did today: maths, figures, results. Maths, figures.
- (I): When you are going through the BEC ones Roger and you come across a problem such as triggering the scope and you are having to rush do you (he interrupts me).
- (S): Chuck it away, yes. Get another instrument, yes. For instance, suppose I didn't know how to trigger the scope, as you say. The trig wasn't set on auto and I hadn't seen it. (He re-enacts what would happen). Bugger it no trace, pick up another one and hope that that was set right. (a smile from the interviewer). No, no, I'm quite serious. If I had a signal generator that was taking it's time warming up, if he was near by I certainly wouldn't mind asking him but if he was talking to someone else to save time I would get another bit of apparatus.
- (I): Would you like it to be different than you describe?
- (S): I would rather have it so that I have practically unlimited time to do the experiment.

To sum up, adoption of the Principle of Context demands a deep change in attitude, for it requires both the teacher and educational researcher to forego the importance both of them have traditionally attached to the script as the major

influence on student academic behaviour in the lab. Stated in its general form, the Principle of Context is an attempt to help teachers and researchers understand better the origins of everyday student behaviour they observe in the lab. The principle also has important implications for more formal interventions to improve laboratory programmes and this is taken up in Working Idea Number Five.

Rule of Intervention: Working Idea Number Five

The Rule of Intervention proposed in Chapter Six was derived from analysing a series of innovatory changes and their consequences over a period of twenty years in the Surrey lab. The rule states: Although all elements of the LIS and LMF influence student activity not all of them need necessarily be changed in a successful intervention, rather an element should be changed in the knowledge that it will then relate differently to other elements. It is to the new total pattern of elements that the student will respond not just to the single element that has been changed.

To make this rule more easily understood, I illustrate the way it works by considering the student act of Working Mechanically

To save time for thinking in the lab students learn to prepare for their experiments and think in advance about how to carry out the script instructions (e.g. what measuring instruments are appropriate and how to use them). This completed

the student is usually able to work through the assigned tasks in the available time, though typically he must proceed with speed. To avoid working mechanically, however, the student has to acquire, in addition, an overall picture of his assigned experiment, and since he has little opportunity to actually develop this in the lab he must again take appropriate preparatory measures. To gather an overall picture of the experiment (i.e. to understand why he is being asked to proceed through the different parts of the experiment as indicated) the student needs to comprehend the electrical and mathematical theory underlying the subject matter covered in the script. If the student fails to grasp this theoretical content at the preparation stage or early in the experiment he is likely to proceed mechanically through the operations outlined in the script and consequently fail to appreciate the subtle concepts and ideas that the designer of the script hoped would unfold during the process of experimentation.

It is a misleading oversimplification to deduce from this analysis that the poor design of theory sections of the scripts cause students to proceed mechanically. It is the whole network of LIS and LMF elements acting together that are the cause. It is true nevertheless, that certain changes made to the present theoretical sections of the instructional scripts (to make them more easily and readily understandable to the students) would likely make a substantial difference to whether students in the Surrey lab end up working mechanically. But

this specific intervention strategy is appropriate only in this context and only while the present LIS and LMF arrangement exists.

To sum up for the reader who turns to these working ideas for help. The general rule of intervention will apply in other laboratory contexts but not the specific strategy of intervention suggested here for Surrey. Similarly the general principle of context will apply to other lab contexts but an analysis of that context will not necessarily reveal the customs of student conduct as at Surrey (because the nature of the LIS and LMF will be different) and the appropriate strategy to be used when intervening in that context to, say, avoid working mechanically, will likely be quite different.

Clearly the working ideas that comprise the explanatory framework are not intended to be specific prescriptions of action. Nor are they exhaustive or the final word. The ideas should stand or fall on their utility and in that sense their ultimate worth should be judged not by me but by each and every teacher who turns to them for help. My hope is that the framework will be used by teachers in their teaching and in programme re-designs, that future researchers will be guided in their observations and interviews by the working ideas, and that gradually, bit by bit, the framework will be elaborated upon and refined.

Having considered some of the main research findings and their relevance to teachers concerned especially with laboratory

programmes I now want to locate the reported research in the wider arena of thinking about educational research.

A central concern of this study (mentioned earlier) was to unravel the various effects on students attending the Surrey lab. First, to try and sensibly interpret the question: What do students learn in a lab programme? And then to try and answer it. Pursuing this line of inquiry I examined, for instance, whether students could use a digital voltmeter, measure amplitude and frequency using an oscilloscope, or appreciate the significance of series resonance in active circuits. This is one sort of learning. At the same time, my attention was continually drawn to the important effects on a student of adjusting to the wider environment of the laboratory (social, academic, and physical). The strategies that students developed in order to cope with being assessed, for instance, represent another sort of learning. Adjustments to being assessed (such as, working quickly) not only constituted important learning in its own right but seemed also to play an important part in influencing how a student would perceive and proceed through assigned instructions relating to, say, series resonance and how he would then use the required digital voltmeter. The one profoundly affected the other. In practice however the two ways of learning seemed to be inseparable. The distinction between the two is academic rather than actual and made only to aid conceptualisation.

Learning in the lab is clearly a process that requires careful investigation. We are not yet at the stage where we can accurately measure learning 'gains' or 'products'. This thesis represents an attempt to broaden out what is conventionally talked of as student learning. It signals the need for a move away from considering (and investigating) the purely cognitive aspects of learning. Learning in the lab means learning not only about educational content but also about self-management in the surrounding educational context. Voicing a still unconventional view Kemmis (1976) has suggested that:

"...the knowledge structures of the student only appear in interaction with features of the learning milieu. What is learned is not bodies of content or information, or even skilled performance dissociable from the contexts of production: when we peel away the context of the manifestations of learning, we are left, not with a discrete learned performance, but with nothing at all. Knowledge is manifest in action and revealed by it, so it is to the structure of action that cognitive psychology must turn."

To learn to adapt and work quickly in the lab may have major long-term psychological implications for a student's future methods of study in settings other than the laboratory. Simple though it may seem, much useful information can be gathered by the investigator who having observed a student's actions in the lab proceeds to discuss them with him. The methodological difficulties involved in adopting this approach are immense but (as the thesis testifies) they are not insurmountable. A purported loss of methodological rigour is rewarded by a rich source of information. The information is different in kind from what has previously been collected and

it will no doubt generate 'new' theories which can then be tested at some later date by more rigorous (though not necessarily traditional) methods.

There is still much to be achieved. Future investigators adopting this stance in the lab will be contributing to the work of a small but growing group of educational researchers who, having identified the importance of contextual influences on student learning in other educational settings (Nuffield, 1976c), have begun to study them systematically (Laurillard, 1978). The broad rationale for this work now exists. What is urgently needed is a series of empirical investigations.

A final point: teaching and learning is a human affair not confined to educational institutions. In his life's work, Jules Henry spanned psychiatry, anthropology, and education. He had no illusions about the fundamental dilemmas that exist in a culture and manifest themselves in the classrooms of that culture. He did not believe, for instance, that the American education system was set up to foster creativity in students. In contrast, he believed it required students to approximate docility:

"When we say a human being is docile we mean that without the use of external force, he performs relatively few acts as a function of personal choice as compared with the number of acts he performs as a function of the will of others. In a very real sense, we mean that he behaves mostly as others wish him to. In our culture this is thought undesirable, for nobody is supposed to like docile people. On the other hand, every culture must develop in its members forms of behaviour that approximate docility; otherwise it could not conduct its business. Without obedience to traffic signals transportation in a large American city would be a mess. This is a dilemma of our culture: to be able to keep the streets uncluttered with automotive wrecks, and to fill our armies with fighting men who will obey orders, while at the same time we teach our children not to be docile," (Henry, 1955).

It is not to stretch the imagination too far to suggest that teaching and learning issues that emerge in university engineering labs are related to the organisation of the wider society in which British universities exist. The Surrey lab, perhaps like many other laboratories, faces a dilemma similar to the one outlined in the United States by Henry. Briefly it is this: teachers in the lab want students to proceed through (and complete in the prescribed manner) each allocated experiment in the programme, to acquaint themselves with the various theoretical ideas and concepts covered in each one and, to use the different pieces of electrical and electronic measuring equipment associated with each experiment. In addition, teachers in the lab want students to keep an open mind, to question the need for each procedural step in the script and, the purpose of using the instrumentation provided.

The question, at the university level, is how to structure the experience of a class of students so that they can do both sensibly. To cover the required material and not become alienated into proceeding through it mechanically. Of course there is no simple answer for the teacher and the professional researcher. But to listen to students talk about their work, to take steps to see the students' academic world as they see it, to understand it through their understanding of it, are undoubtedly steps in the right direction.

APPENDIX I

FOUR INSTRUCTIONAL SCRIPTS

The term instructional script has been used throughout the research study and refers to the small booklet of written instructions (associated with each experiment) which students are expected to proceed through. Four of the sixteen instructional scripts used in the Surrey programme are included in this appendix for the readers perusal.

UNIVERSITY OF SURREY

Department of Electronic and Electrical Engineering

1st Year LaboratoryExperiment RTransistor Experiment

This experiment is designed to demonstrate the simpler properties of a BC507 n.p.n silicon transistor and of its use in a class A amplifier circuit. You will determine (i) the static characteristic curves in the common emitter mode, (ii) observe the effect of loading the transistor with a 1k resistor, and (iii) investigate its large-signal performance for a sinusoidal input.

Read the theory briefly, study the circuit diagram carefully, and then experimental procedure. Refer back to theory to obtain information required for writing up.

THEORY

The Transistor

A transistor is a three-terminal active device, from the point of view of an engineer. The three terminals are identified, for reasons of physics, by the names Base, Collector, and Emitter. Its main use - in fact the reason for it having ever been invented - is to amplify current.

In the common emitter connection (see Figure 1), when a potential difference greater than a few volts is maintained between the collector and the emitter V_{CE} , it will be found that a change in the base current (say in the order of 10's of μA), causes a much larger change in the collector current (in the order of mA's). (When the base current I_B is zero, the collector current I_C is virtually zero; the transistor is turned OFF.)

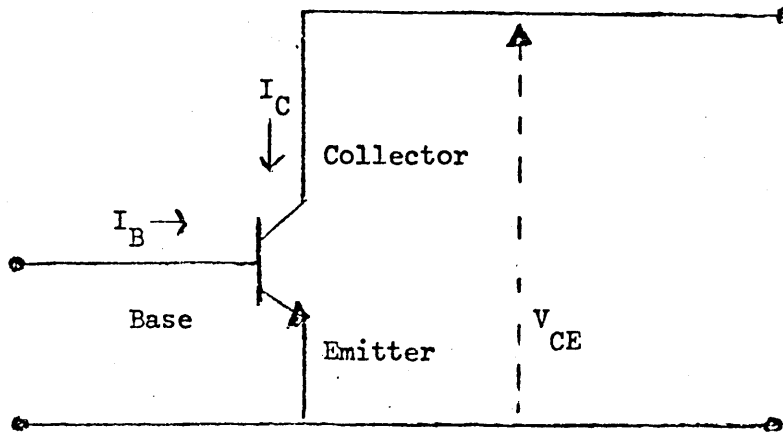


Figure 1

Collector current I_C is also a function of the collector to emitter voltage V_{CE} . Part (i) of this experiment, the determination of the static characteristics, is designed to this functional dependence on both I_B and V_{CE} .

Output conductance (input o.c) and current gain (output s.c)

There are defined as the rate of change of I_C with V_{CE} for constant I_B , and the rate of change of I_C with I_B for constant V_{CE} , respectively.

In mathematics,

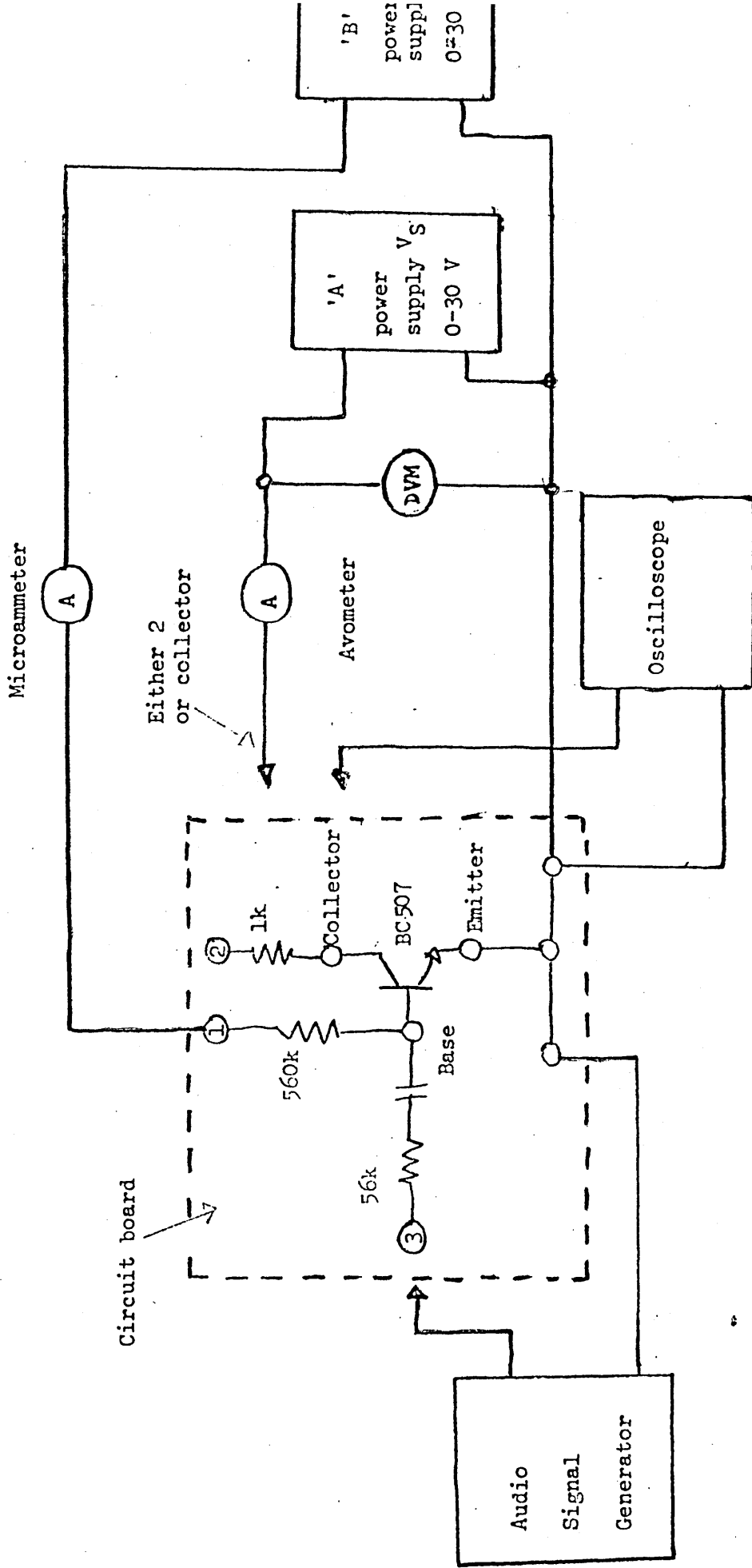
$$\text{Output conductance } h_{oe} = \left. \frac{\partial I_C}{\partial V_{CE}} \right|_{I_B}$$

and

$$\text{Current gain } h_{fe} = \left. \frac{\partial I_C}{\partial I_B} \right|_{V_{CE}}$$

The latter is a convenient measure of the amplification. Note that both h_{oe} and h_{fe} are still functions of V_{CE} and I_B , both of which must be specified. In this experiment they are measured at $V_{CE} = 7$ volts and base current $I_B = \mu A$.

CIRCUIT DIAGRAM



PROCEDURE

You should have

a circuit board with BC507 transistor, resistors, and capacitor.

Two power supplies, variable from 0 to 30 volts.

Avometer - to measure I_B .

Microammeter - to measure I_C .

Digital voltmeter

Oscilloscope and an audio signal generator.

(i) Static characteristics in common-emitter mode

Connect up the components listed above as indicated in the circuit diagram, excepting the generator and the 'scope, which are not used in this part of the experiment. Connect the free end of the Avometer directly to the transistor collector so that V_S , voltage from the 'A' power supply = V_{CE} .

Experimental

Determine, tabulate, and plot immediately the collector current I_C as a function of collector to emitter voltage V_{CE} for constant base currents I_B of 10, 20, 30 and 50 μA . Vary V_{CE} over a range of 0 to about 14 V. Base current I_B is determined by varying the voltage of the

Note

'B' power supply.

To save time determine as few points as is reasonable. You will need results for V_{CE} exactly 7.0 V.

Theoretical

From the 20 μA curve estimate the output conductance h_{oe} (see THEORY) at the operating point of $V_{CE} = 7$ V and $I_B = 20$ μA .

From the 10 μA , 20 μA , and 30 μA curves, estimate the short circuit current gain h_{fe} at this same operating point (see THEORY)

Explain the observed small drift in I_C .

(ii) Effect of collector load resistance

Now connect the Avometer to terminal 2, instead of the collector, putting the $1\text{ k}\Omega$ resistor in circuit. Set the 'A' power supply so that $V_S = 14\text{ V}$. (See Circuit Diagram). Connect the digital voltmeter to the collector.

Experimental

Vary the base current I_B and plot the variation of I_C to V_C on the same graph as in part (i).

Theoretical

The above plot is called a load line. Estimate the current gain about the operating point given by the intersection of this load line and the $20\text{ }\mu\text{A}$ curve. This is done by a method similar to the way you derived h_{fe} in the previous experiment (part (i)). Compare the two different results and comment.

(iii) Large signal A.C amplification

Without changing the connections for part (ii) connect the audio signal generator to inject a sine wave voltage at point 3 on the circuit board and the 'scope' to observe the waveform at the Collector (see CIRCUIT DIAGRAM).

Experimental

Set 'A' power supply to 14 V and the generator to 20 kHz .

Set I_B so that I_C is 4 mA , observe and sketch the waveform when the transistor is over driven by excessive voltage from the signal generator.

Set I_B so that I_C is 10 mA and repeat.

Theoretical

Explain these results, with reference to the static characteristics and the load line. Determine the values of I_B , I_C and V_{CE} which minimise the distortion for the highest voltage swing at the collector.

UNIVERSITY OF SURREY

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

First Year Laboratory

Experiment G

Equivalent Circuits

Object

To study two equivalent circuits of a three-terminal network and to investigate the conditions required for maximum power transfer to a load.

Introduction

A network may in practice contain a large number of elements. To perform calculations it is frequently useful to make use of a simple equivalent circuit whose behaviour at a given frequency is the same as that of the complicated circuit.

Two simple equivalent circuits are shown. Fig. 1(a) is a source plus a T-network and 1(b) the Thevenin equivalent circuit. In the present experiment all the elements are resistive and the supply may be taken as a perfect voltage source, i.e. terminal voltage does not change with load current.

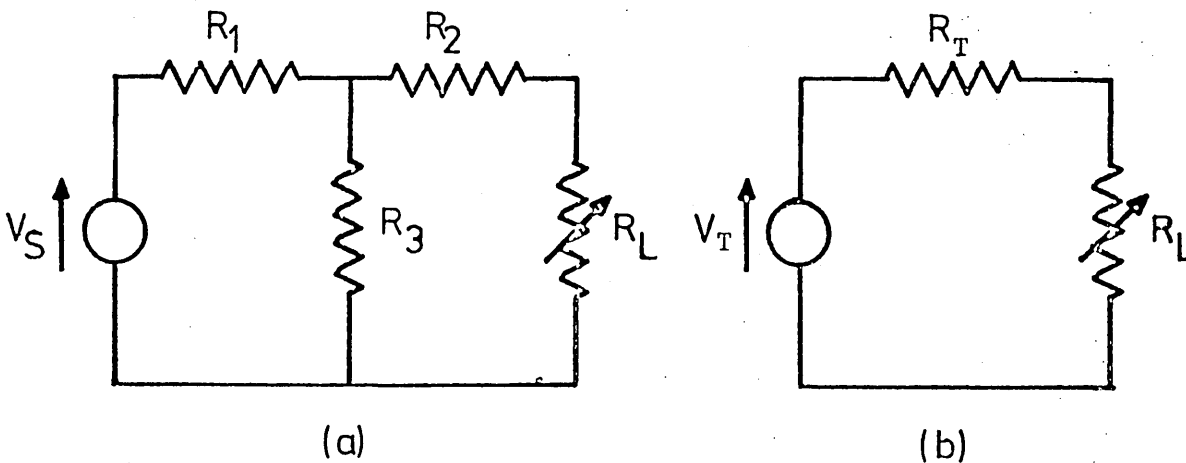


Figure 1

The object of the first part of the experiment is to determine the values of R_1 , R_2 and R_3 for the network supplied (Fig. 1(a)) and to find the values of R_T and V_T in the Thevenin equivalent circuit (Fig. 1(b)).

Procedure

- (a) Connect up the circuit of Fig. 2. Record the values of current and voltage as R_L is varied. Two important values of R_L are a short circuit and an open circuit. Note V_s should be set to 100 V.

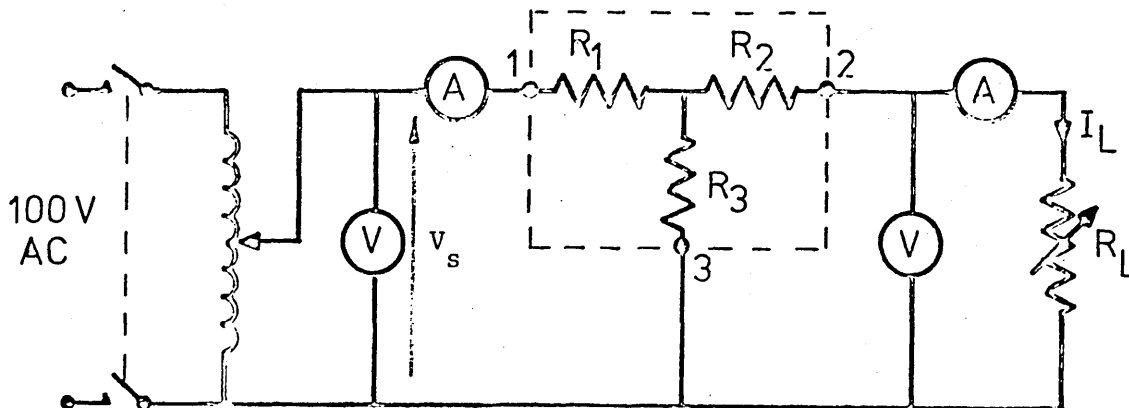


Figure 2

R_1 , R_2 , R_3 and R_T can now be found.

Show also that

$$(i) \quad R_T = R_2 + R_1 R_3 / (R_1 + R_3)$$

$$(ii) \quad V_T = V_s R_3 / (R_1 + R_3)$$

- (b) Plot the output power, $I_L^2 R_L$, against I_L , and determine the value of R_L which results in the maximum transfer of power from source to load.

Preliminary Work

- (a) Derive expressions (i) and (ii) given under the Procedure part (a) from the open and short circuit conditions.
- (b) Plot power in the load R_L against the ratio $R_L / (R_L + R_T)$ for the circuit shown in Fig. 1(b) assuming that $V_T = 10$ V and $R_T = 10 \Omega$.

VARIATION OF IMPEDANCE WITH FREQUENCYOBJECT

To find the impedance of a coil as a function of frequency and to determine an equivalent a.c. circuit.

THEORY

Three elements used to represent electrical circuits are resistance R , inductance L , and capacitance C . Resistors, inductors and capacitors are designed to approximate to these elements, whose impedances are given by:

$$Z_R = R, \quad Z_L = \omega L, \quad \text{and} \quad Z_C = 1/\omega C \quad (1)$$

where $\omega = 2\pi f$ and f is the supply frequency.

However, it must be realised that components are generally a combination of all three elements. At low frequencies, capacitors may often be assumed to behave as "pure" capacitances, but inductive coils should be considered as equivalent to a combination of resistance and inductance in series. Note that the impedance of a coil consisting of R and L in series is given by:

$$Z_{\text{coil}} = \sqrt{R^2 + (\omega L)^2} \quad (2)$$

If a coil and capacitor are connected in series the total impedance Z_T is given by:

$$Z_T = \sqrt{R^2 + (\omega L - 1/\omega C)^2} \quad (3)$$

This series combination has a minimum impedance at the resonant frequency f_o when

$$\omega_o L = 1/\omega_o C \quad \text{or} \quad \omega_o^2 LC = 1 \quad (4)$$

At this frequency $Z_T = R_o$ where R_o is the equivalent a.c. resistance of the coil at the frequency f_o .

Also note that the quality factor Q for a coil (series equivalent circuit) is given by:

$$Q = \frac{\omega_o L}{R_o} \quad (5)$$

and therefore equation (3) may be written in the form:

$$Y_T R_o = 1/\sqrt{1 + Q^2(\omega/\omega_o - \omega_o/\omega)^2} \quad (6)$$

where $Y_T = 1/Z_T$ is the admittance of the series circuit.

Plot $(Y_T R_o)$ against (ω/ω_o) for a coil with $Q = 10$. Choose values of ω/ω_o in the range 0.8 to 1.2. This resonance plot is to be compared with experimental results.

PROCEDURE

1. (a) Use the Avo and/or Digital Multimeter to find the d.c. resistance of the coil.

(b) Use the Universal Bridge (TF 2700) to find the inductance of the coil at the bridge frequency of 1 kHz.

2. Plot the impedance of the coil as a function of frequency (15 Hz - 50 kHz) using the circuit shown in Fig. 1. You will need log 4 cycles x mm graph paper for the impedance plot.

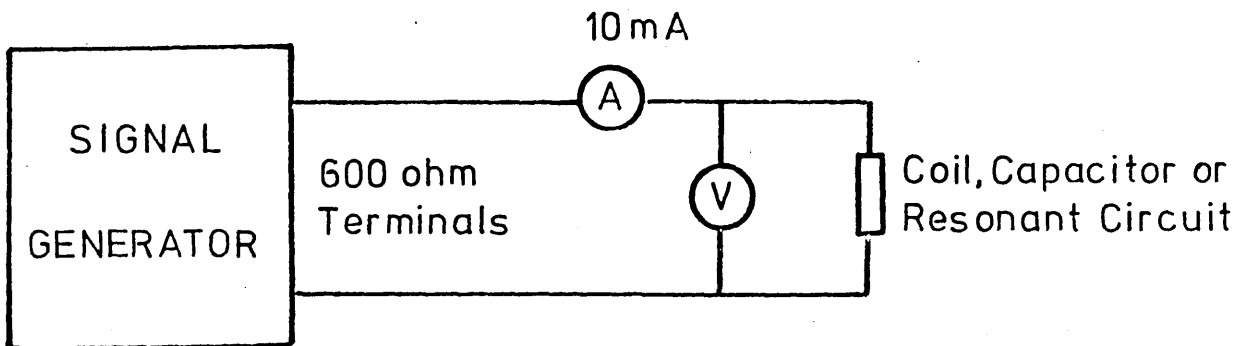


Fig. 1 - Impedance Measurement

3. Determine the resistance of the coil at 1 kHz from 1(b) and 2.
4. Find the capacitance of the capacitor,
 - (a) at 10 kHz using the circuit shown in Fig. 1, and
 - (b) at 1 kHz using the Universal Bridge.
5. Using the series resonance circuit and Fig. 1, plot the admittance Y_T against frequency f . Determine the resonant frequency f_0 and the resistance and inductance of the coil at f_0 . Also determine Q for the coil at the resonant frequency and plot $Y_T R_0$ against f/f_0 (experimental values) on the theoretical curve drawn earlier.

COMBINATIONAL LOGIC

The object of this experiment is to introduce the elementary ideas of combinational logic and to indicate the application of the subject to simple control problems and digital computing.

Apparatus 8 AND gates, 6 OR gates, 6 NOT gates;
4 indicator lamps (to monitor gate output); and
4 manual switches giving a 0 or 1 output.

INTRODUCTION

In electronic logic circuits two states are defined corresponding to two distinct voltage levels, say 5 V and a few tenths of a volt (i.e. approximately zero volts). These voltages represent the binary numbers 1 and 0 and correspond to the TRUE and FALSE of logic.

Three logic operations (gates) are considered in this experiment. Each one will be denoted by a circuit symbol and a TRUTH TABLE which shows all possible input combinations and the corresponding output. Note that all voltages in logic circuits are with respect to a common (earth) point and this is omitted in the symbolic representation.

(a) The AND gate

The symbol and truth table for the AND gate is shown in Fig. 1. $A.B^1$ is read as A and B and it can be seen from the truth table that an output appears (logic 1) if the input A as well as B is at logic 1.

<u>Truth Table</u>		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

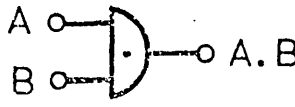
<u>Symbol</u>	
	

Fig. 1 - The AND gate symbol and truth table.

1. The dot can be omitted ($A.B$ is written AB) when you are familiar with the ideas involved but it will be used throughout the explanations in this experiment.

All other combinations give a zero output (logic 0). Note that there can be more than two inputs to an AND gate. All inputs have to be at Logic 1 and the output at Logic 1.

(b) The OR gate

The notation for OR is $A+B$ and this is read as A or B. The symbol and truth table are shown in Fig. 2 and it can be seen that an output appears (logic 1) if either A or B are at logic 1. For several inputs any one or more at logic 1 will result in logic 1 at the output.

Truth Table

A	B	A+B
0	0	0
1	0	1
0	1	1
1	1	1

Symbol

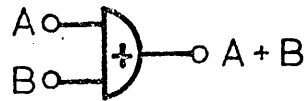


Fig. 2 - The OR gate symbol and truth table

(c) The NOT gate

This is simply an inverter which changes 0 to 1 and 1 to 0. The notation for "not A" is \bar{A} (see Fig. 3).

Truth Table

A	\bar{A}
0	1
1	0

Symbol



Fig. 3 - The NOT gate symbol and truth table

BOOLEAN ALGEBRA

The set of mathematical rules which deal with the true and false statements of logic (i.e. Boolean algebra) are valuable in manipulating the binary variables in digital circuits. The use of Boolean algebra enables logic statements to be simplified so that the minimum number of logic gates are used for a given requirement.

To start with consider a set of Boolean theorems in one variable (Fig. 4a). If they are not obvious they can be checked using a truth table (see example in Fig. 4b).

OR	AND	NOT	A	A	$A+\bar{A}$
$A+0 = A$	$A \cdot 0 = 0$	$\bar{\bar{A}}=A$	0	1	1
$A+1 = 1$	$A \cdot 1 = A$		1	0	1
$A+\bar{A} = 1$	$A \cdot \bar{A} = 0$				

(a) Theorems

(b) Example

Fig. 4 - Boolean theorems with one variable

Boolean theorems with more than one variable are shown in Fig. 5. Check the distribution rules using truth tables. There are eight possible inputs with three binary variables.

<p>Commutation rules</p> $A+B = B+A$ $A.B = B.A$	<p>Association rules</p> $A+(B+C) = (A+B)+C$ $A.(B.C) = (A.B).C$
<p>Absorption rules</p> $A+(A.B) = A$ $A.(A+B) = A$	<p>Distribution rules</p> $A.(B+C) = (A.B)+(A.C)$ $A+(B.C) = (A+B).(A+C)$

Fig. 5 - Boolean theorems in more than one variable

Although it is a simple case it is worth looking at the first absorption rule. The truth table is given in Fig. 6 and it can be

A	B	A.B	A+(A.B)
0	0	0	0
0	1	0	0
1	0	0	1
1	1	1	1

Fig. 6 - Truth table for the first absorption rule

seen by comparing the first and last columns that $A+(A.B) = A$. However, in general the last column may not be simply related to A. If we ignore the relation for the moment we could compare the last column (a required output) with the inputs (A and B) and derive the Boolean expression:-

$$\text{OUTPUT} = A.\bar{B} + A.B$$

This says that there is an output (1) if there is an input (1) at A and not an input (0) at B or an input (1) at A and an input (1) at B. The logic circuit corresponding to the Boolean expression $A.\bar{B} + A.B$ is shown in Fig. 7 but it has utilised a lot of gates in order to make the output independent of the input B. Normally if given the Boolean expression $A.\bar{B} + A.B$ it would be simplified as follows:

$$A.\bar{B} + A.B = A.(\bar{B}+B) = A$$

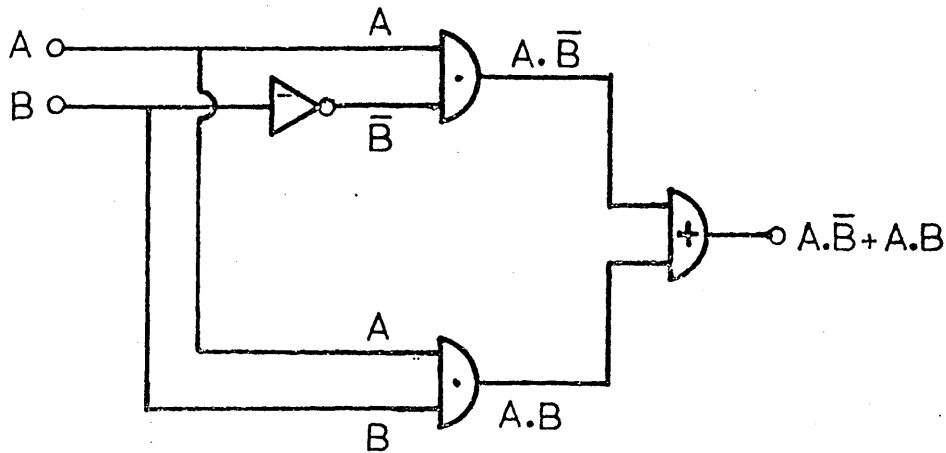


Fig. 7 - Circuit realisation of $A.\bar{B} + A.B$

Taking OUTPUT 1, write a Boolean expression for the truth table in Fig. 8, simplify and draw a logic circuit. Also, derive a logic circuit to produce OUTPUT 2.

A	B	C	OUTPUT 1	OUTPUT 2
0	0	0	0	0
0	0	1	0	1
0	1	0	1	1
1	0	0	0	0
0	1	1	1	1
1	0	1	0	0
1	1	0	0	0
1	1	1	0	0

Fig. 8 - Logic problem

EXPERIMENTAL WORK

(a) Test the Function of each type of gate until you are satisfied with its operation. Note that for the AND gates unconnected inputs behave as logic 1 and for the OR gates unconnected inputs behave as logic 0.

(b) Verify the following theorems using logic circuits:

$$A + \bar{A} = 1$$

$$A.\bar{A} = 0$$

$$A.(A+B) = A$$

$$A.(B+C) = (A.B) + (A.C)$$

(c) Verify De Morgan's theorems:

$$\overline{A+B} = \bar{A} \cdot \bar{B}$$

$$\overline{A \cdot B} = \bar{A} + \bar{B}$$

(d) Design and test a logic network with 3 inputs and an output driving an indicator lamp such that the lamp lights when two and only two inputs are at logic 1. (Set up the truth table and derive a Boolean expression).

(e) Design and test a network with 3 inputs A, B and C that will light a lamp if

(i) A and C are at logic 1 and B is at logic 0; or

(ii) A and B are at logic 1 and C is at logic 0; or

(iii) A is at logic 1 and B and C are at logic 0.

Derive and simplify a Boolean expression.

(f) The next few applications are concerned with digital computing.

(i) The half adder

The truth table for a binary half adder is shown in Fig. 9. A and B are two digits to be added. Set up the logic network for the half adder using lamps to indicate the sum and carry terms.

A	B	SUM	CARRY
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Fig. 9 - The truth table for the half adder

(ii) The sum term is known as the Exclusive-OR and as it is frequently used it has a special symbol $A \oplus B$. It can be shown¹ (using De Morgan's theorems) that

$$A \oplus B = \bar{A} \cdot B + A \cdot \bar{B} = (A+B) \cdot \overline{(A \cdot B)}$$

Compare the two logic circuits which are based on the expressions $\bar{A} \cdot B + A \cdot \bar{B}$ and $(A+B) \cdot \overline{(A \cdot B)}$.

1. See "Circuits, Devices and Systems", by R.J. Smith, (Chap.13) for this proof and an introduction to digital devices and logic circuits.

(iii) The full adder

Write the truth table for a binary full adder having two inputs A and B and a third input C representing any carry term to be added to A and B. Hence derive an expression for the sum term. Check that the CARRY term is given by

$$\text{CARRY} = \bar{A}.B.C + A.\bar{B}.C + A.B.\bar{C} + A.B.C$$

Simplify the expression and set up logic network for the SUM and CARRY terms.

- (g) A frequent requirement in digital computing is the facility to determine which of two binary numbers is the greater or whether they are equal. Design a logic network with two inputs (A and B) and three outputs (connected to indicator lamps) such that one lamp lights if $A > B$ the second if $A = B$ and the third if $A < B$.
- (h) Design a voting system for three people such that lamp 1 lights with a majority 'in favour' and lamp 2 with a majority 'against'. (Note that extra outputs may be obtained by connecting the desired signal to an OR gate input and utilising the OR gate outputs).
- (j) If time permits, design a voting system for 4 voters as in (h) such that the lamps do not light under a 'tie' condition.
- (k) Design a half subtractor and compare with (f)(i).
- (l) Design a full subtractor and compare with (f)(iii).

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