A COMPARATIVE STUDY OF UNDERGRADUATE
LABORATORY COURSES IN CHEMISTRY

by

J.R. WATSON

Submitted as Ph.D. thesis

UNIVERSITY OF SURREY
Guildford Surrey GU2 5XH
This thesis studies methods of teaching and learning in undergraduate chemistry laboratory courses, in order to relate different groups of laboratory aims to different styles of laboratory courses and to examine important factors which are affecting the achievement of the aims.

First a list of aims was drawn up and the different types of laboratory courses described in the literature were examined.

A survey questionnaire about aims and teaching methods used in the laboratory was then sent to 307 chemistry staff. In order to understand the processes of teaching and learning in the laboratory in more depth, six laboratory courses were evaluated using the illuminative style of evaluation.

The methods of evaluation although similar in each case study had to be adapted so that the most effective method of evaluation could be used on each occasion. The evaluations involved the study of any documentary evidence available and the use of questionnaires, interviews and observation. The evaluations started by concentrating on a wide range of issues but progressively focussing on important issues and studying these in more depth.

The final chapter of the thesis draws together all the information collected in earlier chapters. The more important findings and recommendations are described below:

(1) The aims and characteristics of traditional courses are described.
The types of interaction between the different groups of people involved in traditional courses are described and the effect of these interactions on the learning environment is discussed.

The amount and nature of staff and postgraduate demonstrator teaching is discussed and it is found that courses could be improved by providing some sort of postgraduate demonstrator training.

Methods of replacing some aspects of the work of teaching staff are discussed. These include the use of audio-visual materials, computers, group work and students working in pairs.

The aims and characteristics of open courses are described.

The open nature of these courses is found to lead to students sometimes having difficulties with coping with such courses, which in turn leads to more demands being made on staff and demonstrators both in time and in terms of expertise. The need for a lower student:teacher ratio and for postgraduate demonstrator training in this type of course is emphasised.

The problems of teaching practical skills and techniques in open courses are discussed.

Traditional and open courses are compared and it is concluded that often staff and students feel that open courses are better able to achieve their aims. The main constraint preventing a
shift to more open work is lack of sufficient and suitably trained teaching staff.

(9) Finally a number of alternative laboratory styles and a variety of methods available for improving present courses, are discussed.
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CHAPTER 1

INTRODUCTION
1.1 Stating the Problem

The effective use of the laboratory for educating undergraduate scientists is a subject which has continually attracted attention in the literature. In recent years a number of studies have been carried out to investigate what the aims of the laboratory work were thought to be. In 1965 Chambers (30) carried out a survey of physics staff and concluded that much laboratory work is inappropriate for achieving the aims of the academic staff. This work was followed by surveys in mechanical engineering by Lee (94) in 1969 and in chemistry by Tremlett (168) in 1972. Tremlett noted that there was disagreement between staff and students about the aims of laboratory work. He also noted that the aims of academic staff for laboratory courses appeared to change according to the year of the student and that there was a shift in teaching methods in the laboratory as students proceeded through their degree course. In his survey of professional mechanical engineers Lee (94) concluded that criticisms of laboratory practicals arose from confusion about their intended learning outcomes. He went on to say:

"Few attempts were made by practicing teachers or researchers to discover the relations between separately defined objectives and the learning processes associated with them."

The participants at a multidisciplinary three day working session on laboratory courses held in 1973 (118), were agreed that 'a great deal more needed to be known about what went on in laboratories in order to obtain a better understanding of the effects of change ... on the system into which they are introduced.'
This thesis concentrates on clarifying the aims of individual laboratory courses\(^1\) in chemistry and on gathering information about alternative methods of achieving different groups of aims. The emphasis is on examining how successful different methods are in achieving different groups of aims and on the processes within the different methods that facilitate or hinder learning.

One assumption embodied in this thesis that should be stated at the outset, is that laboratory courses are an accepted part of chemistry degree courses. The thesis therefore does not attempt to challenge whether laboratory courses should be included as part of a chemistry degree course but attempts to find the most effective ways of using the laboratory.

1.2 A Framework for Thinking about Laboratories

In order to facilitate the study of the relationship between different aims and the methods used to teach them the various possible aims for laboratory courses have been divided into areas.

1.2.1 Different Areas of Aims

A paper in Nuffield Newsletter number 3 (118) entitled 'Practicals and Projects' outlines four areas of aims. Examination of the literature revealed a fifth area of aims (see Chapter 2). The areas of aims are:

Area A: Aims concerned with the contents of the course or with the

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1. By a laboratory course I mean a course such as a second year Physical Chemistry laboratory course, not the laboratory work in a whole degree course.
nature of chemistry; subject related aims (aims 1 - 5).

Area B: Aims concerned with basic practical skills needed to perform practical work in the laboratory; manual and observational skills (aims 6 - 9).

Area C: Aims concerned with more general skills related to practical work; intellectual and organisational skills (aims 10 - 23; 30).

Area D: Attitudinal aims (aims 24 - 29).

Area E: Aims concerned with personal relationships (aims 31 - 33).

1.2.2 Laboratory Styles

This thesis studies the factors affecting the achievement of aims in the different areas. One factor is the laboratory styles. A number of different laboratory styles are currently being used in chemistry laboratory courses in the U.K. Three main laboratory styles commonly referred to in the literature are:

(1) Traditional laboratory courses

A traditional course is one in which the student is expected to carry out experiments in a predetermined way. The experiments include instruction sheets which contain step-by-step instructions on how to perform the experiment.

*These numbers refer to aims in the aims questionnaire included in Section 2.1.4.2 page 21.*
(2) A course of 'open' or problem-solving experiments.

In open experiments a problem is posed and the student is required to develop an appropriate experiment to solve the problem. For the experiment to be open, there must be more than one possible way to solve the problem although not necessarily more than one solution. Obviously the degree of 'openness' can vary considerably.

(3) Projects

A project is an investigation by a student of a problem. The student may have taken part in the formulation of the problem. He chooses the experimental methods to be used and may reach one of a number of conclusions. A project is usually supervised personally by one member of staff and with its greater student involvement lasts for several weeks or longer.

It is of course, possible to have a laboratory course which contains all three styles. Also the three styles tend to merge into one another with the degree of openness gradually increasing from (1) to (3). Some experiments or courses are thus best described by using more than one of the above descriptions.

In addition, within each laboratory style students may work in groups, in pairs, or individually and the laboratory course may be integrated with the theory or not integrated with the theory.

As well as these different laboratory styles courses may be run as courses lasting a term or a year, or less frequently as unit laboratories.
In unit laboratories the course is broken down into shorter topics of about 3 to 5 weeks in length. Each topic is organised by one member of staff in the way that he feels is most appropriate for achieving the aims. A unit could thus be of any of the laboratory styles described above or even a mixture of the different styles.

1.3 The Structure of the Thesis

The thesis is structured so that the problem of teaching and learning in the laboratory is considered in gradually increasing depth.

Chapter 2 surveys the literature relevant to the aims of laboratory courses, different laboratory styles and possible research methods for investigating laboratory courses.

Chapter 3 reports on the findings of a questionnaire sent to chemistry staff who organise laboratory courses. The questionnaire was designed to obtain basic information about staff opinions of the aims of laboratory courses, about the different styles of laboratory course being used in the U.K. and about the organisation of laboratory courses.

Chapter 4 describes six case-studies. These are detailed illuminative evaluations of different laboratory courses. The evaluations were designed to achieve a greater understanding of how students learn in the laboratory and of the factors which facilitate and inhibit learning.

Chapter 5 is short and describes one facet of the teaching and learning situation in the laboratory, the use of videotapes. It is a comparative study using data from one of the courses described in Chapter 4 and one other course.
Chapter 6 draws together the findings of the earlier chapters. The nature and characteristics of traditional and open styles of laboratory courses are discussed. A number of factors common to each laboratory style are outlined and the effects of changing various parameters within the laboratory styles are discussed. Alternative laboratory styles for achieving different groups of aims are then reviewed and the methods available for improving the effectiveness of laboratory courses are discussed. Finally areas for future research are discussed.
CHAPTER 2

A LITERATURE SURVEY
This chapter first surveys comments in the literature about the aims of laboratory courses in science. It then reviews the different methods that are being used to achieve these aims as well as comments about their efficacy or otherwise. Finally, literature is reviewed, about methods of evaluation which are suitable for investigating the factors affecting the educational effectiveness of the different styles of courses used for achieving different groups of aims.

2.1 Aims of Laboratory Courses

2.1.1 Reason for stating aims and objectives

Many reasons have been given for stating the aims or objectives of courses:

(1) "Aims ... help to establish the ethos of the curriculum. Although for different teachers (or students) a given set of aims may imply different sets of objectives, for any teacher (or student) his aims are likely to help him in judging the worthiness of the objectives. Aims provide an overall standard against which objectives are justified." (145)

(2) Aims and objectives are an aid to systematic planning of courses. (116) They help with the selection and organisation of content (47, 72) and of suitable teaching and learning

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1. In the literature the words, aims and objectives are often used interchangeably. In this thesis an aim is used as a term for "a general declaration of intent which gives direction to a teaching programme, and an objective (as a term) for a particular point in that direction". (100) An example of an aim is 'to teach basic practical skills and techniques', whereas an objective could be 'to teach a student to use a 50 ml burette to carry out acid/alkali titrations with error of less than 0.25%.
materials (42, 54, 56, 72, 101, 133, 145): They provide criteria for teachers to guide learning (67).

(3) Aims and objectives help students to organise their learning (54, 72, 100, 145) and make learning more meaningful to the students (7). Gagné (57) states,

"Telling the learner what is to be his performance when learning is complete ... seems to be of considerable importance to the learning process. It cannot be said with certainty why this is the case. Such instructions may provide continuing direction to learning ... This may mean that they establish a set which is carried in his head by the learner throughout the period of learning, and which makes it possible for him to reject extraneous irrelevant stimuli."

Kapfer (83) suggests that once students know what they are aiming to achieve it is possible to give them a choice of possible teaching and learning methods to achieve those aims. Frazer (54) suggests that objectives can be made the basis of individualised instruction.

(4) Aims and objectives help teachers to communicate with one another about their courses (100, 101, 116, 133, 178)

(5) The statement of aims and objectives makes the teaching and learning process more susceptible to evaluation (54, 72, 101, 145).

(6) Objectives can be used as a basis for assessment and aims can
be used as a guide to the type of assessment required (15, 16, 42, 54, 56, 47, 68, 72, 100, 145).

(7) Objectives can be used as a basis for providing students with information about how successful they have been in achieving the objectives (7, 16) or so that students can evaluate their own progress (101). Beard (8) states that if students are able to see that they are achieving the objectives, more enthusiasm is generated in them.

2.1.2 Limitations of aims and objectives

A number of limitations of aims and objectives have been pointed out in the literature.

2.1.2.1 Limitations of objectives

(1) All possible educational outcomes cannot be predicted accurately (47) and educational objectives do not allow for unexpected outcomes (67). This could have a narrowing effect on teaching (72).

(2) It is difficult to describe all the desired outcomes in terms of students' behaviours (67, 161) particularly in some subject areas such as the arts and with more complex concepts (47, 72). This tends to lead to the trivial being emphasised at the expense of more important though less easily definable objectives (54, 72). It also limits the extent to which objectives can be used as a basis for assessment. If the objectives cannot be stated precisely more judgment has to be exercised in assessing the students' achievement (47).
(3) Objectives give a false impression of precision and of consensus between teachers. Objectives being statements of terminal performance tell one nothing about the knowledge structure of the subject, i.e. the inter-relationship of ideas, nor about the sequencing of concepts and principles for learning a subject (72). Teachers interpret objectives differently and synthesise them in different ways, according them different hierarchical status (161, 181).

(4) Objectives are difficult to use to systematise learning because the relationship between learned ability and learning experience is not well understood (72). Objectives do not specify how a classroom should be organised. The learning environment is very complex and it is more important to be able to understand it as a whole; to understand the effect of the whole curriculum on the students (160, 161), cf item (2) in Section 2.1.1.

As a result of these difficulties teachers do not use objectives as a basis for constructing curricula (47).

2.1.2.2 Limitation of aims

Aims are criticized for their vagueness and ambiguity. This leads to them being of little use in planning learning experiences. It also means that it is difficult to know whether the aims have been achieved. Almost any set of teaching activities and short term learning outcomes can be justified as being appropriate for achieving the aims (145).

2.1.3 Purpose of the Investigation of aims in this thesis

The purpose of this thesis is to provide insight which will enable
course organisers to select appropriate teaching and learning methods to allow students to achieve the aims which they feel are important for Chemistry Laboratory courses at the undergraduate level. In order to do this the aims of laboratory courses need to be clarified. Aims which are implicit in the present courses must be made explicit so that they are open to scrutiny, discussion and possible modification and so that relationships between groups of aims and different teaching methods can be explored. It will thus become possible to provide information about alternative teaching methods that are suitable for achieving different aims.

Aims are thus being studied so that courses can be evaluated (see Section 2.1.1, item (5)) and compared with one another (see Section 2.1.1, item (4)). This should shed more light on the relationship between different groups of aims and different teaching methods (Section 2.1.1, item (2), Section 2.1.2.1, item (4), Section 2.1.2.2).

2.1.4 Possible aims of laboratory courses

In 1970 Entwistle and Percy (48) commented with respect to their study of aims and objectives,

"Here we appear to be working in what amounts to a research vacuum. Much has been written about objectives in higher education but little can be counted as research."

In their literature survey of the aims of universities over the last 180 years, they stated,

"Throughout the range of comment there is a wealth of
superficial statement and conceptual confusion. The task of extracting sense and structure from this area is formidable and might have defeated us."

Fortunately the present literature survey is confined to a study of aims of laboratory courses in science and engineering but nevertheless there has been a vast amount written in this area.

Aims have been drawn from science and engineering as well as from chemistry because of the similarities between the aims in the different areas. It will be seen that many laboratory aims are unrelated to the content of the courses. Some of the differences between the aims of laboratory courses in different subjects are discussed in the analysis of the aims survey in Chapter 3.

2.1.4.1 Methods of classifying laboratory aims and objectives

In 1951 Kruglak (91) drew up a list of objectives which were used to assess students' practical performance in 'Elementary Electricity'. He divided the objectives into six categories:-

(1) Instrumental skills e.g. to manipulate basic apparatus.

(2) Skills in the use of controlled experiments e.g. given a piece of apparatus to determine whether it is in working condition.

(3) Problem solving skills e.g. to solve problems new to the student involving laboratory apparatus.
(4) Miscellaneous skills.

(5) Functional understanding of principles e.g. to predict, on the basis of theory, what is likely to happen with a given laboratory set up.

(6) Habits e.g. neatness, caution, safety.

It can be seen that this list would be very useful in assessing a student's performance, as it specifies the skills, understanding and habits that a student would be expected to have at the end of a laboratory course.

In 1965 Nedelsky (116) drew up a list of suggested objectives for science courses. Part of his list concerns objectives for the laboratory part of science courses. He arranges the objectives in hierarchical order and breaks down Kruglak's terminal skills, understanding and habits into objectives which must be achieved before these terminal objectives can be achieved.

Nedelsky's laboratory objectives are:

(1) Laboratory knowledge

1.1 Knowledge of apparatus and materials
1.2 Knowledge of laboratory procedures
1.3 Knowledge of relations between data and generalisations from the data

(2) Laboratory understanding

2.1 Understanding processes of measurement
2.1.1 Apparatus e.g. set up apparatus to verbal or symbolic specifications
2.1.2 Measurement i.e. select proper apparatus, carry out specified measurements and interpret results

2.2 Understanding the experiment
2.2.1 Experimental design
2.2.2 Experimental process
2.2.3 Interpretation of experimental data

2.3 Intuitive understanding of phenomena e.g. estimate the distance a spring gun will project a pellet.

(3) Ability to learn from experiment or observation

3.1 Ability to pursue an experimental inquiry
3.2 Possession of laboratory skills
3.3 Disciplined thinking
3.4 Imaginative thinking in the laboratory.

It can be seen that Nedelsky's classification tends to emphasise more trivial objectives, which was pointed out as one of the problems of objectives in Section 2.1.2.1. Lower level objectives are described in detail whereas higher level objectives such as 'experimental process', 'disciplined thinking' and 'imaginative thinking in the laboratory' are left with little explanation.

In 1973 Wilkins (174) drew up a list which was 'an attempt to set out a comprehensive classification of practical abilities in hierarchical order, from the more simple to the most complex'. It is as follows:-

1.1 Knowledge of apparatus
1.2 Knowledge of procedures
1.3 Knowledge of ways of using apparatus
2.1 Ability to use apparatus
2.2 Ability to implement procedures
2.3 Ability to select appropriate procedures for a particular experimental problem
3.1 Ability to observe materials under investigation
3.2 Ability to observe changes/differences in materials under investigation
3.3 The ability to record appropriately the observed materials and the changes occurring in them
4.1 The ability to devise new apparatus to meet the demands of a practical problem
4.2 The ability to devise novel procedures to solve a practical problem

This list can again be criticised for emphasising lower level objectives. Also many objectives which many academic staff feel are important are missing, e.g. all the aims and objectives concerned with processing data obtained in an experiment and writing about it and attitudinal aims such as stimulating students' interest.

Swain (164) carried out a literature survey of aims of chemistry laboratory courses at school level and analysed the aims according to the order in which the abilities were needed when performing an experiment in the laboratory:-

(1) The road to the experiment
   1.1 Ability to comprehend the purpose of the experiment
1.2 Ability to plan the experiment
1.3 Ability to obtain a viable experimental set-up

(2) The experiment: Ability to perform the experiment

2.1 Manipulation
2.2 Observation
2.3 Recording

(3) The conclusions to the experiment

3.1 Ability to analyse and interpret the experiment
3.2 Presentation of the experiment

The nature of this analysis means that it is more related to the teaching situation but it again does not include any attitudinal aims and like Nedelsky's and Wilkins's lists does not relate the theoretical part of the course.

One problem with describing the objectives of laboratory courses is that as yet there is much confusion and disagreement, even at the level of aims. Lee (93) states that an attempt to isolate the aims and educational objectives of practical work by means of a literature search showed only that the writers' views on its purpose, aims and relevance were legion and disparate.

In order to draw up a list of objectives, first a list of aims should be drawn up, so that bias towards trivial or easily stated objectives is avoided (see Section 2.1.2.1, item 2 and Section 2.2.1, item 1).
As has already been mentioned in Chapter 1, the Nuffield Newsletter No. 3 (118) provides a useful framework for the discussion of aims of laboratory work. Aims were divided into four areas:

"Area 1 is concerned with practical work as a means of offering the student a deeper understanding and appreciation of the content of the discipline. Laboratory activities in this area may well be seen as an adjunct to the main lecture course: they will be concerned with illustrating and confirming the factual basis, concepts and theories of some particular subject of study." An example of an aim in this area is "to illustrate and amplify lecture material". "Area 2 relates to the acquisition of those techniques or manipulative skills which are seen as an essential mark of competence in a specific discipline." An example of an aim in this area is 'to familiarise the students with important instruments devices and techniques". Aims in areas 1 and 2 are concerned with knowledge and techniques in a particular discipline. Aims in areas 3 and 4 are more generalisable.

"Area 3 concerns ... 'laboratory discipline' - the development of techniques and understanding," for example, "the methodological gathering of data" or "writing reports". Area 4 is concerned with affective or attitudinal aims. Examples are "to provide the student with a stimulant for independent thinking" or "to encourage enterprise, initiative and resourcefulness". A related set of aims is also included within area 4 concerned with the 'social aspect' of laboratory work; for example "the creation of an attitude and approach that will enable students to work effectively as members of a team".
The areas of aims with some minor modifications are used for the discussion of aims throughout this thesis. Area 1, as area A, has been expanded to include aims that are concerned with the nature of the subject e.g. "to demonstrate that chemistry is an empirical science". Areas B and C are identical to areas 2 and 3. Area 4 has been divided into area D which contains most of the aims from area 4 and area E which is concerned with aims about relationships between people.

2.1.4.2 Stated aims of laboratory courses

A list of 33 possible aims for a chemistry laboratory course was drawn up from

(1) an analysis of the literature at the tertiary level;

(2) some preliminary work using an aims questionnaire in course evaluations, and

(3) discussions with members of academic staff (see Chapter 3 Section 3.3.1.1 for further details).

In order to facilitate the organisation of this literature survey, aims given in the literature will be cross-referenced to this final list.

Two types of papers occur in the literature of aims of laboratory work. Firstly, there are papers describing surveys carried out in order to determine the relative importance of different aims in laboratory courses. Secondly there are papers in which individuals assert their own views.

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1. These are described in more detail in Chapter 3, Section 3.3.2.4 and 3.3.2.6.
1. To teach theoretical material not included in lectures and tutorials
2. To illustrate material taught in lectures and tutorials
3. To demonstrate that chemistry is an empirical science
4. To demonstrate that chemistry is a useful science
5. To study a small area of chemistry in depth
6. To teach basic practical skills (e.g. manipulative and preparative skills and techniques)
7. To familiarise students with some important instruments and devices
8. To train students in observation
9. To make students aware of specific hazards in experimental chemistry and to teach them to take the necessary safety precautions
10. To simulate conditions in research and development laboratories
11. To develop students' skill in problem-solving by experimental work
12. To train students in experimental design
13. To develop students' ability to recognise problems which can be solved through experimental chemistry
14. To develop students' ability in making hypotheses
15. To develop students' ability in selecting techniques, procedures or apparatus appropriate for a particular experiment
16. To develop students' ability to make a critical assessment of the methods used to obtain experimental data
17. To teach a logical and methodical way of working in a chemistry laboratory
18. To train students in keeping a day-to-day laboratory notebook
19. To develop students' ability to make deductions from experimental data and to interpret experimental data
20. To develop students' ability in accepting or rejecting a hypothesis
21. To develop students' ability in estimating the size and significance of errors
22. To train students in writing reports on experiments
23. To develop students' ability to communicate results orally (e.g. in seminars and discussions)
24. To provide the students with a stimulus for independent thinking
25. To encourage initiative and resourcefulness in the students
26. To stimulate and maintain students' interest in chemistry
27. To encourage perseverance in experimental chemistry
28. To develop honesty and scientific integrity
29. To develop open-mindedness and flexibility of attitude (e.g. willingness to consider new facts)
30. To train students in extracting information from the literature (including training in the use of the library)
31. To provide closer contacts between students and academic staff
32. To provide closer contacts between students within the course
33. To develop students' skill in working and co-operating with others
The distribution of aims in different subjects has been studied but few differences are noticeable. These are reported in the comments about each area of aims.

2.1.4.2.1 Area A: Aims concerned with the content of the course or with the nature of the subject; subject related aims

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<td>5</td>
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a Number of aim in aims questionnaire (see opposite)
b Number of reference (see Appendix A)
c Total number of papers citing aim
d Papers specifically about projects

Clearly aim 2 'to illustrate material taught in lectures and tutorials is most important. A number of authors expanded on this aim, for example

D.A.Aikens et al (2): To develop an awareness of practical methods of dealing with systems as they actually behave in the real world in contrast to the 'ideal' behaviour normally stressed in lectures.
L.S. Lee (94): To illustrate supplement and emphasise material taught in the lectures.

Aim 4 'to demonstrate that chemistry is a useful science', is related to a number of recent papers which discuss the role of chemistry in society as a whole (33, 98, 177).

2.4.2.2 Area B: Basic practical skills

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<td>7</td>
<td>30, 168, 19</td>
<td>180, 91, 29, 26, 162, 174, 63</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>168, 139</td>
<td>180, 175, 117, 118</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>182, 91</td>
<td>2</td>
</tr>
</tbody>
</table>

Aim 6: 'to teach basic practical skills' is clearly considered to be important.

Aim 7: 'to familiarise students with some important instruments and devices', is mentioned less by Chemists than by Physicists or Engineers, presumably because simple apparatus tends to be used more in Chemistry.
2.1.4.2. Area C: Aims concerned with general skills related to practical work; intellectual and organisational skills

<table>
<thead>
<tr>
<th>Aim</th>
<th>Survey</th>
<th>Individual</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>94, 19</td>
<td>118</td>
<td>171</td>
</tr>
<tr>
<td>11</td>
<td>94, 19</td>
<td>91, 26, 116</td>
<td>6, 146</td>
</tr>
<tr>
<td>12</td>
<td>30, 19</td>
<td>182, 63, 116</td>
<td>65, 160, 146</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>164</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>123</td>
<td>108, 160, 6</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>123, 91, 113</td>
<td>6</td>
</tr>
<tr>
<td>16</td>
<td>30, 168, 19</td>
<td>91, 29, 162, 117, 118</td>
<td>41, 6</td>
</tr>
<tr>
<td>17</td>
<td>30</td>
<td>91, 138, 118, 116</td>
<td>171, 6</td>
</tr>
<tr>
<td>18</td>
<td>94, 168, 19</td>
<td>175, 123, 29, 174, 63, 113</td>
<td>9</td>
</tr>
<tr>
<td>19</td>
<td>94, 30, 168, 19</td>
<td>180, 123, 182, 91, 29, 162, 174, 117, 116, 113</td>
<td>108, 64, 160a</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>164</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>94, 168, 19</td>
<td>29, 26, 118</td>
<td>6</td>
</tr>
<tr>
<td>22</td>
<td>94, 30, 168</td>
<td>180, 175, 123, 182, 91, 29, 162, 117, 63, 66, 118</td>
<td>146, 166, 171, 6, 132</td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>182, 162, 66, 118</td>
<td>166, 6</td>
</tr>
<tr>
<td>30</td>
<td>168</td>
<td></td>
<td>171, 146</td>
</tr>
</tbody>
</table>

Two aims are considered to be very important in this area: i.e. aim 19 and aim 22.

Several authors expanded in some of the aims. For example:

Aim 11: 'to develop students' skill in problem-solving by experimental
Boud (19): (a) To use experimental data to solve specific problems; (b) To develop students' skill in problem-solving in a multi-solution situation; (c) To demonstrate the use of an experimental method as an alternative to the analytical method so solving problems.

Tremlett (168): To develop an appreciation and comprehension of a problem.

Aim 12: 'to train students in experimental design'.

Wilkins (175): (a) To develop the ability to devise new apparatus to meet the demands of a practical problem; (b) To develop the ability to devise novel procedures to solve a practical problem.

A number of authors proposed more general aims which include many of those described in area C.

For example:

Read (136), Menzie (109) and Martin (104): To give experience with and appreciation of the various methods used in experimental science.

Nedelsky (116): To develop the ability to pursue an experimental enquiry.
A number of authors phrased the aims in rather different terms. For example, aim 24.

Dronsfield (43): (a) The student should have an opportunity to make personal investigative decisions; (b) The laboratory instruction should provide an environment in which discovery, by the student, is both possible and encouraged.

Aim 26: Includes the following aim of Boud (19) 'to provide motivation for the student to acquire specific knowledge.'
The list of papers included in this survey is by no means comprehensive: The literature survey was terminated when the important articles on aims had been reviewed and when a search of other papers failed to produce any new aims.

The Nuffield Group for Research and Innovation in Higher Education (118) noted that area B was considered to be of more importance than area A. It also seemed from visits to about 150 departments of science and engineering that there was a shift in emphasis (not necessarily a clear substitution of aims) from areas A and B towards C and D.

Tietze in 1972 (165) interviewed 55 members of staff in twelve chemistry departments and confirmed the emphasis on area B with the aim 'to teach experimental skills' being more frequently mentioned. Another important aim was to help 'to learn the facts and theories of chemistry' (area A). Tietze also pointed out that there were differences between the aims of advanced, i.e. final year, laboratory courses and those of a more introductory nature. Aims in the advanced laboratory courses include 'learning how to plan and design experiments'. Another aim that was frequently mentioned was to use laboratory work to generate enthusiasm for chemistry.

The emphasis on areas A and B in chemistry is also confirmed in the Ourisson report (1966) (125) and the Eaborn report (1970) (44). The Eaborn committee also emphasised that they thought the primary aim of laboratory work was 'to give the student a feeling of the nature of chemical experimentation' (area C).

It is interesting to note that the papers describing project work put more emphasis on aims in areas C and D than on A and B. Obviously
In recent years there has been much discussion of a move from education in chemistry to education through chemistry. In 1973 Frazer (54) said, "At tertiary level a consensus is emerging that there should be less emphasis on the factual content of courses, and more attention to (a) understanding principles and application to problems and (b) the acquisition of skills, attitudes and abilities expected of any educated person and useful in many diverse careers not only in chemistry". Similar comments were made by Lord James (78) in 1975.

The shift in emphasis towards aims in areas C and D is in accord with a change in emphasis to education through chemistry.

2.2 Different Styles of Laboratory Work

This section examines the variety of styles of laboratory work that are currently used at the undergraduate level. The literature survey concentrates on laboratory courses offered in chemistry in the UK but references are also made to laboratory work in other countries and other subjects. This thesis concentrates on teaching and learning styles in laboratory courses, rather than on the content of the courses, and within the science and engineering area there is considerable overlap in laboratory styles. It is therefore felt that many of the comments and criticisms of non-chemistry laboratory courses are relevant to this study.
2.2.1 Classification of Styles of Laboratory Work

Few attempts have been made to classify different styles of laboratory work. Three styles which are quoted throughout the literature are traditional laboratory work, open or problem solving laboratory work and projects.

In 1964 the Hale Report (63) identified a variety of teaching and learning styles in the laboratory: "Practical work in the laboratory may take on a great variety of forms ranging from the set experiment, planned in detail with its accompanying instruction sheet and occupying the period of a single practical class, to the 'open-ended' research project in the later years differing only in scope and duration from the work of a post-graduate research student. The students concerned may work singly, in pairs or even in groups; practical work may progress step by step with the lecture course to which it forms an extension, or it may be quite unrelated to the topics of theoretical instruction which are being studied at the same time. A laboratory may be set up with a group of experiments which are unchanged over a long period, the students rotating between them as each experiment is completed, or the class material may be changed at every practical, each student being provided with identical equipment or specimens".

In 1972 Fowler (53) identified three alternative styles to the traditional or 'cookbook' style:

(a) The 'laboratory library' and the 'corridor laboratory'. These laboratories both contain experiments "designed to
demonstrate phenomena or to provide simple experimental data for analysis". The experiments are designed so that they can be attempted unsupervised and are accompanied by self-instructional materials which enable students to do the experiment unaided.

(b) The 'open laboratory'
"The open laboratory is an attempt to allow the student complete freedom in the laboratory. The instructor provides the equipment and guidance for its use, the student selects his experimental goal or goals, designs the experiment, including the making of necessary decisions as to what will be measured and to what accuracy etc. and evaluates his result."

A "divergent laboratory" is also described. This is similar to an open laboratory but the amount of openness is limited by providing a limited number of routes through the experiment.

(c) The 'project laboratory'
This is described as "a single in depth experimental project which occupies the entire term". Projects are more open than the experiments described above; "the student is responsible for the conception and design of the experiment and essentially for all decisions which guide it to conclusion".

Tremlett (168) proposed a hierarchy of four distinct levels of laboratory experience which he thought were necessary in an undergraduate course in order to develop appropriate skills and attitudes in students.
(a) Level 1: The closed experience
The function of this level is to develop manipulative procedures and specific laboratory techniques that would be needed in later laboratory work.

(b) Level 2: The structured experience
At this level students do structured experiments which use the experimental skills and techniques learnt in level 1 and which relate to the students' theoretical studies. "Level 2 is highly structured deliberately and is programmed with the intention of developing observational measurement, analytical and interpretational skills."

(c) Level 3: The semi-open experience
Level 3 introduces a more open kind of laboratory programme and allows the student greater responsibility and freedom of action so as to encourage and develop an attitude of enquiry.

(d) Level 4: The fully-open experience
This level is intended to offer students more extensive opportunities for discrimination and judgment by attempting investigations entirely independently.

Tremlett successfully designed and tested a short experimental course based on this hierarchy. Neither of the classifications above include the variety of laboratory styles that have been reported in the literature.
2.2.2 Different Styles of Laboratory Courses

This section reviews comments made in the literature about traditional, open (or problem-solving) courses and about projects. A number of alternative laboratory styles are then reviewed.

2.2.2.1 Traditional Laboratory Courses

This section surveys comments in the literature about traditional laboratory courses and then about a particular type of traditional laboratory course, the 'circus laboratory'.

In his survey of the literature about laboratory courses Tremlett (168) quoted many references which are relevant to this survey and these are included where appropriate. Inevitably comments in the literature are mainly critical of traditional laboratory courses because traditional laboratory courses are the norm: If a teacher wishes to introduce a new kind of course he must show that it is superior to traditional courses. Also the dominance of traditional laboratory courses has not yet been threatened and so teachers have not yet been compelled to write in their defence. Notwithstanding, the literature although biased does offer some useful criticisms of traditional laboratory courses.

Traditional courses have been criticised for having limited aims, for their inadequacy in achieving their aims and for undesirable effects on both staff and students.
2.2.2.1.1 Aims

The most common and fundamental criticism of traditional laboratory courses is that they are said to be only able to achieve aims in areas A and B and to a limited extent in C (see Section 1.2.1 for a description of the aims in the different areas).

(a) Aims in area C

Traditional laboratory courses have been criticised because:

(1) They are unrealistic and do not teach true experimentation; they do not teach students the process of enquiry. (Chemistry 43, 181; Physics 29, 109, Tremlett 168, outlines similar comments made in Medical Education 21, 141, and Engineering 105.)

(2) Students after doing a traditional course were 'unable to use an experiment to attack a chemical problem'. (Chemistry 120.)

(3) They do not teach 'scientific method' (Chemistry 36, 59) and do not encourage preliminary planning (Chemistry 99).

(b) Aims in area D

(1) Tremlett (168) points out that science laboratory courses have been criticised by students because they do not

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1. The numbers refer to the number of the reference in the list of references; chemistry refers to the subject area.
allow students to think independently or to exercise originality and creative thought (103, 114, 39, 25) and because they want to take more active part in the learning process (114).

Similar criticisms are made by staff (Chemistry 45, 34, 149; Physics 59). For example Eaborn (45) said that he suspected "that the major defect of existing courses is that they give the student little or no opportunity to exercise his originality, individuality and creative ability. Tremlett (168) quotes similar comments made in Engineering (3, 61, 79, 88, 89, 96, 143, 162).

Ogborn (121, p. 25), however, points out that students oscillate between complaining about experiments which are routine and require no initiative and complaining about experiments in which too much initiative is required and students become lost. Clearly a balance is needed.

(2) In Chemistry, traditional courses have been criticised because they fail to develop the attitudes of an investigative chemist (84). Wood said that one of the main aims of Engineering should be to develop in a student a highly critical approach to experimentation (179).

(3) Traditional courses have often been criticised because they have been found to fail to stimulate interest, and in fact in some cases they have a bad effect on student
interest (Chemistry 25, 90, 13; Physics 29, 109, 30, 136; Engineering 162, 94; Biochemistry 176; Science and Engineering 118). Chambers (30) and Holliday and Hughes (73) pointed out that many students now come to university with a background of project work and that traditional courses fail to interest them. Fowler (53) pointed out that 'There is no room in this type of experiment for student choice, certainly not as far as as what is to be investigated, usually not even as far as methods of investigation. With no room for failure, there is no great reward in success'.

(4) Traditional courses have also been found to produce undesirable attitudes about the relationship between theory and experimental work. Students carry out experiments to verify theory. If, however, they find a discrepancy between their data and the theory, the theory is the last thing that they will question (Physics 107, 26).

2.2.2.1.2 Method

The methods of teaching used in traditional laboratory courses have been criticised on a number of grounds:

(1) They are not the most appropriate method of teaching. Hoare (70) carried out a controlled investigation to compare a traditional chemistry laboratory course with a project type of course and found that the project laboratory was superior for teaching basic laboratory skills, awareness of the laboratory as a method
of acquiring knowledge as well as attitudes such as enterprise initiative and resourcefulness. Nugent (120) claims that after taking a traditional organic chemistry laboratory course, 'when put in a new situation even good students were not able to perform routine crystallizations, distillations or spectral identifications. Tremlett notes that similar criticisms of the low level of learning in traditional laboratories have been made in Biological Sciences (176, 1).

Kruglak carried out a controlled investigation in which he compared the achievement of laboratory and non-laboratory groups (92). He found no significant difference between the two groups on a theory test indicating that the laboratory work had not helped the students with the theory, but he found that the laboratory groups were significantly better than the non-laboratory group on all tests dealing with laboratory work.

Chambers (29) argues that much of what students learn in Physics laboratories could be learnt from lectures.

(2) There is a risk of students working mechanically (Chemistry 43; Science 43, 121, 14). Traditional courses do not encourage students to think about the practical work in hand (Chemistry 99) and understanding is frequently gained in students' subsequent study rather than in the laboratory (60). Students become frustrated with predictable exercises (Chemistry 181, 163, 52, 151, 49).

(3) Lee (Engineering 94) and Black and Whitworth (Physics 12) criticise laboratory work for being inadequately integrated with
2.2.2.1.3 Organisation

Laboratory courses in general have been criticised because "the laboratory often absorbs as much or more student learning time" as other methods of teaching, "demands a much smaller student to instructor ratio, requires more floor space and expensive apparatus" (26). Similar comments were made by Aikens et al (2).

Fowler (53) commented that as compared with other types of laboratory course, however, traditional courses are logistically simple to organise: "Cookbook laboratories have a compelling logic: everyone knows exactly what to do". He adds that more open courses are more demanding in terms of the pedagogical expertise required of the instructors. A similar point is made by Ogborn (121, Sec. 9.6). Bradshaw (20) in 1955 commented that supervision of engineering laboratory work is generally unpopular and is normally left to the young demonstrator. Jennings (79) eight years later made a similar comment adding that an impression of the unimportance of laboratory work is conveyed to the student leading to unresponsive attitudes towards laboratory work.

In a department where supervision of laboratory work was unpopular, traditional courses would have the advantage for staff of being less demanding.

2.2.2.1.4 'Circus' laboratories

The references below are related to courses where there are a number of
experiments available for students to do in any order. These are often referred to as 'circus' laboratories. Richards (138) pointed out that 'in the education of engineers "set-piece" laboratory work is centered upon items of hardware which are expensive and difficult to utilise fully. Two consequences follow; firstly in an effort to improve utilisation staff are tempted to use the set-piece in the same way year after year to give every student experience of using the hardware. Secondly, a pool of highly skilled technician staff is used uncreatively to commission and service equipment. The skilled man becomes bored and if he is replaced by one of lower calibre innovation may become impossible.'

Black and Whitworth (12) criticised circus laboratories for:

(1) the lack of coherent development in the sequence of experiments performed by the students;
(2) the impossibility of a timely relation between the laboratory and the theory courses;
(3) the difficulty of following the progress of individual students (particularly in large classes) and hence providing close personal supervision; and
(4) staff often not knowing or being sympathetic with the aims of the experiments.

They do however have some advantages:

(1) in a circus arrangement, individual experiments can be modified or replaced so that the process of change can be continuous or gradual;
2.2.2.2 Open or problem solving laboratory courses

In the Nuffield Newsletter No 3 (118) it was pointed out that the change in emphasis in aims from areas A and B to areas C and D was accompanied by the development of more open styles of laboratory work. It appears that in order to produce chemists with the abilities to take up many diverse careers not only in chemistry (113) and in order to educate through chemistry rather than in chemistry (97), alternative methods of teaching to the traditional are felt to be more appropriate.

The shift in emphasis to more open styles of laboratory work has also reflected changes in other parts of the education system. Many students when starting a degree course in Chemistry have prior experience of heuristic practical work and are therefore quickly discouraged by the closely structured traditional laboratory styles (118, 119). In addition, project work has become firmly established particularly in the final year of science degree courses and in some departments it is felt important to prepare the students for project work by giving them some experience of open laboratory work in earlier years (31).

Many of the papers in the literature describing open and problem solving styles of laboratory work are written by members of academic staff who feel that they have successfully established courses of this type in their departments. The papers must therefore be considered to be a biased sample of open styles of laboratory work. On the whole...
only successful courses are reported. In addition disadvantages of open styles of laboratory work are rarely reported and it is often difficult to discern whether a course has been successful because of the particular laboratory style used or because of the enthusiasm of the members of staff. It would be interesting to find out if the courses reported below were still so successful after the member of staff who promoted the course had handed it over to other members of staff to organise and when the students ceased to be an experimental group (Hawthorne effect).*

2.2.2.2.1 Courses surveyed

Table 2.1 lists the open or problem solving course surveyed below:

<table>
<thead>
<tr>
<th>Author</th>
<th>Reference Number</th>
<th>Year of Course</th>
<th>Subject Area</th>
<th>Country where course is run</th>
<th>Sources of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betteridge</td>
<td>10</td>
<td>2</td>
<td>Inorg Chem</td>
<td>U.K.</td>
<td>-</td>
</tr>
<tr>
<td>Bobbitt et al</td>
<td>17</td>
<td>2</td>
<td>Org Chem</td>
<td>U.S.A.</td>
<td>-</td>
</tr>
<tr>
<td>Chisholm</td>
<td>32</td>
<td>1</td>
<td>Org Chem</td>
<td>U.S.A.</td>
<td>Student questionnairre</td>
</tr>
<tr>
<td>Dronsfield</td>
<td>43</td>
<td></td>
<td>Org Chem</td>
<td>U.S.A.</td>
<td>-</td>
</tr>
</tbody>
</table>

1. Discussion with an author (confidential source) of a paper described in this section, revealed that after 2 years of running the open laboratory course he had relinquished control over the course, thinking that it was well established, but the course was initially modified to include more traditional experiments along with the open experiments and then, after a further year it was changed back to a completely traditional form. The main reasons for the changes seem to have been that the staff taking over the course did not wish to become as involved in the course as was demanded by the open style and because they disagreed with the author over the aims of the course: they felt that the course should be designed to put more emphasis on the teaching of basic practical skills.

One wonders how many of the open courses described in the literature have suffered a similar fate.
TABLE 2.1 cont

<table>
<thead>
<tr>
<th>Author</th>
<th>Reference Number</th>
<th>Year of Course</th>
<th>Subject Area</th>
<th>Country Where Course is Run</th>
<th>Sources of Data^1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>51 (and part 2)</td>
<td>1</td>
<td>Inorg Chem</td>
<td>U.K.</td>
<td>-</td>
</tr>
<tr>
<td>Fowler</td>
<td>53</td>
<td>-</td>
<td>Physics</td>
<td>U.S.A.</td>
<td>-</td>
</tr>
<tr>
<td>Haake et al</td>
<td>62</td>
<td>1</td>
<td>Chemistry</td>
<td>U.S.A.</td>
<td>-</td>
</tr>
<tr>
<td>Hoare</td>
<td>70</td>
<td>1</td>
<td>General Chem</td>
<td>Australia</td>
<td>Student Questionnaire</td>
</tr>
<tr>
<td>Kovacic</td>
<td>90</td>
<td>1</td>
<td>Org Chem</td>
<td>U.S.A.</td>
<td>-</td>
</tr>
<tr>
<td>MacDuffie</td>
<td>99</td>
<td>1</td>
<td>Inorg Chem</td>
<td>Ceylon</td>
<td>-</td>
</tr>
<tr>
<td>Nechamkin</td>
<td>115</td>
<td>1</td>
<td>General Chem</td>
<td>U.S.A.</td>
<td>Student Questionnaire</td>
</tr>
<tr>
<td>Nugent</td>
<td>120</td>
<td>1</td>
<td>Org Chem</td>
<td>U.S.A.</td>
<td>-</td>
</tr>
<tr>
<td>Parlett</td>
<td>128</td>
<td>-</td>
<td>Electrical Eng</td>
<td>U.S.A.</td>
<td>Independent Evaluator</td>
</tr>
<tr>
<td>Pearson et al</td>
<td>130</td>
<td>1</td>
<td>Org/Inorg Chem</td>
<td>U.S.A.</td>
<td>Student Questionnaire</td>
</tr>
<tr>
<td>Richards</td>
<td>138</td>
<td>1</td>
<td>Mech Eng</td>
<td>U.K.</td>
<td>Independent Evaluator</td>
</tr>
<tr>
<td>Silberman et al</td>
<td>149</td>
<td>2</td>
<td>Org Chem</td>
<td>U.S.A.</td>
<td>-</td>
</tr>
<tr>
<td>Venkatacherlam et al</td>
<td>170</td>
<td>-</td>
<td>General Chem</td>
<td>U.S.A.</td>
<td>-</td>
</tr>
</tbody>
</table>

2.2.2.2.2 Aims

One of the main reasons for introducing open or problem solving courses has been to try to achieve different aims from those which it was felt could be achieved by traditional courses. Although in many courses (10, 43, 13, 115, 62, 70) it was still considered important that a course should teach basic skills and techniques, staff wanted to achieve additional aims: Staff wanted to place more emphasis on

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1: i.e. sources of data other than the subjective opinions of the author.
on students achieving aims in areas C and D:

Area C

e.g. (1) to learn how to plan experiments (99, 90);
(2) to solve problems through experimental work (120);
(3) to get to know what it is like to do research (43, 90).

Area D

A number of attitudinal aims are implicit in the courses described and were occasionally stated explicitly:

e.g. (1) to involve students in the course (99, 10, 128);
(2) to stimulate the students' interest (10, 70, 90, 115, 128, 130, 149):
(3) to encourage students to use their initiative (10, 62, 70, 128, 149, 17);
(4) to encourage students to think independently (32, 62).

A number of course organisers also required students to make more use of the library (32, 90, 99, 115, 120, 17, 149, 62) and to carry out a literature search.

2.2.2.2.3 Organisation

(a) Type of experiments

The style of open laboratory courses varies considerably: Some courses start with traditional experiments, which are either related to the lecture courses or are designed to teach specific laboratory skills and techniques, and then finish with short open or project style experiments (62, 90, 115, 149). A variation on this is the course described by Venkatachelam et al (170) which consists of experiments made up of 2 parts: First students learn basic chemical principles
and laboratory skills by means of reading, discussion, 'cookbook' experiments, calculations and the experimental write-up and then they tackle the open part of the experiment.

Pearson et al (130) describes a course also consisting of 2 parts. First students do a number of experiments, where the amount of openness is limited and only involves modifying existing instructions for experiments. After this students do a five week project. ¹

Other courses consist of a series of open unstructured set experiments in which the students have some choice of experimental methods (10, 32, 43, 51, 53, 99, 120, 138). As is pointed out by Fowler (53) the essence of this type of course is that the student is given the impression of openness when tackling the practical problem although in reality the number of options open to him to choose may be very limited.

Finally, in some courses particularly in the U.S.A. each students does one project style experiment ² which is usually chosen from a number which are outlined by the staff each year. None of the project style experiments included in this survey exceeded one semester in length (70, 128, 17).

In some courses(e.g. 149) students had to choose and design their own experiments whereas usually they had a choice of prespecified

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¹ See also unit laboratories in Section 2.2.4.2

² These project style experiments differ from the projects described in Section 2.2.2.3 in the style of supervision, students do these experiments in the laboratory in a class, in their openness and usually in their length, being on the whole somewhat shorter.
experiments. In such courses (i.e. 149) students had to submit plans for their experiments before they started the practical work.

(b) Staffing

Those authors who comment about staffing in open types of laboratory courses indicate that this type of course makes extra demands on staff in two ways: more staff are needed and the role of staff in the laboratory becomes more demanding necessitating the use of more experienced staff or demonstrators.

Four authors give staffing ratios. Betteridge (10) had a student: staff ratio of 11:1, Silbeman et al (149) of 10:1, Chisholm (32) had a student to instructor ratio of 12:1 and Richards (138) felt that the ideal student to staff ratio would be 8:1 when students were working in pairs, although it would be possible to cope with a ratio of 15:1 if students worked in trios. 1

A number of staff (17, 32, 51, 149) stated that more staff/demonstrators were needed than in a traditional course and Nugent (120) said that this type of course made large demands on both faculty and library staff. Nechamkin (115) said that "laboratory periods are best taught by faculty members assisted perhaps, by senior students. This helps to raise the laboratory meeting from the unjustified low level in which they so often are found when laboratory instruction is done by graduate students, the least qualified of faculty personnel etc."

It is pointed out by Richards (138) and Ogborn (121) that the teacher's

1. c.f. 8.8:1 in 2nd year open courses in survey, Section 3.3.3.2.1
role in an open laboratory course is different from his role in a traditional laboratory. He has to stimulate the students by asking them the right questions at the right time: Students should be guided by discussion rather than didactic instruction. As Fowler (53) puts it, "the divergent laboratory style changes ... the teaching assistants' ... role from drill sergeant to guide." Richards goes on to say that "the character and effectiveness of the course are totally dependent on the style and quality of supervision". In developing an open course there was no pool of teaching experience in open courses and it was found necessary to gradually introduce staff to this method of teaching over a number of years.

Parlett (128) noticed similar difficulties in the course he evaluated. Some of the teaching assistants seemed unable to adapt to their new role. Some teaching assistants adopted a very authoritarian stance and seemed to see their role as one of an assessor as opposed to other teaching assistants who were friendly and helpful to the students.

Brooks et al (23) describe a short course for graduate laboratory instructors which would be helpful for training demonstrators to undertake their role in the laboratory.

Richards (138) also pointed out that it is important to have laboratory technicians who are sympathetic to the aims of the course and Betteridge (10) commented that an open course tends to make more demands on technicians because what the students will do is to some extent unpredictable.
(c) Methods of learning practical skills and techniques

One problem with open courses is that students tend to be doing different experiments at the same time and it therefore becomes more difficult to teach the necessary practical skills and techniques. This problem is overcome in a number of ways. In some course (149, 90, 62, 115, 170) students are able to learn the practical skills and techniques in an earlier part of the course which has a more traditional or structured style.

In some courses (10, 120) the skills and techniques were taught in tutorials or lectures plus discussion sessions which ran concurrently with the laboratory course. Richards (138) used a short lecture course to acquaint students with methods of analysing and reporting their results.

Other methods used for teaching practical skills and techniques were videotaped demonstrations (10) and handouts containing the necessary manipulative details (51). Reid and Arsenau (137) suggest that open laboratories can be enhanced by using audio visual aids in the form of previewing slides, film loops and videotapes. These audiovisual materials reduce the need for much individual attention, allowing staff to help students in other ways. 1

(d) Assessment

The aims which are emphasised in open courses tend to be more in areas C and D (see Section 2.2.2.2.2). The assessment of the students,

1. The use of videotapes in the laboratory is discussed more fully in Chapter 5.
however, was usually based on written reports but in some courses other methods of assessment were used. Some members of staff actually observed the students at work in the laboratory (138, 51) whereas others questioned the students about the experiments in oral sessions (90, 10, 51).

Bobbitt (17) pointed out that "because of the numerous aspects of the work which are beyond your control and the high level of initiative required grading of the course is very difficult".

2.2.2.2.4 Reactions to Open Courses

(a) Student reactions

The majority of authors reported favourable student reactions. Students found the courses interesting (10, 32, 51, 62, 70, 130, 138, 149), liked the greater sense of involvement (51, 99, 128), liked to be able to organise (128) and choose (149) their own experiments and enjoyed making greater use of chemical instrumentation (32). In this type of open course the practical work seems more relevant to the students' work as chemists (43, 99) or electrical engineers (128).

In Parlett's study (128) students found that in doing 'projects' they drew on their previous knowledge and that the 'project' integrates different areas of course work. Both Parlett (128) and Silberman (149) reported that students liked to be able to work at their own pace; they could work when and as much as they liked.

A number of negative student reactions are reported. Field (51) and Parlett (128) noticed that some students concentrated on their open or
or project work to the detriment of other work. Silberman et al (149) also commented that the open course tended to involve more work.

One problem that occurs in this kind of course is that some students, especially weaker students, have problems in selecting suitable experiments (32) and that they may become lost and bewildered during the first few sessions of the course (10, 115). Betteridge (10) made efforts to rapidly identify and help the weaker students and in Nechamkin's course (115) students had to present a bi-weekly progress report which must have helped staff to deal with this problem.

Dronsfield (43) also recognised the problem: "We noted that the occurrence of disappointing experiences increased as the calibre of students decreased." This problem, however, was avoided by allowing only the best students to do a four week project near the end of the course.

Betteridge (10) commented that the problem of experiments 'not working' ceases to exist in this kind of course: Students are encouraged to investigate the problem. On the other hand Dronsfield (43) saw the fact that success cannot be guaranteed as problematic and leading to student frustration. Betteridge makes a systematic effort to avoid this kind of frustration by encouraging feedback from the students about the experiments so that the poorer ones can be eliminated.

Chisholm (32) suggested "more rigorous guidelines are required to help the students overcome the bewilderment of the first few weeks". (He also noted that students had difficulties with the treatment of data and presentation of laboratory notebooks and reports.)
This problem was overcome by Venkatachelam et al (170) by introducing the students to the experiments by an initially more traditional experiment and then by guiding the students in the open part of the experiments with printed open-ended questions.

A further problem noticed by Parlett (128) was that students were unwilling to discuss their experiments with other students because they were afraid of revealing their ignorance about what they were doing. Quite the opposite effect was noted by MacDuffie (99) where "students sometimes had quite lively discussions amongst themselves in the planning stage". Field (51) also reports lively discussion amongst students during seminars.

(b) Staff Reactions

The staff reactions to open laboratory courses was reported to have been favourable in 4 courses (32, 90, 115, 120). It appears that favourable staff attitudes are essential for the successful running of this kind of course (see Section 2.2.2.2.3b).

2.2.2.2.5 Costs

It has already been pointed out that open laboratories tend to be more costly in terms of staff time.

Five authors commented on the cost of materials for this type of course. Three of these (115, 120, 138) found the open courses to be cheaper than the traditional ones which they replaced. This appears to be because more emphasis was placed on students designing experiments for themselves, rather than on learning how to use expensive pieces of
equipment. The two other courses were more expensive than the traditional ones which they had replaced. In one case this was because of the heavy use made of instruments which could lead to break down and costly repairs (17, 32).

2.2.2.2.6 Other Factors

In papers about both traditional and open courses there is little, if any, comment of the effects of different ways of organising courses within the overall laboratory styles. For example, none of the papers compare the effects of having students working individually or in pairs and few papers comment on the use of groups of students in practical work.

2.2.2.3 Project Work

It is apparent from the literature that project work is popular and well institutionalised. For example, Chambers (30) points out that "there is no doubt that project work arouses the interest and enthusiasm of students far more effectively than set experiments. On the other hand, the more traditional kinds of laboratory work that generally predominate in the first 2 years of degree courses are less popular (see Sections 2.2.2.1 and 3.3.3.2.1). It was therefore decided to concentrate this thesis on the first two years of Chemistry Laboratory Courses rather than on the final year. This survey of the literature of project work is therefore confined to a review of a few recent papers about project work.

2.2.2.3.1 Aims

In 1969 Jones (81) reported on the efficacy of chemistry degree courses as a preparation for work in industry and outlined a number of deficiencies in current degree courses, i.e. in report writing, verbal delivery, literature searching, statistical analysis, project planning and costing:
Amongst the suggested remedies for degree courses was a recommendation to include more project work.

The Nuffield Group for Research and Innovation in Higher Education (118) points out that project work is becoming increasingly more important as the shift towards aims in areas C, D and E continues. Hewton (69) points to two broad areas of aims which projects are used to achieve. His first group corresponds to aims in areas A and B and those aims in area C which might "loosely be termed as 'subject related aims'." His second group corresponds to aims in areas D and E and other aims in area C (i.e. more generalisable skills). He states that "although subject related aims may still predominate" (i.e. areas A, B and part of C), "particularly in some science and engineering courses, there is evidence of a growing trend which lays more emphasis on the broader educational and social aims" (i.e. areas D, E and part of C.)

Some aims which have been suggested as being important in projects are included in Section 2.1.4.2. It can be seen that the emphasis lies strongly in areas C, D and E.

2.2.2.3.2 Organisation of projects

In most universities project work is confined to the final year, a notable exception being the 'degree by thesis' in Molecular Science at Sussex University (45, 106), where project work lasts for 7 terms.

Typical methods of organising project work are described below:

Several months before students start their projects, they are able to choose one from a list of projects generated by the staff (69, 106, 30, 171, 41, 102). Students work in the research laboratories (106, 171) or sometimes in separate 'project laboratories' (102). Each student
is supervised by one member of staff with a second member of staff available for extra help if needed. Each student discusses the project with his supervisor and decides what he will do (106, 102). In some institutions he may be involved in the ordering and making of equipment (102).

Projects vary in length. In many institutions project work comprises all or a large part of final year laboratory work (102, 171, 41).

At the end of the experimental work each student is required to write a report of his work (30, 102, 41). In most institutions the students are assessed by their supervisors and by a second member of staff within the department. Within a department staff members are often familiar with a number of projects thus ensuring comparable standards (69, 106, 102, 119, 171). External examiners are also used to validate the internal standards (41). The criteria on which projects are assessed vary. Types of criteria often used are "experimental design, the planning of time and resources, the experimental technique, the analysis of data, the presentation of results, and what might be called the 'forward look', that is the ability to see where the project is leading and to make suggestions for further work" (119). Other qualities considered are resourcefulness, creative thinking, perseverance, initiative and where appropriate, ability to work in a team (119).

Assessment of these qualities is made on the basis of the report (30, 102, 41) and accompanying orals (102). In some institutions continuous assessment of a student's progress is also used (128, 69, 106). Methods of continuous assessment include the use of log books, essays, literature surveys, and observation (106).
2.2.2.3.3 Problems with Project Work

(a) One reservation about projects has been that they lead to over-specialisation (30, 69). Where a project occupies the whole of the final year, skills, techniques and illustrative experiments which would previously have been taught in the final year either have to be fitted into earlier years or omitted.

In the 'degree by thesis' at Sussex (106) this problem was recognised at the outset and students were provided with a core curriculum which had to be studied.

(b) Another problem is that students must be sufficiently prepared for project work (121). Hewton (69) states that "some teachers ... perceive project work as not an isolated activity, but as the coalescence of several aspects of the course which have been deliberately created and directed with this end in view". For example one motivation for introducing open work in second year laboratory courses is to prepare students for the openness of project work.

At Sussex (106) students found it difficult to cope with the greater freedom given to them in both their learning activities, which involved little formal structure and required a substantial degree of initiative and independence, and in the organisation of their learning environment, which was relatively instructured. Also too little guidance was given about the nature of degree by their coursework.

After the first year of running the degree by thesis it was therefore found necessary to provide students with more structure and support.
This was provided "in terms of suggested programmes of work as well as a greater degree of discussion, advice and feedback from the students' advisors. Students would develop report writing techniques through termly research reports". It was also found that there were times when the research seemed to be making little progress and at these times "supervisors played an important role in being sensitive to the students' progress and difficulties".

(c) Hewton (69) mentions that finding suitable projects can be a problem and Mansell (102) points out that in some projects the supervisor has not thought sufficiently about the sophisticated apparatus needed. This can lead to students needing an excessive amount of help when using the apparatus and to considerable delays waiting for the apparatus to be built in the workshop. Similar comments are made by Ogborn (121).

(d) Mansell (102) points to the central role of technicians in the success of projects. He says that "an important aspect is that the technicians understand the aims of the projects and in a real sense are involved in the learning process going on in the laboratory".

He also points out that the technicians serve both the departments research activities and student projects. This means that sometimes research work is slowed down, but this problem was not serious.

(e) Courtis (35), a student on the degree by thesis course at Sussex, says that projects are difficult to correlate with the lecture course. On the other hand Waddington (171) comments that students "find the chemistry 'fitting into place' as they apply chemical principles which
(f) Courtis (35) also commented that students tend to become too involved in project work to the detriment of other aspects of their lives and Downie (41) and Ogborn (121) pointed to the need to sometimes curb students' enthusiasm so that students see their project work in the correct perspective with other work.

(g) Another problem with projects is that they try to foster qualities which have not previously been included in courses; qualities which are less easy to define precisely such as creativity, individuality etc (see Section 2.1.4.2). This has meant that new methods of assessment have had to be developed (see Section 2.2.2.3.2). Mansell (102) found that because new methods of assessment were being used students only seemed to have the vaguest idea of what was being assessed. Black et al (119) suggest that "there may be value in exploring a 'contract of expectation' with a student at the start of a project. Supervisor and student can discuss the stages through which a project is expected to pass and the criteria that will be used to assess the stages".

Harding (66) carried out a survey of project work in three science and technology departments and concluded that the necessity for the assessment of projects had an overriding effect on the project as a learning situation. The initial phases of scientific method, i.e. 1) identification and recognition of a problem; 2) construction of a hypothesis and creative inclination; 3) deduction of an experiment to test that hypothesis, were rarely undertaken by students because to quote one of his respondents 'the student would get very
little done'. The student would not have a product available to be assessed.

The work the students do carry out is also influenced by assessment. For example, students rarely work in pairs because of the difficulties this would cause for assessment. Harding also maintains that "the pressure of grading, the need to produce a product, is bound to reduce the chances of students being faced with decision-making since both students and faculty will be concerned to limit the experience to yield a suitable product".

Downie (41) comments that projects involve the staff in extra work but says that there are no shortages of lists of projects submitted to the students because lecturers enjoy supervising them.

2.2.2.3.4 Overall reactions

In spite of these problems the overall reactions of both staff and students, reported in the literature, are overwhelmingly favourable. Waddington (171) comments on the enthusiasm of students for project work. He goes on to say, "Many of us (i.e. the academic staff) find the projects a most enjoyable experience.... We have the pleasure of seeing students working beyond their own expectations and in seeing them appreciate chemistry in a fresh perspective and finding a real sense of achievement."

Chambers (30) and Downie (41) also found that projects aroused students' interest. This was born out by the evaluations of students' opinions carried out by Mansell (102) and Mathias (106) and by opinions
collected by Ogborn (121). Courtis (35) thought that the 'degree by thesis' produced original thinking, initiative and independence and was a good preparation for a PhD student and Mathias (106) found that students thought that the 'degree by thesis' course provided a better and truer reflection of a student's ability and potential than the traditional course.

Mansell (102) reports that "the technicians noted a marked increase in the maturity and confidence on the part of the students which they ascribed to the experience of tackling and overcoming the design and experimental problems in projects". He also reports that in interviews students said that they felt "that they were experiencing a real-life situation in physics, learning what research was like, troubleshooting, having responsibility for organising both their time and available resources."

In conclusion it appears that the openness of projects has led to a number of problems (Section 2.2.2.3.3 a, b, d, e, f, g, h) but it is this openness which is the essential feature of project work which students enjoy and which leads to the achievement of many aims in areas C and D (Section 2.2.3.1)

2.2.3 Alternative ways of organising traditional courses, open courses and project work.

Within the styles of laboratory courses described in the preceding sections a number of different teaching methods and ways of organising the laboratory are used. This section deals with the integration of laboratory and lecture courses, the use of group experiments, the use of audio-visual aids and computers and the effects
2.2.3.1 Integration of Laboratory and Lecture Courses

The integration of laboratory and lecture courses is difficult. As a result few papers have appeared describing such courses.

Barrett and Blake (6) describe a course in which laboratory and lecture courses were integrated. 'The guiding theme in constructing the course was that at every point in the development of the subject the most appropriate teaching activity would be used.' The course was a short one and it was found necessary to re-timetable the course into two complete days. This was longer than the previous time allocation for the lectures and laboratory work for the course. The methods of teaching used included live demonstrations, traditional quantitative experiments, problem solving and discussion groups: a conscious effort was made to break down the passive role of the students.

In addition to the extra time devoted to the course the student to staff ratio of 8:1 was much more favourable 'than in circus laboratories where the ratio is closer to 25:1 or 12.5:1 if research student demonstrators are used.

The students who did this course achieved a mean mark of 18% above that of a comparable control group doing the conventional course, in problem types of questions. Students liked the integrated course because they were able to use freshly generated results in both lecture theatre and laboratory. They also liked the greater degree of involvement due to the less passive role of the students, and the generally higher level of interest which had resulted.
It is not clear from this study whether the improvement in both student learning and attitudes is due to the increased time given to the course, the improved student to staff ratios, the problem-solving nature of the course or to the integration of theory and practical. It is clear, however, that in order to achieve an integration of theory and practical work, a complete reorganisation of both the timetable and teaching methods was needed. On a longer course integration of theory and practical work would be more difficult to achieve.

2.2.3.2 Use of group work in the laboratory

Students usually work in groups under the supervision of a member of staff. The group meets at the beginning of the experiment and it is decided what each student should do. At the end of the experiment the group meets again in order to discuss the results and conclusions of the experiments after which the students are required to write an account of their own work and that of the group (51, 6, 50, 11).

Group experiments have been used:

(1) as a method of generating data more rapidly (6) and in order to familiarise students, indirectly through the group experience, with a wide range of apparatus and techniques (11, 51);

(2) in order to promote accurate recording of observations and conclusions and to promote communication and discussion amongst members of the group (11, 51). Field (51) found that in seminars oral contributions of students started off very hesitantly but rapidly improved as a result of ruthless criticism
by student peers. He found the powerful motivators of students were their efforts to try to avoid losing esteem amongst their peers.

Student reactions to group work were favourable in three of the four courses (51, 6, 11). Field (51) and Ogborn (121) report that the students enjoyed the greater involvement. Biersmith et al (11) report that students appreciated the rapid generation of results. They also liked the security afforded by the group; there were other people with whom to share the successes and failures of the experiments and there were always other people to turn to if help was needed.

Biersmith et al (11) also report a differential effect of the achievement of students in a written examination on the practical work. Poorer students benefitted from working in groups whilst better students did worse than when working individually.

Some problems with working in groups were reported by Biersmith et al (11): some students had difficulties getting on with other students in the group. Fentem (50) reports that staff and students were unenthusiastic about the course. This perhaps stems from the size of the groups, i.e. 12 per group, which must have made informal discussions more difficult than in other courses. The only course with comparably sized groups was that of Barrett and Blake (6), but in this course discussions appear to have been limited to drawing together the results of different experiments and were lead and closely guided by staff. In Fentem's course (50) the emphasis was much more on students presenting and defending their results and conclusions.
In summary, groups appear to be useful for the rapid generation of results, familiarising students with a wide range of laboratory techniques and apparatus, for promoting skills in report writing and oral communication and for promoting discussion which is particularly beneficial to the understanding of weaker students.

2.2.3.3 Use of Audio-Visual Aids and Computers in the Laboratory

Audio-visual aids have been used in the laboratory to introduce experiments (74,137), to teach basic practical skills and techniques and in order to completely replace experiments (36). Computers have been used to replace the tutorial role of teachers and also to completely replace experiments (137, 5, 38, 110, 85).

2.2.3.3.1 Use of audio-visual aids and computers to supplement laboratory instruction

An example of the use of audiovisual aids to supplement laboratory instruction is the use of videotapes for teaching practical skills and techniques. Videotapes have been introduced for a number of reasons:

(1) To save staff and demonstrator time so that they can give more individual attention to students (22, 76, 137, 144, 150, 172).

(2) To produce demonstrations of a better quality than those which they are replacing (10, 74, 127, 172, 150) because they are more carefully prepared. Howland (74) points out that when demonstrators are required to give a demonstration repeatedly the
quality of the demonstration tends to fall. It is also pointed out by Betteridge (10), Simpson (150) and Howland (74) that the camera is able to focus on small details that are difficult to see in a live demonstration.

(3) To offer a service to the students that is more flexible; students are able to see videotapes when and as often as they wish (22, 75, 76, 150, 172).

Kempa and Palmer (85) have shown that videotapes are superior to written instruction for teaching practical skills and in a recent systematic study of staff and student opinions (172), it was found that both staff and students judged videotapes to be an effective medium of instruction for practical skills and techniques. It was also found that videotapes which are produced in one institution can be used in another, thus opening up possibilities of more cost-effective use of videotapes.

Computers have also been used to supplement laboratory instruction, using them to revise theoretical material related to experiments (4) and using them in a tutorial mode (5, 38, 4, 111). For example, in the Calchem programme in the U.K. (5) computers are used to guide students in the planning and evaluation of an experiment, emphasis being on the decisions made in setting up a viable laboratory experiment. They are also used to assist in the interpretation of spectra and in problem solving.
2.2.3.3.2 Use of audio-visual aids and computers to replace laboratory experiments

Coyle and Servant (36) describe the use of film to replace laboratory experiments. The students were shown films describing a research project about the preparation of compounds of the inert gases. They then discussed it in small groups, were shown the film again and made notes of apparatus, reaction conditions etc and then wrote up the experiment. The students were thus able to see the scientific method in use and to criticise the practical exercises. The emphasis of this 'practical work' was therefore shifted from actual practical preparative work to scientific method and critical understanding.

Computer simulations have been used to replace laboratory experiments (5, 38, 110, 154, 4). Snadden and Runquist (154) point out that simulated experiments direct the emphasis away from teaching manipulative skills towards the manipulation of data and allow students to vary the experimental parameters beyond the physical time limits of the laboratory. The computer also makes it possible for the students to participate in the planning and design stage of the experiment, time is saved, experiments do not have to be performed in the laboratory, thus saving laboratory space and finally experiments do not have to be done during the laboratory time and can therefore be more closely integrated into the theory course.

2.2.3.4 Personal Teaching Styles

Few studies have been reported of the effect of an instructor's personal teaching style in the laboratory. Uricheck (169) has studied, by means of observation using the Flander's system of interaction analysis, the
effect of direct and indirect teacher influence on students working in the laboratory. He found that students performed best in written examinations and performance tests if they were allowed more freedom (indirect influence) in the first half of the course followed by more direct instruction in the second half of the course. He thought that the initial freedom to discover and clarify learning goals decreased students' dependence on the teacher and developed in them the habit of thinking through the problem on their own initiative.

2.2.4 Alternative Laboratory Styles

2.2.4.1 Alternatives to traditional laboratory courses

A small number of papers have been written describing courses which attempt to achieve similar aims to traditional courses i.e. aims mainly in areas A, B and parts of C.

2.2.4.1.1 The audio-tutorial approach

The audio-tutorial approach is an individualised system of instruction in which students are guided through an integrated sequence of theoretical and practical work by means of audio-tapes. This approach was first introduced by Postlethwait (134) in 1961 for a biology course and similar approaches have since been reported in microbiology (40) and biochemistry (58). Postlethwait claimed that using the audio-tutorial approach better instruction could be given with equal or fewer staff and less space than with conventional courses, costs were reduced for equivalent levels of instructions, grades and student interest increased at all levels, there were more opportunities for staff-student contact, the students were able to engage in an enquiry
approach and students of varying abilities were catered for.

2.2.4.1.2 The Keller Plan

The Keller Plan is another method of individualised learning. The course work is broken down into units containing details of the objectives of the units and details of the work to be done. When the student thinks he has achieved the objectives of the unit he takes a test and if he passes proceeds to the next unit. If he fails he has to spend more time studying the unit and then takes another test.

Laboratory courses possessing most of the features of the Keller Plan have been described in the literature (148, 27) but little information is included describing the effectiveness, the advantages or the problems of these courses.

2.2.4.1.3 Self-service laboratories

The 'laboratory library' and 'corridor laboratory' have already been mentioned in Section 2.2.1 (Fowler, 53).

On the basis of the M.I.T. 'corridor laboratory' a 'self-service' laboratory course was designed at the University of Surrey (131). A group of 10 short experiments orientated to teach specific aims, were designed to take an hour each to complete and were streamlined so that no setting-up or adjusting of apparatus was required. The experimental scripts were programmed and spaces were left for results so that no writing-up was necessary.
Responses to a questionnaire indicated that the students generally approved of the streamlining of experiments, they liked the structuring of the experimental scripts and the feature of no writing-up and they felt that their time was used efficiently.

2.2.4.2 Unit Laboratories

A unit laboratory is a system of instruction in the laboratory which is flexible and can be used to achieve aims normally achieved in traditional laboratories, open laboratories and to a limited extent projects.

Black and Whitworth (12) describe a unit laboratory as having the following features:

(1) The body of students on the course is divided into smaller groups, each passing from one unit to another as the year proceeds.

(2) In each unit laboratory, a teacher is given sole responsibility for looking after the small groups of students for a few weeks, during which time he is free to arrange their work in the laboratory in the way he judges is best.

(3) His laboratory will be connected with a specific theme and he must consider the educational aims that can be reached in an experimental study of that theme and the patterns of goals and activities which will help his student group to attain them.

The unit laboratory is thus based on the concept of a member of staff
providing an integrated coherent learning sequence about a particular theme. Black and Whitworth in an evaluation of the unit laboratories reported very favourable staff and student reactions. Davies and Penton (37) also evaluated a unit laboratory. They found student reactions to be overwhelmingly favourable. The two most common reasons for liking the laboratory course were:

1. the feeling that they were actually understanding and learning the material presented.

2. the integration of theory with practical. Many students appreciate the opportunity to immediately apply newly learnt theoretical knowledge in a practical situation and to construct immediately useful theoretical models from the data. Ogborn (121, Section 6.5) points out that the sequential nature of work within a unit means that students are studying the same work at the same time and so group discussions can be used to enhance understanding of the theory.

One drawback reported by Black and Whitworth (12) was that more staff were needed for teaching (a student to staff ratio of about 12:1). Davies and Penton, however, showed that postgraduate demonstrators could be used on such a course as well as academic staff, thus reducing the load on academic staff. In a later report of this course Ogborn (121, Section 6.5) states that the whole of this course is now run by postgraduate demonstrators and that the unit laboratory is now seen much more as 'a convenient organisational method for making proper use of graduate demonstrators and providing them with an excellent opportunity to do some good teaching'.
Ogborn (121, Section 8.4) points out that unit laboratories are better suited to large departments where there will be sufficient numbers of students for it to be worthwhile developing the units, but warns about the dangers of staff becoming bored if they are required to teach the same unit, year after year.

2.2.5 Some Conclusions

As a result of the literature survey it was decided not to study project work.

It can be seen from a study of different laboratory styles in the literature survey that many important aspects of laboratory courses in current use remain undocumented. None of the papers surveyed includes a study of the effect of using pairs in the laboratory and there is little information about the use of groups. Most of the papers are concerned with traditional or open laboratory courses in which students work individually and which are generally not closely integrated with the theoretical courses. The papers about traditional courses are mainly critical whereas papers about open courses tend to limit themselves to the advantages of such courses.

In order to try to increase the educational effectiveness of the use of laboratories, I therefore felt that two kinds of information would assist course organisers in choosing appropriate methods of instruction in the laboratory and in modifying existing methods of instruction:

Firstly, basic general information about what goes on in undergraduate chemistry laboratories throughout the U.K. should be sought: information
such as the extent to which traditional and open courses are used, what they are used for, the extent to which groups and pairs are used, staffing ratios, etc. This would enable course organisers to compare courses which they run with other courses and to have access to basic information about alternative methods of organising laboratory courses.

Secondly, detailed information about different styles of courses, what they were trying to achieve, how they went about achieving the aims and the factors that were important in influencing the educational effectiveness or otherwise of different styles of courses, should be sought. This would give course organisers insight into laboratory courses and would suggest methods of improving them.

The areas in which the research could concentrate were very wide since little information was available about many aspects of laboratory work.

The next section in this chapter surveys methods of evaluation which were felt appropriate for gathering this type of information.

2.3 Research Strategies

Isaac and Michael (77) describe four types of education research:

1. descriptive research
2. true experimental research
3. quasi-experimental research
4. action research.

Descriptive research includes 'survey studies'. The purposes of these
"(a) To collect detailed factual information that describes existing phenomena.
(b) To identify problems or justify current conditions and practices.
(c) To make comparisons and evaluations.
(d) To determine what others are doing with similar problems or situations and benefit from their experience in making future plans and decisions."

These purposes coincide with the first type of information to be sought about undergraduate chemistry laboratories, mentioned in the previous section. (Section 2.2.5). For this reason it was decided to carry out a survey of undergraduate chemistry laboratory courses throughout the U.K. (see Chapter 3).

True experimental\textsuperscript{1} and quasi-experimental research (also described by Borg and Gall (18) emphasise pre-specifying the objectives of teaching, rigorous management of experimental variables and conditions either by direct manipulation or by randomisation (the control of variables is less rigorous in quasi-experimental research), the use of control groups and the administering of tests which would measure the levels of achievement of the various objectives.

Pace (126) thinks that these methods of research are suitable when the unit to be evaluated is a small unit; small in size, limited in scope.

\textsuperscript{1}This research design is called 'pre-ordinate evaluation' by Stake (159) and the agricultural botany model by Parlett and Hamilton (129).
and short in time, such as a half-hour film, a specific unit of instruction in a single course, a particular method of teaching, or a programmed text.

It was decided that these types of research were unsuitable for the present study because:

1. The aims and objectives of laboratory courses are generally ill-defined. Before the experimental research design can be used it is necessary to discover the aims of laboratory courses and break them down into behavioural objectives. The survey described in Chapter 3 is designed to elicit the aims of laboratory courses as the first step towards stating laboratory objectives in behavioural terms.

2. Too little is known about the teaching and learning situations. Many important factors affecting teaching and learning in the laboratory have not been explored. Before manipulation of variables can commence they must be elucidated.

3. The lack of information about teaching and learning in the laboratory also precludes setting up a pre-specified research plan. An approach which is exploratory and can be moulded to pursue issues as they emerge, is needed.

4. Undergraduate laboratory courses usually contain relatively small numbers of students which makes the use of control groups, which would have significant numbers of students, very difficult.
When the unit to be evaluated is large, complex and or long duration, such as a school system or a total institutional programme Pace (126) maintains that:

(1) the treatment (unit to be evaluated) 'cannot be clearly and explicitly defined because it is not in fact a unitary phenomenon but is, instead, made up of many units interacting with one another in varied ways and having varied purposes;

(2) gross differences between treatment can sometimes be found and compared, but control groups in the usual experimental sense do not exist;

(3) random assignment of subjects to treatments is impossible except occasionally in some small segment or limited part of the treatment;

(4) treatments constantly undergo change'.

'Under these conditions, relevant evaluation:

(1) must consider a broad range of educational and social consequences;

(2) should never be limited or confined to the stated objectives or intended effects of the programme or treatment;

(3) should look for but may not always find contrasting conditions in natural settings for comparative analysis;
Of the four alternative methods of research proposed by Isaac and Michael (77) this is closest to action research which is described as "practical and directly relevant to an actual situation in the working world". "It provides an orderly framework for problem-solving and new developments that is superior to the impressionistic, fragmentary approach that otherwise typifies developments in education. It also is empirical in the sense that it relies on actual observations and behavioural data, and does not fall back on subjective committee "studies" or opinions of people based on past experience." It is "flexible and adaptive, allowing changes during the trial period and sacrificing control in favour of responsiveness and on-the-spot experimentation and innovation."

The next two sub-sections examine research strategies that are suitable for gathering the type of information described in Pace's (126) large scale studies. They include a number of closely related research paradigms variously described as illuminative evaluation, anthropological evaluation, field research and participant observation.

2.3.1 Illuminative Evaluation - The Theory

2.3.1.1 Overall Philosophy

Parlett and Hamilton (129) have described the advantages of illuminative evaluation over traditional evaluation, i.e. experimental research described in the previous section. Illuminative evaluation as well as examining instructional systems also considers the wider contexts or
'milieu' in which the programme functions. The learning milieu is affected by and affects the instructional system, e.g. the learning milieu has an effect on the attitudes of staff and students which may affect their reactions to the instructional system. Snyder (155) describes the over-riding effects of the learning milieu on which students study and why. Parlett and Hamilton (129) state that illuminative evaluation is a research strategy that aims to be adaptable to the situation being studied. The methods used are defined by the problem being studied. No method is used exclusively or in isolation; different techniques are combined to throw light on a common problem.

Schatzman and Strauss (146) describe a similar approach: The researcher 'sees any method of inquiry as a system of strategies and operations designed, at any time, for getting answers to certain questions about events which interest him'. Parlett and Hamilton (129) outline three stages in illuminative evaluation: (1) observe
(2) inquire further
(3) seek to explain

In the first stage the evaluator becomes knowledgeable about the scheme. At the second stage questioning is more focussed. The third stage consists of seeking general principles underlying the organisation of the programme; spotting patterns of cause and effect within its operation and placing individual findings within a broad explanatory context.

Parlett and Hamilton (129) point out that as an evaluation moves from the exploratory observations to further inquiries, it focusses progressively on important issues, thus narrowing the width of the
study. This allows the evaluation to study important issues in depth, thus giving a greater understanding of them.

Brophy et al (24) emphasise the need to define the 'critical audiences' for the evaluation and the types of information that they would desire. They state that before the evaluation 'the evaluator and client should be able to define those variables which they believe have an important influence on the specific situation being evaluated' but add that as the evaluation proceeds the relative importance of the variables may shift and new variables may be delineated. Once the important variables have been identified the evaluator is able to decide likely sources of information and what evaluation tools to use.

Becher (9) proposes a similar model of investigation divided into four stages:

1. the selection and definition of problems, concepts and indices;
2. the check on the frequency and distribution of phenomena;
3. the incorporation of individual findings into a model of the organisation.
4. presentation of evidence and proof.

In the first stage the researcher notes that 'a certain event occurred once, or that two phenomena were observed to be related in one instance; the conclusion says nothing about the frequency or distribution of the observed phenomenon'. The researcher uses his data 'to speculate about possibilities, to make provisional hypotheses.'
Smith and Pohland (152) emphasise that it is important at the beginning of an investigation to make an 'initial problem statement' but that during the investigation the problems will evolve and be redefined. They suggest that previous research could be used to help define the initial problem statement.

(2) In the second stage the researcher attempts to quantify the data although the exigencies of the field situation sometimes limit this. This is similar to Parlett and Hamilton's second stage where the researcher attempts to delve deeper into a particular area of interest.

(3) In the third stage the researcher constructs a theoretical model and 'seeks greater accuracy by successively refining the model in the light of new evidence. (This is similar to Parlett and Hamilton's third stage.)

(4) Becker adds a valuable fourth stage of final analysis and presentation of results. 'The final systematic analysis carried on after the field work is completed, consists of rechecking and rebuilding models as carefully and with as many safeguards as the data will allow. For instance, in checking the accuracy of statements about the frequency and distribution of events, the researcher can index and arrange his material so that every item of information is accessible and taken account of in assessing the accuracy of any given conclusion.'

Webb et al (173) and Parlett and Hamilton (129) emphasise the concept of 'triangulation', cross-checking data from a number of sources. Smith and Pohland (152) have extended this concept in order to assist in
more generalisable theory building. As well as using a number of
different methods of obtaining information from a wide variety of
people and sources, they examine a diversity of variables in a number
of different situations. The deliberate widening of the number of
variables and situations enables theories to be explored in a number
of different settings.

Kemmis (84A) describes how an understanding of a programme is
gained by observing the programme and developing private theories
about 'emergent themes'. The programme is observed using insights
found useful in past situations and observation categories such as
Stake's matrix (Fig. 2.1) or check lists such as those suggested by
Brophy et al (24) and modifying these to fit the present situation.
'In a short time one has a view of some stability, the result of
emergence of significant features as they are drawn out by the
observation categories one brings to bear on the situation.' The
integration of these significant features may produce a crude 'theory'
of the situation.' These tentative 'theories' are evolved further by
discussing them with the participants and obtaining further relevant
information.

2.3.1.2 Data collection

Parlett and Hamilton (129) suggest the following methods of data
collection: observation, interviews, questionnaires and tests and
finally examination of documentary and background sources. Smith and
Pohland (152) use similar sources but put more emphasis on keeping
field notes of observations and interpretations.
Stake distinguishes 3 types of data: antecedents, transactions and outcome data.

'An antecedent is any condition existing prior to teaching and learning which may relate to outcomes' e.g. a student's aptitude or previous experience.'

'Transactions are the countless encounters of students with teacher, student with student, author with reader, parent with counsellor - the succession of engagements which comprise the process of education.'

Outcomes include 'abilities, achievements, attitudes, and aspirations of students resulting from an educational experience. Outcomes, as a body of information would include measurements of the impact of instruction on teachers, administrators, counsellors and others'.

Antecedents, transactions and outcomes are included in both a descriptive and judgment matrix. The descriptive matrix includes what was intended to happen (intents) and what actually did happen (observations). 'Judgmental statements are classified either as general standards of quality or as judgments specific to a given programme.'

Within the descriptive matrix the evaluator should look for contingencies between antecedents, transactions and outcomes and for congruence, or lack of it, between intents and observations (see Fig. 2.2).
## Figure 2.1 Data Matrix

<table>
<thead>
<tr>
<th>Intent</th>
<th>Observations</th>
<th>Antecedents</th>
<th>Transactions</th>
<th>Outcomes</th>
<th>Judgments</th>
<th>Description Matrix</th>
<th>Rationale</th>
</tr>
</thead>
</table>

### Judgement Matrix

- Standards
- Intents
- Observations
- Antecedents
- Transactions
- Outcomes
Figure 2.2 Descriptive Matrix
in the sense that evaluation is the search for relationships that permit the improvement of education, the evaluator's task is one of identifying outcomes that are contingent upon particular antecedent conditions and instructional transactions... Whenever intents are evaluated the contingency criterion is one of logic... Evaluation of observation contingencies depends on empirical evidence.'

The evaluator should also examine the reasons for and the effects of non-congruence between 'Intents' and 'Observations'.

As well as collecting information for the descriptive matrix an evaluator can obtain information about the standards that individuals use as a basis for judging the instructional programmes. These standards 'vary from student to student, from instructor to instructor and from reference group to reference group'. Stake (157) states 'that to understand education one needs to understand what people expect from education'. Judgment data such as 'personal value commitments, educational aims, goals, objectives, priorities, perceived norms and standards' help to explain 'intents' and 'observations'. For example, 'the evaluator should consider not only how education objectives manifest themselves in teaching and learning, but also how these objectives embody the aspirations and discontents of the people involved'.

It is emphasised by Stake (156) that in a single evaluation it would be impossible to collect data for all the boxes in the matrix. Scriven (147) argues that it is the evaluator's responsibility to make judgments about the worth of a programme whereas Stake (156) suggests the alternative of gathering objectively, independently of the evaluator's
opinions, the opinions or judgments of 'persons of special qualification'.

Kemmis (84A) feels that it is sufficient for an evaluator to furnish a 'representation' or a 'surrogate experience' of an instructional programme. 'Once furnished with an adequate representation of the programme ... clients or audiences ... may be able to formulate their own judgments of its worth. In such a situation, the audience of the 'evaluation' will be the real evaluators.'

Kemmis (84A) states that there are two sorts of situation in which such representations will be particularly useful: 'When an interested audience cannot directly experience the programme and cannot accurately judge it without some surrogate experience 'of it', or when participants are too closely involved with the programme to be able to step back from it and see it in perspective.

Stake (159) describes how decisions are made about the kinds of information to be collected. He advocates the concept of responsive evaluation. 'An educational evaluation is responsive evaluation:

1. if it orients more directly to programme activities than to programme intents,

2. if it responds to audience requirements for information and

3. if the different value-perspectives of the people at hand are referred to in reporting the success and failures of the programme.'

The evaluation should therefore concentrate on issues arising out of a study of the programme's activities and the issues which will be of most assistance to members of the audience in their decision making capacities.
Scriven (147) proposes the terms 'formative' and 'summative' evaluation to distinguish evaluations which collect different types of information. Formative evaluations supply information which is useful in the development of an instructional programme whereas summative evaluations collect information which is suitable for making comparisons and judgments with respect to alternative instruction programmes. Stake (158) develops the distinction between formative and summative evaluation by defining them in terms of utility. He points out that formative evaluations are appropriate to programme developers whereas summative evaluations are appropriate to programme clients.

2.3.1.3 Report writing

The final stage of the evaluation is finding a suitable way of portraying the programme and the evaluator's understanding of it to the respective audiences. (Emphasised by Brophy et al (24), Stake (159), and Parlett and Hamilton (129)). Kemmis (84A) recognises that judgments are made by the evaluator in the choice of observation categories and 'emergent themes' but unlike Scriven (147) feels that the evaluator should simply portray the programme leaving the audience to judge its worth and extract information relevant to their decision making needs.

Similarly Smith and Pohland (152) emphasise a descriptive account. They feel that (1) in order for theories to be generated from the data a 'thorough going descriptive account' is necessary. (2) 'The utilisation of theory for the solution of practical problems in education is very important. In order to be able to generalise "theories" that have been generated one needs to know the context out of which the concepts came.
'When an investigator begins his work, he does not know the full range of 'theoretically relevant concepts'. He must therefore initially cover a wide area to enable him to concentrate on theoretically relevant concepts later.' (4) Careful description of a study enables it to be integrated more easily with data from other studies. Smith and Pohland (152) like Kemmis (84A) collect formative information but they also emphasise the generation of 'theories'. They state that 'theories' generated in such studies tend to be of limited generalisability but will be good hypotheses for testing in other situations. Although Smith and Pohland (152) feel that it is important to write a descriptive report in an interesting and lucid style, because of the summative aspects of their work they tend to be writing for a less closely defined audience than Kemmis (84A).

The presentation of the results in a form which will allow the reader to check their validity is a problem which Becker (9) suggests can be overcome by presenting the evidence as it came to the attention of the observer during the successive stages of his conceptualisation of the problem and by presenting the inferences and conclusions drawn from the data.

Schatzmann and Strauss (146) point out that the communication and discussion of reports can help to establish the validity of findings. The researcher can test major propositions against the experience and understanding of his host and of other researchers. Different researchers looking from different perspectives may build up different conceptual frameworks but these should not contradict but supplement or complement the findings of the research.

In this thesis formative and summative information has been sought. The
emphasis is on portraying laboratory courses and gaining a greater insight of them so that course organisers will be able to judge the worth of different types of laboratory courses for different purposes.

2.3.2 Illuminative Evaluation - The Practice

Illuminative evaluation requires methods of data gathering which will enable the evaluator to identify and define the issues in a course which have an important effect on the success or otherwise of the course and to explore new issues as they emerge. In an illuminative evaluation the amount of information that can be collected is extremely large but resources are always limited. Decisions, therefore, have to be made about the methods, or combination of methods, of data collection which will yield the most relevant and reliable data. This section examines different methods of data collection.

The methods of data collection have been divided by Parlett and Hamilton (129) into four areas.

(1) Questionnaires and test data

(2) Interviews

(3) Observation

(4) Documentary and background information

2.3.2.1 Questionnaires and Test Data

Oppenheim (124) describes a wide range of questionnaires ranging from 'closed' questionnaires with a choice of fixed responses, to questionnaires which include 'open' questions which allow respondents to express themselves in their own words.
Closed questions have the advantages that they are easier and quicker to answer and quantification of data is straightforward: More questions can therefore be included in the questionnaire.

Closed questions have the disadvantage of loss of spontaneity and the possible introduction of bias by forcing respondents to choose a particular alternative. Closed questions are cruder than open questions in that there is no opportunity to probe and it is possible to lose rapport with the respondents if they feel that the choice does not do justice to their own ideas.

Three types of questionnaire have been used in the present study:

1. Questionnaires designed to elicit specific information about prespecified areas of interest.

2. Questionnaires used for initial probing in order to raise and examine important issues and to study them in more depth as the evaluation proceeds. These questionnaires contain a large proportion of open questions.

3. Questionnaires designed to obtain quantification of the qualitative opinions expressed elsewhere in the study.  

In the first category two types of questionnaire have been designed for use in undergraduate laboratory courses:

(a) aims questionnaires

(b) feedback sheets

Boud (19) modified a questionnaire designed by Lee (94) in order to

1. Obviously all three types of questionnaire could be used simultaneously.
elicited opinions of the importance of different aims of laboratory courses. A similar questionnaire has since been used by Johnstone and Wood (80).

Penton (131) in his study used 'feedback sheets' (short questionnaires) as a means of obtaining basic information about how well particular experiments were running in the laboratory so that the experiments could subsequently be improved. Knipe (87) has used similar feedback sheets at the New University of Ulster.

Both aims questionnaires and feedback sheets have been used in the present study.

The last two categories of questionnaires described above are situation specific and must therefore be designed for the requirements of each separate course.

2.3.2.2 Interviews

Oppenheim (124) points out that the greatest advantage of the interview is its flexibility. Interviewers can make sure that the respondent has understood the question and the purpose of the research and can probe and ask additional questions in particular areas of interest. Interviewers can also build up and maintain rapport with the respondents and keep the respondents interested and responsive until the end of the interview.

Parlett and Hamilton (129) state that structured interviews are convenient for biographical, historical and factual information while

1. See Chapter 4 for an example of a feedback sheet.
more open-ended and discursive forms are suitable for less straightforward topics.

Kahn and Cannell (82) say that 'the choice between open and closed questions should also be guided by the probable degree of structuring of the respondent's opinion on or experience with the topic'. If the respondent has well thought out ideas on the topic closed questions may be suitable but if 'the respondent's thoughts are less structured on the topic in question the interviewer must assist the respondent to recall order and perhaps evaluate his experience,' then open questions will be more appropriate. Open questions must also be used in exploratory studies when the researcher is in a poor position to formulate closed questions to match the respondent's experience, vocabulary and frame of reference. Becker (9) points out that volunteered information is a better indicator of preoccupations than information given in response to fixed questions.

Schatzman and Strauss (146) state that, at first, the researcher should regard the data obtained from interviews as a cumulative experience: the content of each interview or conversation gives form and substance to the next one. It may be necessary when using a variable interview schedule such as this, to return to former respondents if subsequent interviews suggest that the respondents were sources of information not previously given.

Oppenheim (124) points out that 'the interview situation is, however, fraught with possibilities of bias. The interviewer may give an inkling of her own opinion or expectations by her tone of voice, the way in which she reads the questions, or simply by her appearance, dress and accent. She may unwittingly influence the respondent by pausing
expectantly at certain points, by probing with leading questions, and by agreeing with the respondent in an effort to maintain rapport. Her own expectations and her selective understanding and recording of the answers may produce bias.'

Kahn and Cannel (82) suggest that instead of thinking about the adequacy of interviews as a means of measurement in terms of face validity, a better way of validating them would be in terms of convergent validity, i.e. the comparison of the interview data with data obtained from other measures which have already met the test of validity. This is similar to the concept of triangulation where different measures are validated against one another.

Kahn and Cannel (82) also discuss the techniques and skills of interviewing but these will not be discussed here.

2.3.2.3 Observation

Rosenshine (142) and Borg et al (18) describe 2 kinds of observation instruments: category systems and rating systems. Category systems can be used to count the number of times a particular objective behaviour is used and are generally 'low inference measures'. Rating systems can be used to evaluate behavioural constructs such as 'clarity of presentation' in terms of rating scales. Rating systems are high inference measures as the items examined lack specificity.

It is pointed out by Mitzberg (112) that in order to be able to use either category systems or rating systems the researcher must have some basic understanding of the issues under investigation. If observations were too structured initially, this could lead to an inability to develop
an understanding of things about which nothing is known initially.

Schatzman and Strauss (146) point out that it is impossible to observe the whole field and that research must therefore include some selective sampling with respect to times observed, localities observed, people observed and events observed. They suggest the use of 'observational notes', 'theoretical notes' and 'methodological notes' as an alternative to using category and rating systems:

Observational notes are statements bearing upon events experienced principally by watching and listening. They contain as little interpretation as possible.

Theoretical notes represent self-conscious controlled attempts to derive meaning from any one of several observational notes.

A methodological note is a statement that reflects an operational act completed or planned: an instruction to oneself, a reminder, a critique of one's own tactics. Schatzman and Strauss's method enables observation to be used in preparatory work to focus interest, even if little is initially known about the learning environment.

Schatzman and Strauss recommend four different modes of participant observation that may be used in different stages of the research:

(1) Passive presence: 'The field researcher is present in the situation but decides to observe passively. He does not enter into interaction with participants and avoids as much as possible obtruding himself into the event.' It is suggested that this method of observation is suitable for
early stages of the research but can be disturbing to the people being observed if maintained for any length of time.

(2) Limited interaction: 'The researcher engages in minimal clarifying interaction ... This type of activity has two distinct advantages: it gets at meaning, and it meets the expectations of the host insofar as the researcher is not only an observer, but is revealed as personable and interested.' : the host gains some idea of the purposes of the research.

(3) Active control: As well as observing 'the researcher engages in active conversation, not only posing general questions but provocative and challenging ones ... If well controlled this level of participant observation is very stimulating for researcher and hosts alike'.

(4) Observer as participant: 'The researcher is a full participant in ongoing activities while simultaneously his identity as a researcher is fully known.' This mode has the disadvantages that if the researcher's participatory activities are especially demanding of time and energy then the research work will suffer and that the foci and range of the researcher's attention are also affected.

Two factors have an important effect on the validity and reliability of observations (18):

(1) The effect of the observer on the observed;
observed bias.

Schatzman and Strauss (146) state that a researcher should try to
minimise the effects of his presence on the environment which he is
observing and that the researcher should persist with his
observations until 'in time his presence, eventually seen as no
threat, will become integrated and normalised'.

Borg and Gall (18) describe a number of ways in which the opinions of
an observer can affect his observations.

3.3.2.4 Documentary and background information

This includes minutes of committee meetings, funding proposals,
architectural plans and consultants' reports (129). Such data can
provide a historical perspective of the educational setting being
studied and may also indicate areas for inquiry.

Webb et al (173) describe a wide variety of 'unobtrusive measures'.

3.3.2.5 Combination of methods of data collection

Illuminative evaluation depends heavily on the researcher making
intelligent decisions about the issues to be investigated and the methods
of investigation, as the research is proceeding. It is this aspect of
illuminative evaluation that makes it a powerful tool for investigating
relatively unexplored areas but it is an aspect of illuminative
evaluation that can be biased by the subjective opinions of the
researcher. It is therefore important that data should be obtained
from a variety of sources and cross-checked (triangulation).
have included the use of essay-type questions, experts' judgments, interviews and case-studies, judgments by friends or co-workers, self-ratings and observed overt behaviour. Similar methods of validation are embodied in the illuminative evaluation paradigm described in Section 2.3.1.
CHAPTER 3

A QUESTIONNAIRE SURVEY OF UNDERGRADUATE LABORATORY COURSES IN CHEMISTRY
3.1 Introduction

This chapter describes a survey of chemistry undergraduate laboratory teaching in universities and polytechnics in 1975.

The survey was essentially a fact finding exercise. Little work has been carried out to find out what academic staff think chemistry laboratory courses are, and should be, trying to achieve, or to find out how staff go about achieving their aims. The survey was designed to obtain basic information in this area.

It will be seen that the information obtained in the survey serves two main purposes:

(1) It provides norms with which individual courses can be compared. For example, it is useful to know whether an individual course has an exceptional student:staff ratio. If the ratio was very high and the course still achieved its aims one would be interested to find out why the course was more efficient than others. Conversely, if the ratio was low one could reasonably expect it to be more successful than others.

(2) The information obtained is important for the development of laboratory courses. For example, it becomes clear, in this chapter, why the use of open or problem solving courses is restricted in spite of the fact that staff feel them to be educationally desirable.

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1 The literature describing the different styles and organisation of laboratory courses is reviewed in section 3.2 and the literature which surveys opinions about the importance of various aims for laboratory courses is included in section 3.3.
The main aims of the survey were therefore:

(1) To find out what aims staff who organise undergraduate chemistry laboratory courses were trying to achieve.

(2) To find out what aims they would like to achieve in an ideal situation.

(3) To determine the distribution of different teaching styles in laboratory courses at different levels and to relate these to the aims.

(4) To find out how the different styles of laboratory courses are organised and what learning resources (e.g. written material, people) are made available to the students.

(5) To find out how chemistry laboratory courses have changed in recent years.

(6) To relate the findings in (1) - (5) to one another.

3.2 A literature survey of the nature and organisation of laboratory courses in the U.K.

This section concentrates on studies of chemistry laboratory courses in the U.K. Studies of physics and engineering courses are also included for comparison because of the many similarities to chemistry courses in both aims and methods.
3.2.1 The nature of laboratory courses.

3.2.1.1 The amount of traditional, open or project work.

In 1966 (125) and 1972 (165) the major part of students' time in chemistry laboratory courses was spent doing traditional experiments in which they followed detailed duplicated instructions.

A similar situation was reported in physics courses in the U.S.A. by Kruglak (92A) in 1960 with 64.2% of the time in the laboratory being spent on 'conventional' laboratory work, 20.6% on partly free laboratory work and 1.6% on 'completely free' laboratory work.

The Ourisson committee (1966) (125) reported that students started to do some research in the laboratory, usually in the final year (19 out of 21 respondents) or only after completing their B.Sc. (2 out of 19 respondents). The amount of open work was limited with about two thirds of the respondents sometimes encouraging the students 'to employ methods of their own stipulation' whereas one third never used open work.

In 1972 Tietze (165) reported a similar situation in the first two years of a degree course. All the twelve departments visited except one used detailed duplicated instructions for all experiments. In one second year course only literature references were given and students had to obtain the necessary experimental instructions from these. Students generally had to work through a number of set experiments in a specified order in the first year whereas in the second year they usually had some freedom to choose experiments under guidance depending upon the availability of apparatus.
The main change between 1966 and 1972 was the introduction of research projects as the main or only practical work in the final year.

The more open-ended nature of practical work was also reported by Smythe (1973) (153) with at least 30% of universities and 25% of polytechnics offering open-ended experiments in the second year, and with students in 91% of the universities doing project work in the final year (84%) and/or during the vacation (7%). Project work has also been introduced in earlier years in a small number of institutions, e.g. New University of Ulster and University of Sussex (Eaborn 1970) (45).

Chambers (1972) (30) reports similar changes in Physics Laboratory courses. Between 1965 and 1972 only minor changes occurred in the first two years of the degree course but there had been a large increase in the amount of project work in the final year. In 1965 only 5 out of 38 university physics departments, as compared with 6 out of 8 C.A.T. physics departments, used project work throughout the final year. In 1972 two thirds of the physics departments in the U.K. followed this pattern.

A similar trend was reported in Lee and Carter (1972) (95) in Electrical Engineering. Two thirds of the respondents to a letter sent to 20 electrical engineering departments reported no substantial change in the patterns of laboratory work at the first year level, in the recent past. Many departments, however, had introduced project work in the final year and in some cases in the 2nd year.

There is clearly a trend for undergraduate laboratory courses to include more project types of work, initially in the final year but
increasingly in earlier years too.

3.2.1.2 Content

Tietze (165) reported a variety of ways of organising the content of the first year. Four out of the 12 institutions ran a Common First Year course with chemistry as one section of it. Others had preliminary courses for 2 or 3 terms followed by an Honours course that runs for five or six terms while the remaining departments have courses in the 3 main branches of chemistry. In 3 of the preliminary courses there was some integration between the different branches of chemistry.

In the second year there are courses in each of the three branches of chemistry in all departments usually followed by projects in the final year.

Tietze summarises the structure of the degree courses as shown in Table 3.1.

| TABLE 3.1 |
| ORGANISATION OF LABORATORY WORK |

| 1st year | Common course including 100 hrs. chem. lab. |
| or       | Preliminary course with 100 hrs. chem. lab. |
| or       | 60-100 hrs. chem. lab. for each branch either consecutively or concurrently. |

| 2nd year | 60-100 hrs. chem. lab. for each branch either consecutively or concurrently. |

| 3rd year | as 2nd year |
| or       | variable time for research projects. |
3.2.1.3 Report writing and assessment

In 1966 Ourisson (125) a full report was required on each experiment in 19 out of 25 departments. In addition in 24 out of the 25 departments there were compulsory practical examinations.

A very similar situation existed in Physics (29A) in 1964 with about 80% of the departments requiring a full report on each experiment, and with the further 20% requiring full reports on about a third of the experiments. In physics, however, only about one quarter of the departments held compulsory practical examinations in any one year of a course.

In 1972 (Tietze) (165) there was still a strong emphasis on report writing although some departments did not always demand full reports. Practical examinations had, however, almost completely disappeared and had been replaced by continuous assessment based on marks given for students' reports and the quantity and quality of products.

Smythe (1973) (153) confirms the substantial decrease in the use of practical examinations in chemistry degree courses with only 3 out of 44 (7%) university departments indicating widespread use of practical examinations. A further 22% only set practical examinations for below standard students or for special courses, whilst 71% did not use practical examinations at all. In the polytechnics 50% still had practical examinations.

3.2.2 Resources for laboratory work

3.2.2.1 Time allotted

The Ourisson committee (1966) (125) reported that in a chemistry degree
course students spent 970 hours in the laboratory out of a total teaching
time of 1470 hours (spent on chemistry) i.e. 68%. This is significantly
more than the 45% reported by Robbins (140) and the 43% reported by
Hale (63) for pure science courses, and more than 56% reported by
Chambers in 1964 (29A). Nine out of the 25 respondents in the Ourisson
(125) report thought that this was insufficient time whereas 16 thought
it was adequate.

In 1964 Chambers (29A) noted a trend towards a reduction in length of
physics laboratory courses.

In 1969, however, Jones (81) found that 20% of the professional scientists
included in his survey wanted the amount of practical work in degree courses
reduced. A similar finding was made by the Eaborn Committee (1970)(44)
who said that in spite of the substantial reduction in the amount of
practical work in chemistry degree courses, 25% of undergraduates thought
that too much time was spent on it whilst 4% disagreed.

In 1972, Tietze (165) reported a substantial reduction in the time
allocated to laboratory work with courses then containing between 500
and 900 hours.

Smythe's (1973)(153) figures are in substantial agreement with Tietze's.
The mean time spent on practical work during chemistry degree courses in
50 universities and polytechnics was 760 hours (standard deviation =
190 hours).
3.2.2.2 People

The Hale committee (1964)(63) reported that in science laboratory courses with classes of 10 and over usually more than one member of staff was present and with classes over 20, usually more than two members of staff were present.

It is clear from the findings of the Hale committee(63) that larger classes tend to have less favourable staff student ratios. A fall in class sizes was reported as courses proceed with 80% of the classes being over 20 in size in the first year, 67½% in other non-final years and 52% in the final year. It would, therefore, appear that student staff ratios become more favourable as the courses proceeded.

Chambers (1972)(30) reported that in Physics departments, as the laboratory course proceeds from year to year progressively less use is made of postgraduate student demonstrators and more of academic staff. This indicates a change in the quality of student to teacher contacts as well as a change in the amount of contact.

The distribution of student to staff + demonstrator ratios reported by the Ourisson Committee (1966)(125) is shown below:

| TABLE 3.2 |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| RATIO           | 5:1             | 10:1            | 15:1            | 20:1            | 25:1            | 30:1            | 40:1            | 50:1            |
| Number of       | Actual distribution | -              | 5               | 11              | -               | 2               | 1               | -               |
| respondents     | Desirable distrib. | -              | 8               | -               | -               | -               | -               | -               |

The overall mean student:staff + demonstrator ratio was therefore about 19:1.
More recent information is not available for staffing ratios in chemistry laboratory courses.

3.2.2.3 Materials

Written materials were supplemented by:

(1) Brief talks given at the beginning of a laboratory course. These were common in introductory courses and less common in later years (Tietze)(165).

(2) Audio visual materials. Three out of the 12 departments visited by Tietze used audio-visual materials, i.e. film loops in conjunction with audio tapes, video tapes and in one department a complete teaching aids room with books, programmed texts, model kits, calculators, film loops, slides, etc., was available.

Smythe (1973)(153) reported that in 34% of the universities audio-visual materials were in 'general use' in the laboratory and that a further 21% the use of audio-visual materials was in an experimental stage.

3.3 The survey: How it was carried out and analysed.

3.3.1 The design of the questionnaire and its distribution.

3.3.1.1 Pilot study.

During the spring term of 1975, sixteen members of academic staff in two university chemistry departments and one polytechnic were interviewed. The data from these interviews was used to design
section A of the questionnaire which classifies the style, the organisation and the teaching methods used in the laboratory courses. These three departments were excluded from the questionnaire-survey.

An aims questionnaire based on that of Boud (19) and on a list of aims appearing in the Nuffield Newsletter No. 3* (118) was used during the academic year of 1973 to 1974 as a tool for two laboratory course evaluations. Analysis of the results indicated that the wording of some of the aims was unclear and that some possibly important aims had been omitted. An extensive literature search was carried out (Chapter 2) and a more comprehensive list of aims was drawn up. This was discussed in detail with six members of academic staff at the University of Surrey and after a few minor alterations, the aims questionnaire used in section B of the current survey was drawn up.

3.3.1.2 The survey.

The survey took place in two stages. First a letter was sent to Heads of Departments and then the questionnaire was sent to members of academic staff who organised undergraduate laboratory courses.

3.3.1.2.1 Stage I - Letter to Heads of Departments.

A letter, very similar to that used by Lee and Carter (1972)(95) was sent, during the Spring term of 1975, to Heads of Chemistry Departments at all the universities and polytechnics in the U.K. (with the exception of the three departments already mentioned).

The letter asked each Head of Department to indicate which members of academic staff, who organised laboratory courses, might be willing to fill

*Appendix to Chapter 3
in a questionnaire about laboratory work. It also asked them to outline any recent changes and developments that had taken place in their undergraduate laboratory work in recent years.

The original letter was followed up by a reminder about a month later which increased the overall response rate by 15%.

The response rates to the letter are indicated in Table 3.3 below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Universities</td>
<td>56</td>
<td>40 72</td>
<td>35 63</td>
<td>18 32</td>
<td>4 7</td>
</tr>
<tr>
<td>Polytechnics</td>
<td>28</td>
<td>13 46</td>
<td>12 43</td>
<td>9 32</td>
<td>0 0</td>
</tr>
</tbody>
</table>

No. = Number of replies
% = Percentage of sample which replied
Total replies = This includes any kind of reply
Replies w. list = Replies which included a list of laboratory course organisers
Replies w. c & d = Replies including an account of recent changes and developments
Negative replies = Replies declining to take part in the survey

Less than half of the respondents described recent changes and developments in undergraduate laboratory courses, and many of the respondents suggested that the staff organising laboratory courses should be consulted about this aspect. Section C was therefore added to the questionnaires being sent to departments where recent changes and developments had not been described.*

* Appendix to Chapter 3
The responses from the universities have been classified using a similar classification scheme to one used in the Eaborn report (45).

(a) Scottish universities
(b) London universities (excluding (d))
(c) Oxford and Cambridge
(d) ex-C.A.T.'s
(e) New universities
(f) Other.

These categories are not mutually exclusive. If a university is described by more than one group it has been assigned to the first which appears in the above list, in Table 3.4.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Distribution of departments</th>
<th>Number of letters sent</th>
<th>Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>8 14</td>
<td>8</td>
<td>7 18</td>
</tr>
<tr>
<td>b</td>
<td>10 17</td>
<td>9</td>
<td>8 20</td>
</tr>
<tr>
<td>c</td>
<td>2 4</td>
<td>2</td>
<td>0 0</td>
</tr>
<tr>
<td>d</td>
<td>7 13</td>
<td>6</td>
<td>2 6</td>
</tr>
<tr>
<td>e</td>
<td>10 18</td>
<td>10</td>
<td>9 23</td>
</tr>
<tr>
<td>f</td>
<td>20 35</td>
<td>20</td>
<td>14 35</td>
</tr>
</tbody>
</table>

It can be seen that the distribution of responses is well representative of the total population.
The questionnaire was sent out in the Summer term of 1975 addressed to the staff specified by the Heads of Departments or to a person who had been specified by the Head of Department to coordinate the distribution of questionnaires within the department.

The response rates are given in Table 3.5 below.

**TABLE 3.5**

<table>
<thead>
<tr>
<th></th>
<th>Number of questionnaires sent out</th>
<th>Number of questionnaires returned</th>
<th>% of questionnaires returned</th>
</tr>
</thead>
<tbody>
<tr>
<td>All the Questionnaires</td>
<td>University 223, Polytechnic 84</td>
<td>University 134, Polytechnic 45</td>
<td>University 60, Polytechnic 54</td>
</tr>
<tr>
<td>Questionnaires sent to individuals</td>
<td>University 193, Polytechnic 46</td>
<td>University 129, Polytechnic 23</td>
<td>University 67, Polytechnic 50</td>
</tr>
<tr>
<td>Questionnaires sent to coordinator</td>
<td>University 30, Polytechnic 38</td>
<td>University 5, Polytechnic 22</td>
<td>University 17, Polytechnic 58</td>
</tr>
</tbody>
</table>

It is interesting to note how the different administrative structures in universities and polytechnics affect the response rates with the different modes of distribution of the questionnaires.

It was decided to exclude the Open University from the second stage of the survey because an examination of the laboratory manuals and other information sent by the Open University showed that the nature and particularly the organisation of practical work in the Open University was too different from conventional laboratory courses to be meaningfully included in the statistical analysis being used for the present survey. It should be emphasized, however, that materials developed for practical work by the Open University could well be used in other universities.

These response rates are higher than comparable studies described in Section 3.2.
18 out of the 45 questionnaires from polytechnics describe courses other than undergraduate degree courses, and because of the rather difficult constraints operating on this type of course it has been decided to exclude these courses from the present survey.

The distribution of responses from different categories of universities has been examined and is again seen to be representative of the total population:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Distribution of departments</th>
<th>Questionnaires sent out</th>
<th>Responses</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
<td>Number</td>
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<tr>
<td>a</td>
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<td>14</td>
<td>37</td>
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<tr>
<td>b</td>
<td>10</td>
<td>17</td>
<td>40</td>
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<tr>
<td>c</td>
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<td>4</td>
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<td>13</td>
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<td>10</td>
<td>18</td>
<td>43</td>
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<tr>
<td>f</td>
<td>20</td>
<td>35</td>
<td>90</td>
</tr>
</tbody>
</table>

The questionnaire was followed up by a reminder letter after about a month but no more questionnaires were returned as a result of this.

3.3.2 Aims of chemistry laboratory courses

3.3.2.1 The questionnaire*

In section B of the questionnaire, the respondents were asked to rate

* See appendix to Chapter 3
each of the 33 aims on two five point scales ranging from 1 (not an aim) to 5 (a very important aim), with respect to a laboratory course which they organised. The first scale was designed to measure the importance of each aim in the present course. The second scale allowed the respondents to express the degree of importance that they thought should have been given to each aim in the course, i.e. the opinion of the aims of an ideal course.

3.3.2.2 Method of analysis

For the purposes of analysis the responses have been divided into 3 groups 1.

Group I: All first year courses, 2nd year Scottish courses
(4 year degree).

Group 2: All second year courses except 2nd year Scottish courses;
3rd year Scottish courses; 3rd year of 4 year sandwich
degree courses (some polytechnics).

Group 3: All final year courses.

Within each year group the courses were divided into the 3 main branches of chemistry and 'other' courses. For each group the mean and standard deviation for each aim has been calculated. The differences between the different branches of chemistry, however, were small and statistically insignificant (at the 0.01 level) 2.

1 This classification was used by Chambers (30).
2 T-test for correlated means.
Within the second year group the aims of courses containing open or problem solving experiments were compared with traditional* courses. No significant differences were found (at the 0.01 level).

Within the final year group the aims of non-project courses were compared with the aims of projects and some significant differences were noted. These are discussed below.

3.3.2.3 Aims of the present courses.

(1) First the eleven most important aims in each group will be discussed (see Table 3.7 for mean ratings).

(a) Four aims are important (i.e. amongst the eleven most important aims) in all the groups of courses irrespective of level or type of course. They are aims 8, 19, 22 and 26**.

(b) Another four aims are important in all but final year projects. They are aims 2, 6, 7 and 17.

(c) Three aims which are also important in group 1 and group 2 courses are aims 18, 28 and 31.

* See questionnaire for definitions of these terms (Appendix A3).
** See page 21 for list of aims.
<table>
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<tr>
<th></th>
<th>GROUP 1</th>
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<th>FINAL YEAR PROJECT</th>
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<td>Mean</td>
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<td>1.7</td>
<td>0.9</td>
<td>82</td>
<td>1.8</td>
</tr>
</tbody>
</table>

S.D. = standard deviation
n = number of responses

TABLE 3.7
AIMS OF PRESENT COURSES
Non-project final year courses also emphasize aims 11, 16 and 21.

Final year project work emphasizes aims 11, 16, 18, 24, 25, 29 and 30 as well as those in (a).

It can thus be seen that:

(i) there is a core of 4 aims that permeate all groups of laboratory courses,

(ii) the aims in groups 1 and 2 concentrate mainly on illustrating the lectures (area A) and on the basic skills needed to work in a chemistry laboratory but which do not necessarily require a student to plan an experiment himself, i.e. aims which it is possible to achieve in a traditional* type of experiment, (area B and some aims in area C),

(iii) final year courses put more emphasis on problem solving through experimental work (area C) particularly in projects where it is hoped to develop attitudes such as initiative, resourcefulness, open-mindedness, etc. (i.e. aims 24, 25, 29, area D) and where basic skills are emphasized less.

(2) Analysis of aims at all levels of importance.

(a) There are no statistically significant differences in the ratings of the eleven most important aims (at the 0.01 level) in the first and second year courses but half of the rest of the aims are emphasized more strongly (significant at the 0.01 level) in the second year course. These are:

Area C: Aims 11, 12, 13, 14, 15, 20, 23, 30.

Area D: Aims 24, 25, 29.

* See questionnaire for definition of traditional (appendix to Chapter 3).
Thus although the main emphasis is still on illustrating the lectures and on basic skills needed for practical, there is an increase in emphasis on abilities needed for open or problem solving practical work.

(b) None of the aims in the final year courses are significantly less important than in previous years, indicating that although the emphasis is on work of a more open and problem solving type (areas C and D) the basic skills needed for practical work (area B and some aims in area C) and illustrating the lectures are still considered important. It appears that staff feel students in their final year are capable of achieving a wide range of aims through the more open, problem solving and project types of work (see section 3.3.3.2 for further details of the types of practical work in different years).

3.3.2.4 Comparison with surveys of present courses in the literature

Two studies have asked respondents to say what they think the aims of their laboratory courses are, i.e. Chambers (30) and Tremlett (168).

Chambers, in 1965, sent a questionnaire to 45 physics departments (U.K.) asking the staff to rate the importance of eleven aims. He achieved an 80% response rate.

Tremlett (1972) interviewed 36 academic staff in 8 institutions (in the U.K.) and during the interviews asked them what they thought were the important aims in chemistry laboratory courses.
The results from these studies are shown in Table 3.8. For comparison purposes the aims in Chamers' and Tremletts' studies are cross referenced to the questionnaire used in the present survey. The separate lists of aims appear in the appendix.

It can be seen that on the whole there is good agreement between the surveys, the emphasis being very much on basic skills needed in the laboratory (area B) and skills necessary for processing, interpreting and reporting the data obtained (area C).

There are, however, 3 aims over which there is disagreement.

(a) Aim 26 does not appear in Tremlett's list. This is surprising considering its very high level of importance both in the present study and Chamber's study.

(b) Aim 8 was not included in Chamber's study and is ranked in a low position in Tremlett's study. It is possible, however, that this aim is implicit in Chamber's Aim 3 and Tremlett's Aim 1.

(c) Aim 2 is very important both in the present study and Tremlett's study but is relatively unimportant in Chamber's study, indicating a fundamental difference in the nature of practical work in undergraduate courses for chemists and physicists.

A recent survey by Frazer et al (55) of student opinions of the aims of undergraduate chemistry courses found a similar ranking for aims connected with laboratory work, to those above, with the main emphasis being on practical skills, somewhat less emphasis on communication and a very low emphasis on developing the ability to design experiments.

---

1 The five least important aims of Tremlett's survey have been omitted from Table 3.8 to aid clarity.

2 The strong agreement between the ratings for Chamber's aims in Table 3.8 and those in the present survey on Table 3.7 is remarkable.
In the present study aims were ranked for each year of the course. In order to make a comparison with Chambers and Tremlett the following coding has been used:

- **a** = aim amongst the 11 most important aims for all years
- **b** = aim amongst the 11 most important aims for 2 years
- **c** = aim amongst the 11 most important aims for 1 year only

N.B. The wording of the aims is not identical, e.g. Chambers 3 and the present study 6 & 7. Brackets indicate very different wording.

<table>
<thead>
<tr>
<th>Present study</th>
<th>Chambers</th>
<th>Tremlett</th>
</tr>
</thead>
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<td>No. and ranking</td>
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</tr>
</tbody>
</table>

(i) No. = Number used to designate aim

(ii) Ranking = Rank order of aims

(iii) Rating = Mean rating rescaled onto a 1 to 5 scale

(iv) Comment frequency = Total number of times aim was mentioned during interviews

(v) In the present study aims were ranked for each year of the course. In order to make a comparison with Chambers and Tremlett the following coding has been used:
One aim which stands out as being more important in Frazer's list is the aim 'to develop an ability to work safely in a laboratory'. The three universities and two polytechnics in Frazer's study must therefore put more emphasis on safety factors than most chemistry departments.

3.3.2.5 Aims for ideal courses

Table 3.9 summarises the results for the aims for ideal courses at the different levels. Again no significant differences were found between the different branches of chemistry and between courses in the 2nd year group which used open or problem solving work and those which did not. There are, however, significant differences between non-project courses in the final year and final year projects. Table 3.9 therefore comprises four groups:

(a) 1st year group
(b) 2nd year group
(c) Final year non-project group
(d) Final year project group.

It can be seen that many of the discordance values (defined as the mean rating for an ideal course minus the mean rating for the actual course) are significant below the 0.01 level. In order to determine the educational significance of the discordances, scatter graphs have been plotted of the mean rating for an ideal course against the discordance (graphs 3.1, 3.2, 3.3) for all the aims where the discordance value is statistically significant. The aims for which there is an educationally significant discordance lie in the top right hand corner of the graphs and have been arbitrarily defined on each graph according to the scatter as:
**TABLE 3.9**

<table>
<thead>
<tr>
<th>Aim</th>
<th>Mean S.D n</th>
<th>Dis. Sig.</th>
<th>Mean S.D n</th>
<th>Dis. Sig.</th>
<th>Mean S.D n</th>
<th>Dis. Sig.</th>
<th>Mean S.D n</th>
<th>Dis. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aim</td>
<td>Mean S.D n</td>
<td>Dis. Sig.</td>
<td>Mean S.D n</td>
<td>Dis. Sig.</td>
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<td>Dis. Sig.</td>
<td>Mean S.D n</td>
<td>Dis. Sig.</td>
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<td>1</td>
<td>2.5 1.2 76 0.4 NS</td>
<td>2.6 1.3 53 0.1 NS</td>
<td>3.0 1.1 26 0.2 NS</td>
<td>3.2 1.4 11 0.4 NS</td>
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<tr>
<td>2</td>
<td>4.3 1.0 77 0.3 NS</td>
<td>4.3 1.0 53 0.3 NS</td>
<td>4.5 0.9 26 0.3 NS</td>
<td>3.7 1.3 11 0.3 NS</td>
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<td>3</td>
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<td>2.8 1.4 46 0.3 NS</td>
<td>2.8 1.6 24 0.2 NS</td>
<td>3.3 1.2 10 0.5 NS</td>
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<td>4</td>
<td>3.2 1.4 75 0.7 S</td>
<td>3.7 1.3 49 0.8 S</td>
<td>3.9 1.4 26 0.9 NS</td>
<td>3.4 1.3 11 0.4 NS</td>
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<td>1.5 0.8 75 0.1 NS</td>
<td>2.2 1.4 53 0.1 NS</td>
<td>2.4 1.5 27 0.9 NS</td>
<td>4.3 1.3 11 0.1 NS</td>
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<td>4.5 0.9 53 0.6 S</td>
<td>4.1 1.2 27 0.4 NS</td>
<td>4.0 1.2 11 0.3 NS</td>
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<td>4.2 0.8 53 0.3 NS</td>
<td>4.2 1.0 27 0.5 NS</td>
<td>4.0 1.1 10 0.3 NS</td>
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<td>8</td>
<td>4.5 0.7 77 0.7 S</td>
<td>4.7 0.6 54 0.9 S</td>
<td>4.5 0.9 27 0.6 NS</td>
<td>4.7 0.7 10 0.5 NS</td>
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<td>3.7 1.1 78 0.7 S</td>
<td>3.6 1.1 53 0.7 S</td>
<td>3.8 1.2 26 0.8 NS</td>
<td>3.5 1.6 10 0.0 NS</td>
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</tbody>
</table>

Mean = Mean of ratings for an ideal course
S.D. = Standard deviation
n = Number of responses
Dis = Dissonance value
Sig = Significance
S = Significant at 0.01 level
NS = Not significant at 0.01 level
Statistically significant differences against aims of ideal course first year group

Graph 3.1
Second year group Ideal versus Difference

Graph 3.2
Final year Ideal versus Difference

\[ X = \text{non project} \]
\[ Q = \text{project} \]
Graph 3.1, year group 1 - rating ≥ 3.4, discordance ≥ 0.9
Graph 3.2, year group 2 - rating ≥ 3.7, discordance ≥ 0.7
Graph 3.3, final year - rating ≥ 3.5, discordance ≥ 1.1

The differences which are educationally significant are shown below:

**Table 3.10.**

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<thead>
<tr>
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<th>AREA B</th>
<th>AREA C</th>
<th>AREA D</th>
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<tbody>
<tr>
<td>Year Group I</td>
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<td>24 25 26 27 28 29</td>
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<tr>
<td>Year Group 2</td>
<td>8</td>
<td>11 - 15 16 - - - -</td>
<td>24 25 - - - 29</td>
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<tr>
<td>Final year, non-project</td>
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<td>-14 15 - - - 20 23 30</td>
<td>24 25 - - - 29</td>
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<tr>
<td>Final year, project</td>
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<td>- - - - - - - - 23 -</td>
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</tbody>
</table>

(1) It is notable that the discordance values for final year projects are significantly smaller than for all other groups (see table 3.9). This factor combined with the small numbers in the final year project group produce only one aim on which staff would like to put more emphasis, aim 23.

(2) Nearly all the aims which staff feel are underemphasised fall in areas C and D. Three aims are consistently underemphasised. They are aims 24, 25 and 29.

Aim 11 is underemphasised in year groups 1 and 2 and aim 15 in year group 2 and the final year non-project group.

Staff would clearly like to see more emphasis on students making decisions about how to carry out experiments and on students having more control over how they work in the laboratory.
It is clear that in order to achieve this reorientation of the aims of laboratory work, more open, problem-solving and project work will have to be introduced at all levels of laboratory work.

(3) It is important to note that all but one of the dissonance values is positive indicating that although the staff would like to increase the emphasis on the aims mentioned above, they would like to do so without decreasing the emphasis on those aims which are already well represented in present courses. In fact, the eleven most important aims for ideal courses in each of the groups are very similar to the eleven most important aims in the present courses. (see Table 3.11).

It would seem unrealistic to hope to eliminate the dissonance between the aims of present courses and those of ideal courses. Instead one must attempt to reduce the dissonance in those areas where it is most educationally significant. The results would indicate that a shift in emphasis towards a more open, problem-solving or project type of laboratory work is desirable, even if it would mean increasing the dissonance for some of the aims which are considered to be important in present courses1. Clearly a balance has to be struck when deciding which aims should be emphasized most. At the moment the balance lies too much towards those aims which can be achieved by traditional laboratory work and too little towards many of the aims in areas C and D.

1It may, however, be possible to achieve a wider range of aims using alternative methods. This possibility is examined in section 6.4 of this thesis.
A table containing the eleven most important aims for present courses and for ideal courses for each year group.

<table>
<thead>
<tr>
<th>YEAR GROUP 1</th>
<th>YEAR GROUP 2</th>
<th>FINAL YEAR NON-PROJECT</th>
<th>FINAL YEAR PROJECT</th>
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<tbody>
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<td>PRESENT</td>
<td>IDEAL</td>
<td>PRESENT</td>
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</table>
3.3.2.6 Comparison with surveys of aims of ideal courses in the literature

Two studies have asked respondents to say what they think the aims of laboratory courses should be.

Lee (1969)(94) in a 2% sample of university graduates who were Associate members of the Institution of Mechanical Engineers, asked the respondents to rate on a 5 point scale 16 possible aims for mechanical engineering practical work at university, according to their importance. He achieved a response rate of 59%. From Lee's results the mean and standard deviation for each aim has been calculated and these are included in Table 3.11.

Ring (1975)(139) sent a similar aims questionnaire to members of staff in the physics department at the Lowell Technological Institute, U.S.A., asking them to rate 23 aims depending on how important they thought each aim should be in an ideal introductory physics laboratory course. He achieved a 48% response rate. The results are included in Table 3.12.

Again the aims have been related to the aims in the present study in Table 3.12. The lists of Lee's and Ring's aims appear in the appendix to Chapter 3.

The surveys are compared below:

Area A:

The respondents in the 3 surveys were agreed that Aim 2 'To illustrate

---

1 Some of the aims in Lee's and Ring's surveys do not correspond to any of the aims included in the present survey and are therefore not included in Table 3.10. These aims are:
Lee: 8,13,14,15. Ring: 1,19,20,22.
<table>
<thead>
<tr>
<th>Present No*</th>
<th>Study Ranking</th>
<th>Lee</th>
<th></th>
<th></th>
<th></th>
<th>Ring</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Ranking</td>
<td>Rating</td>
<td>S.D</td>
<td>No</td>
<td>Ranking</td>
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* The column headings are explained in Table 3.6.
material taught in lectures and tutorials (including Ring's aims 4, 22 and 23) should be important in an ideal course.

Area B:
It was felt that the aims in this area should be strongly emphasised in chemistry laboratory courses. The physics staff (Ring ¹) would like to put less emphasis on basic skills and techniques (aim 6) and on familiarising students with some important instruments and devices (aim 7) but would put strong emphasis on the aim 'to teach the principles and attitudes of doing experimental physics'. Clearly the staff felt that the aims of an introductory physics course should be orientated to provide a basic laboratory training. It would appear, however, that in chemistry there is a larger body of specific skills and techniques that students are expected to learn.

In contrast the mechanical engineers (Lee) felt that training students to use 'particular apparatus, test procedures or standard techniques' should be a low priority aim.

Area C:
In all 3 surveys it was felt that aims to do with processing experimental data (aims 16 and 19) should be very important in an ideal laboratory course.

The chemists and mechanical engineers both felt that training students in writing reports (aim 22) was important but this was thought to be less important for an introductory physics course.

¹ N.B. The rankings and ratings for the physics staff are for an introductory course and should be compared with year Group 1 on Table 3.7.
It was felt that there should be quite strong emphasis on problem solving in the laboratory (aim 11) in both chemistry and mechanical engineering courses but not in an introductory physics course.

Area D:

It was agreed that stimulating interest (aim 26) should be very important in both chemistry and physics laboratory courses, but not so important (rating 3.8) for mechanical engineering.

It was thought that aim 24 'to provide the student with a stimulus for independent thinking' should be the most important aim for mechanical engineering laboratory courses and should be quite important in chemistry courses particularly in the final year (also aim 25 for chemistry courses). It was thought, however, that it should be of quite low importance in an introductory physics course.

Area E:

It was thought that aims in this area should be unimportant with the exception of aim 31 for chemistry laboratory courses.

Again there is quite good agreement between the findings of the present survey and those aims related to laboratory work in Frazer's (55) survey, with the exception of the aim 'to develop an ability to work safely in a laboratory' which it was felt should be the most important aim for a chemistry laboratory course and the second most important aim of the whole degree course.
Summary

The aims for an ideal course in the 3 different surveys are similar, the differences being attributable to differences in the nature of the subjects, e.g. aims in area B, and to the level at which it was being studied, e.g. aims in area D. It is surprising, however, to find that mechanical engineers did not rate stimulating interest as a very important aim.

3.3.3 Methods of teaching and learning

3.3.3.1 Organisation of Laboratory Courses

3.3.3.1.1 Subject

Table 3.13 shows that most laboratory work is organised within the traditional branches of chemistry.

<table>
<thead>
<tr>
<th>Subject</th>
<th>YEAR GROUP I</th>
<th>YEAR GROUP 2</th>
<th>FINAL YEAR NON-PROJECT</th>
<th>FINAL YEAR PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of courses</td>
<td>%</td>
<td>No. of courses</td>
<td>%</td>
</tr>
<tr>
<td>Organic</td>
<td>21</td>
<td>25</td>
<td>18</td>
<td>32</td>
</tr>
<tr>
<td>Inorganic</td>
<td>13</td>
<td>16</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td>Physical</td>
<td>29</td>
<td>35</td>
<td>18</td>
<td>32</td>
</tr>
<tr>
<td>Integrated</td>
<td>17</td>
<td>20</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>12</td>
</tr>
</tbody>
</table>

Notes: (1) 'Integrated' indicates a course which integrates 2 or 3 of the main branches of chemistry: 58% of the 'integrated' courses integrate all 3 branches of chemistry.

(2) 'Other' includes analytical (10), biochemistry (3 final year courses), polymer science (1) and materials science (1).
The distribution of courses by subject area and year group shows some differences from the distribution of courses in Smythe's survey(153) which included about twice the number of courses. Smythe's survey found an even distribution over the three main branches of chemistry. The distribution of courses in each year group in the present survey is similar to Smythe's but with year group I being more heavily represented in the present survey, and year group 2 correspondingly less well represented.

3.3.3.12 Individuals / Pairs / Groups

For the majority of courses students work individually in the laboratory (Table 3.14).

Physical chemistry is exceptional in that the students more often work in pairs than individually. In the first two years when working as pairs, students usually perform the same experiment as a pair but for about a quarter of the experiments they do similar experiments and pool their results. In the final year the number of experiments in which they pool their results, when working in pairs, increases to about half.

Students only occasionally work in groups of 3 or more.

Students rarely work in pairs in final year projects. In one of the eleven final year projects students sometimes worked on similar experiments and pooled results.

All the staff who were interviewed and who ran courses in which students worked as pairs did so primarily because of constraints of apparatus or space, and when sufficient apparatus was available usually preferred
Part 1:

Percentages indicate the number of courses which include group work.

<table>
<thead>
<tr>
<th>Subject</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>71%</td>
<td>59%</td>
<td>65%</td>
<td>74%</td>
</tr>
<tr>
<td>Chemistry</td>
<td>67%</td>
<td>53%</td>
<td>62%</td>
<td>75%</td>
</tr>
<tr>
<td>Biology</td>
<td>61%</td>
<td>49%</td>
<td>55%</td>
<td>63%</td>
</tr>
</tbody>
</table>

Part 2:

Number of courses

<table>
<thead>
<tr>
<th>Subject</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>31</td>
<td>30</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>Chemistry</td>
<td>28</td>
<td>27</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Biology</td>
<td>26</td>
<td>25</td>
<td>27</td>
<td>28</td>
</tr>
</tbody>
</table>

Part 3:

All experiments are done as parts of groups or groups of 5 or more, but less than all the experiments within the course are done in parts of 5 or more.

<table>
<thead>
<tr>
<th>Subject</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>29</td>
<td>28</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Chemistry</td>
<td>26</td>
<td>25</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>Biology</td>
<td>24</td>
<td>23</td>
<td>25</td>
<td>26</td>
</tr>
</tbody>
</table>

Part 4:

All experiments within the course are done individually.

<table>
<thead>
<tr>
<th>Subject</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>31</td>
<td>30</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>Chemistry</td>
<td>28</td>
<td>27</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Biology</td>
<td>26</td>
<td>25</td>
<td>27</td>
<td>28</td>
</tr>
</tbody>
</table>

Notes:

(1) Ind. only

Table 3.14
students to work individually.

The present findings support these opinions in that there is a larger proportion of courses in which students work in pairs in the 2nd year group than in the first year group as the apparatus and equipment needed becomes more specialised. In the final year course students work individually more. This becomes possible because of the drop in the size of the classes from the second year group to the final year (see section 3.3.3.16).

Chambers (29A) found similar trends in physics. In the first year there was no correlation between the size of classes in different departments and the extent to which students worked in pairs, but in subsequent years the amount of working in pairs dropped as the size of classes dropped.

The educational benefits and disadvantages of students working in pairs are examined in the case studies in the next chapter.

3.3.3.13 Sequencing of experiments

In the first year group in most inorganic courses the students do the same experiments at approximately the same time (a) whereas in the physical courses different students usually do different experiments at the same time (b). In the organic courses the students do the same experiments at the same time in about a third of the course whereas in about half the courses students do a mixture of (a) and (b).

In the second year group and the final year the number of courses where students do different experiments at the same time (b) increases
particularly for inorganic chemistry.

### TABLE 3.15 SEQUENCING OF EQUIPMENT

<table>
<thead>
<tr>
<th></th>
<th>First Year Group</th>
<th></th>
<th>Second Year Group</th>
<th></th>
<th>Final yr. Non-project</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>a</td>
<td>b</td>
<td>c</td>
</tr>
<tr>
<td>Organic</td>
<td>8</td>
<td>314</td>
<td>10</td>
<td>48</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Inorganic</td>
<td>7</td>
<td>64</td>
<td>318</td>
<td>318</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Physical</td>
<td>1</td>
<td>3</td>
<td>18</td>
<td>62</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Integrated</td>
<td>8</td>
<td>42</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>53</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>67</td>
</tr>
</tbody>
</table>

(a) Students do the same experiments at approximately the same time.

(b) Different students do different experiments at the same time.

(c) Students do a mixture of (a) and (b).

n = number of course.

% = percent of courses within subject and year group.

The extent to which experiments in a practical course can be sequenced depends on the availability of apparatus, in a similar way to the amount of individual work discussed in the previous section.

#### 3.3.3.14 Length of courses and length of experiments

There is wide variation in the length of courses and the length of experiments within courses:
TABLE 3.16  

<table>
<thead>
<tr>
<th></th>
<th>Length of courses (hrs)</th>
<th>Length of experiments (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>1st year group</td>
<td>62</td>
<td>45</td>
</tr>
<tr>
<td>2nd year group</td>
<td>83</td>
<td>39</td>
</tr>
<tr>
<td>Final year-Non project</td>
<td>89</td>
<td>48</td>
</tr>
<tr>
<td>Final year - project</td>
<td>176</td>
<td>67</td>
</tr>
</tbody>
</table>

Mean = Mean length of course/experiment  
S.D. = Standard deviation  
n = Number of courses

These figures are in close correspondence with those calculated from Smythe's data.

There are no significant variations between the different branches of chemistry except for the 1st year group courses where the mean length of organic, inorganic and physical courses was about 50 hours as opposed to integrated courses which were about 80 hours long \(^1\) (c.f. Table 3.1).

The increasing complexity of practical work as the degree courses progress is reflected in the increase in the length of time spent on each experiment.

\(^1\) Some integrated courses were short introductory courses. Other replaced all the laboratory work in the traditional branches of chemistry during year 1.
3.3.3.15 Type of students attending chemistry laboratory courses

Many chemistry laboratory courses are taken by a large number of students from other subject areas as well as students from chemistry. The largest groups of students attending chemistry laboratory courses, apart from chemists, are biological scientists but students also attend from medicine, dentistry, pharmacy, engineering, geology and other sciences.

### Table 3.17 Percent of courses attended by different groups of students

<table>
<thead>
<tr>
<th></th>
<th>Chemists only</th>
<th>Chemists + Biological Sciences</th>
<th>Chemists + other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st year group</td>
<td>28</td>
<td>38</td>
<td>34</td>
</tr>
<tr>
<td>2nd year group</td>
<td>77</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>Final year</td>
<td>97</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Non project group</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.3.3.16 Size of classes

The size of classes taking chemistry laboratory courses steadily decreases throughout the degree reflecting a fall off in the number of non-chemists taking chemistry courses, and presumably increased specialisation and a decrease in the number of chemists in each year as some of them drop out. A similar trend was noted by Chambers (29A).
### TABLE 3.18 SIZE OF CLASSES

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Number of courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st year group</td>
<td>38</td>
<td>22</td>
<td>75</td>
</tr>
<tr>
<td>2nd year group</td>
<td>27</td>
<td>15</td>
<td>55</td>
</tr>
<tr>
<td>Final year</td>
<td>15</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>Non project group</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.3.3.17 Staffing

The following ratios have been calculated for each course:

- Students: P.G. Demonstrators
- Students: Academic staff
- Students: P.G. Demonstrators + Academic staff

The means and standard deviations of these ratios have been calculated for:

- 1st year group classes with > 30 students
- 1st year group classes with ≤ 30 students
- 2nd year group classes with > 30 students
- 2nd year group classes with ≤ 30 students
- Final year non project group classes with ≤ 30 students

There were no final year non project courses with > 30 students.

(N.B. The mean ratios calculated represent a mean for courses, not a mean ratio for the 'average' student or 'average' member of teaching staff).

The results are shown overleaf in Table 3.19.
<table>
<thead>
<tr>
<th></th>
<th>1ST YEAR GROUP</th>
<th>2ND YEAR GROUP</th>
<th>FINAL YEAR NON PROJECT GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 30 students</td>
<td>≤ 30 students</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>S.D</td>
<td>n</td>
</tr>
<tr>
<td>Student:Demonstrator</td>
<td>19.1</td>
<td>9.6</td>
<td>36</td>
</tr>
<tr>
<td>Student:Staff</td>
<td>35.1</td>
<td>13.9</td>
<td>37</td>
</tr>
<tr>
<td>Student:Demonstrator + staff</td>
<td>13.5</td>
<td>7.4</td>
<td>37</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>2ND YEAR GROUP</th>
<th>FINAL YEAR NON PROJECT GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D</td>
</tr>
<tr>
<td>Student:Demonstrator</td>
<td>22.7</td>
<td>13.8</td>
</tr>
<tr>
<td>Student:Staff</td>
<td>25.8</td>
<td>10.0</td>
</tr>
<tr>
<td>Student:Demonstrator + staff</td>
<td>12.7</td>
<td>5.3</td>
</tr>
</tbody>
</table>

A number of interesting trends can be noticed:

1. Smaller classes have significantly better student:demonstrator + staff ratios and student:staff ratios. The student:demonstrator ratios are similar for different sized classes.

A similar trend was noted by Chambers (29A) in physics.

This leads to differences in staffing ratios for certain types of courses:
(a) 1st year organic courses are usually held with larger classes 
(i.e. Mean = 46, S.D. = 28, c.f. all 1st year courses 
Mean = 38, S.D. = 22) consequently the staffing ratios tend 
to be worse, although this is not statistically significant 
at the 0.01 level.

(b) First year group courses at polytechnics tend to have smaller 
numbers of students than courses at universities (i.e. 
mean = 16, S.D. = 6 at polytechnics compared with mean = 40 
S.D. = 22 at universities) and therefore the overall student: 
staff + demonstrator ratio tends to be more favourable in 
polytechnics (i.e. mean = 8.8, S.D. = 4.0 at polytechnics compared 
with mean = 11.6, S.D. = 6.2 at universities). Again the 
differences are not statistically significant at the 0.01 level.

(2) There are no significant differences between the 1st year groups 
and the 2nd year groups in Table 3.19. There is, however, an 
overall improvement in the student:staff ratio (significant at the 
0.01 level) in the 2nd year group because of the decrease in number 
of larger courses in the 2nd year group.

(3) The final year non project courses have significantly better (at 
the 0.01 level) student:staff and student:demonstrator + staff 
ratios than the previous years.

(4) Differences in the amount of usage of postgraduate student 
demonstrators are shown in Table 3.20.
TABLE 3.20 FRACTION AND PERCENT OF COURSES NOT USING POSTGRADUATE STUDENT DEMONSTRATORS

<table>
<thead>
<tr>
<th></th>
<th>1ST YEAR GROUP</th>
<th>2ND YEAR GROUP</th>
<th>FINAL YEAR</th>
<th>NON PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fraction</td>
<td>Percent</td>
<td>Fraction</td>
<td>Percent</td>
</tr>
<tr>
<td>Polytechnic</td>
<td>7/13</td>
<td>54</td>
<td>6/9</td>
<td>67</td>
</tr>
<tr>
<td>University</td>
<td>5/70</td>
<td>7</td>
<td>6/44</td>
<td>14</td>
</tr>
</tbody>
</table>

The fact that universities tend to employ postgraduate student demonstrators in laboratory courses more than polytechnics means that members of academic staff are more often employed in the teaching laboratory in polytechnics. The differences between student:staff ratios in universities and polytechnics are highly significant in the first year group courses. The differences in later years are not statistically significant. Table 3.21 compares the student:staff ratios for the university and polytechnic first year groups.

TABLE 3.21

<table>
<thead>
<tr>
<th></th>
<th>POLYTECHNIC</th>
<th>UNIVERSITY</th>
<th>t-test for significant difference at 0.01 level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D</td>
<td>n</td>
</tr>
<tr>
<td>&gt; 30 students</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>≤ 30 students</td>
<td>11.8</td>
<td>4.9</td>
<td>13</td>
</tr>
</tbody>
</table>

(5) The staffing ratios in Table 3.19 represent a considerable improvement on those reported by the Ourisson Committee in 1966.

In spite of the widespread use of postgraduate student demonstrators as teaching staff in laboratory courses, some of the staff interviewed (8 out of 17) mentioned problems with postgraduate demonstrators:
The standard of postgraduate demonstrators varied considerably. Many were considered competent but in some courses postgraduate demonstrators did all the marking because the staff felt that they, the staff, were better equipped to help the students with their work in the laboratory whereas in others staff did all the marking because they felt that postgraduate demonstrators did not have a sufficient grasp of the course. Very little help was given by staff to postgraduate demonstrators. Usually demonstrators were given the instruction sheets before the class started and were given little other help.

The most frequently mentioned problems were that some postgraduate demonstrators lacked knowledge of, or familiarity with, the course content and that some had problems in communication and knowing how to approach students. In one department the problems with postgraduate demonstrators were accentuated by the fact that most of the postgraduates were foreign and came from different educational backgrounds and many did not speak good English.

These problems with the staffing of courses recur throughout the case studies in the next chapter where they are examined in more detail. It would appear, however, from the data presented in this chapter that these problems limit the range of educational aims that can be achieved in laboratory courses particularly those with large student numbers and correspondingly poorer staffing ratios.

3.3.3.18 Marking

Another factor that affects the effective student to staff and demonstrator ratios is the amount of time spent marking reports on
experiments. This varied considerably from course to course. Usually between 0 and 40% of a member of staff's or postgraduate demonstrator's time was spent marking. In about a quarter of the courses no marking was done in the laboratory, in a third of the courses both staff and postgraduate demonstrators did the marking and in a further third of the courses only the staff did the marking.

3.3.32 Types of styles of laboratory courses

3.3.3.21 Amount of traditional, open or problem solving and project work in laboratory courses.

Table 3.22 shows the amount of 'openness' in laboratory courses at the different levels.

**TABLE 3.22**

<table>
<thead>
<tr>
<th>TYPE OF EXPERIMENT</th>
<th>FIRST YEAR GROUP</th>
<th>SECOND YEAR GROUP</th>
<th>FINAL YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>All traditional/ None open</td>
<td>82</td>
<td>99</td>
<td>30</td>
</tr>
<tr>
<td>&lt; 25% expts open</td>
<td>0</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>≥ 25% &amp; &lt; 50% open</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>≥ 50% &amp; &lt; 100% open</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>100% open</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Number of course including project work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part of course project work</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>All project work</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

n = number of courses
% = percentage of course within year group
"open" = open, problem solving or project work

1 These terms are defined in the questionnaire (see appendix to Chapt. 3).
2 The proportion of projects in this survey is thought to be substantially lower than the proportion in the total population because Heads of Departments were asked to indicate members of staff who might be willing to complete the questionnaire with respect to courses which they organised. The questionnaire has therefore been completed mainly by staff organising courses rather than project work.
The amount of open, problem solving or project work in the first year group is minimal reflecting the strong emphasis on teaching the basic skills needed to work in the laboratory and on illustrating lectures (see section 3.3.2.3).

There is slightly more open, problem solving and project work in the second year group but only 22% of the courses consist of half or more of this type of work. The slight increase in open types of practical work reflects the slight increase in emphasis on aims in areas C and D noted in section 3.3.2.3. The main emphasis, however, remains on basic skills and illustrating the lecture material, aims which can be achieved by traditional laboratory work.

The number of courses providing open or problem solving work in the 2nd year group of courses appears to have increased since Smythe's survey in 1973\(^1\) and Tietze's survey in 1972 (see section 3.21).

There is a sudden transition to the use of open, problem solving and project work as the main style of laboratory work in the final year reflecting the increased emphasis on aims in areas C and D (see section 3.3.2.3.)

A number of factors appear to be affecting the amount of open work used in degree courses

\(^1\) It is not clear from Smythe's figures what percentage of departments provided open-ended experiments in the 2nd year: 30% of the universities and 25% of the polytechnics stated specifically that they had open-ended experiments in the 2nd year, but 79% of the universities and 92% of the polytechnics provided open-ended experiments where appropriate.
1. Aims

Traditional courses are felt to be appropriate for achieving and emphasising the basic skills needed to work in the laboratory (area B and some aims in area C) and for illustrating the lectures (area A). When aims such as training students in experimental design (area C) or encouraging initiative and resourcefulness (area D) are considered to be important more open work has to be used.

The findings in section 3.3.25, however, indicate a desire to put more emphasis on aims in areas C and D in an ideal situation. It appears that staff feel constrained to the more traditional approach in the real situation.

2. Staffing

One of the factors which could be affecting the ability of staff to provide more open types of work is a shortage of adequate staffing.

The courses in the 2nd year group which comprise half or more open or problem solving experiments tend to be slightly smaller than average (not significant at 0.01 level) and have a student : staff + demonstrator ratio which is significantly lower (at the 0.01 level) than other 2nd year group courses, i.e. more staff and demonstrators are used.

Similarly the final year non-project courses which comprise mainly open or problem solving types of experiments have significantly lower (at 0.01 level) student : staff + demonstrator ratios than courses in earlier years (section 3.3.3.17).
Projects which require individual supervision obviously also make greater demands on staff time than traditional laboratory courses.

3. Ability of students

Many of the staff felt that students were unable to tackle open or problem solving work in the first and, to some extent, in the second year because they had not yet learnt the necessary basic practical skills. It is clear, however, from the large number of successful open or problem solving courses reported in the literature that this is a fallacy (see Section 2.2.2.2).

3.3.3.22 Integration of lecture and laboratory courses

Out of the 170 courses (not including projects) described in the questionnaires only 9(5%) claimed to be integrated with the lecture courses and 4 claimed partial integration.

Five of the 'integrated' courses were in the 2nd year group and the final year group. In all these 5 courses different students did different experiments at the same time, and one would suspect that this severely limited the amount of integration. One of the courses was, in fact

---

1 Nine out of the seventeen interviewed
followed up and is the case study V. The amount of integration was found to be limited to the laboratory course running concurrently with the lecture courses supplemented by 2 Calchem programmes which were studied in the laboratory.

In two of the 4 integrated courses in the 1st year group, the students studied the same experiment at approximately the same time, whereas in the other 2 courses students did different experiments at the same time. The respondents for the latter 2 courses described how integration was achieved without the students having to work through the experiments at the same time.

1. One course achieved integration by using a wide range of teaching methods: "individual work, group work experiments, tutorials, graphical integration type calculations, short observation/conclusion type experiments, tape-slides and programmed learning."

2. The second course was run for 3 weeks at the beginning of term 1 and 2½ weeks at the beginning of term 2, followed immediately by examinations. The practical element of the course was small and practical work was only used when seen as appropriate. The course was run in eleven 2½ day units (8 hours per unit). Informal lectures were followed by problem class/tutorial sessions with one tutor to about 15 students.

Clearly integration of lecture and laboratory courses is difficult to achieve particularly if insufficient apparatus is available for the whole class to work on the same experiment at the same time. It has, however, been found to be possible in the two courses described above by:
(1) the extensive use of individualised learning materials
or
(2) a complete departure from conventional timetabling.

3.3.3.3. Methods of teaching and learning within the courses

This section examines the methods of teaching and learning that were auxiliary to the actual practical work.

The relevant section of the questionnaire is included below:

11. Below is a list of different ways of learning that are auxiliary to the actual practical work. Please rate each way of learning on the scale according to its importance in the course:

1 = Not important  5 = Very important

<table>
<thead>
<tr>
<th></th>
<th>Practical demonstrations to all, or a large part of the class, by staff or postgraduate demonstrators.</th>
<th>1 2 3 4 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>Instruction sheets</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>(c)</td>
<td>Individual instruction by postgraduate demonstrators, given to the student when required</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>(d)</td>
<td>Individual instruction by the staff, given to the student when required</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>(e)</td>
<td>Help given by one student to another</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>(f)</td>
<td>Text books or periodicals</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>(g)</td>
<td>Video-tapes</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>(h)</td>
<td>Tape-slides</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>(i)</td>
<td>Other (please specify)</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>(j)</td>
<td>Other (please specify)</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>
The mean and standard deviations of the ratings for a to f are shown in Table 3.24 for each year group.

TABLE 3.24

<table>
<thead>
<tr>
<th>YEAR GROUP 1</th>
<th>YEAR GROUP 2</th>
<th>FINAL YEAR NON-PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>S.D.</td>
<td>n</td>
</tr>
<tr>
<td>a</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>b</td>
<td>4.6</td>
<td>0.8</td>
</tr>
<tr>
<td>c</td>
<td>4.4</td>
<td>0.9</td>
</tr>
<tr>
<td>d</td>
<td>4.5</td>
<td>0.9</td>
</tr>
<tr>
<td>e</td>
<td>2.6</td>
<td>1.2</td>
</tr>
<tr>
<td>f</td>
<td>2.4</td>
<td>1.3</td>
</tr>
</tbody>
</table>

1. The main auxiliary teaching is done through individual instruction by staff (d), instruction sheets\(^1\)(b) and individual instruction by postgraduate demonstrators (c) when they are present.

2. Help given by one student to another (e) is thought to be quite important. (The increase in importance from year group I to the final year group is not statistically significant at the 0.01 level).

3. Textbooks and periodicals play an increasingly important role as the courses become more advanced. (The increase in importance from year group I to year group 2 and to the final year group is significant at the 0.01 level).

\(^1\) Tietze (165) reported widespread use of instruction sheets in 1973
4. The amount which demonstrations (a) are used varies considerably from course to course. Demonstrations are used significantly less in 1st year group Physical Chemistry laboratory courses than in the rest of the laboratory courses in the 1st year group. This is obviously related to the sequencing of experiments described in Section 3.3.3.13.

Table 3.25 shows that when demonstrations were used they were often thought to be an important component of the laboratory course.

**Table 3.25 Importance of Demonstrations**

<table>
<thead>
<tr>
<th>Rating</th>
<th>1ST YEAR GROUP</th>
<th>2ND YEAR GROUP</th>
<th>FINAL YEAR NON-PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>1</td>
<td>33</td>
<td>39</td>
<td>29</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>15</td>
<td>6</td>
</tr>
</tbody>
</table>

n = number using the particular rating

% = % using the particular rating in the year group.

5. The responses of the 2nd year group were analysed to determine whether there were any significant differences between the courses which consisted wholly of traditional experiments and those which contain some open or problem solving working. The only statistically significant difference (at the 0.01 level) was for (a). Demonstrations were used a lot less in courses which
included open work (Mean = 2.1, S.D. = 1.3) than wholly traditional courses (Mean = 3.6, S.D. = 1.5).

6. Table 3.26 shows that audio-visual media such as videotapes and tape-slides rarely play an important role in the laboratory.

TABLE 3.26 DISTRIBUTION OF RESPONSES FOR 11 g & h

<table>
<thead>
<tr>
<th>Rating (Number of staff giving each rating)</th>
<th>1ST YEAR GROUP</th>
<th>2ND YEAR GROUP</th>
<th>FINAL YEAR NON-PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Videotapes</td>
<td>Tape-slide</td>
<td>Videotape</td>
</tr>
<tr>
<td>1</td>
<td>73</td>
<td>73</td>
<td>42</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>% courses using medium</td>
<td>15%</td>
<td>15%</td>
<td>26%</td>
</tr>
<tr>
<td>% courses using both media</td>
<td>9%</td>
<td>19%</td>
<td>7%</td>
</tr>
</tbody>
</table>

It is interesting to note the large proportion of the courses using both video-tapes and tape-slides.

6. Staff mentioned a variety of other teaching methods and materials used in response to questions 11i and j. They are shown overleaf in Table 3.27.
TABLE 3.27 Teaching Methods or Materials

<table>
<thead>
<tr>
<th>Method</th>
<th>Frequency of Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Lectures: introductory lectures, explanatory lectures</td>
<td>8</td>
</tr>
<tr>
<td>(2) Computer assisted learning (physical courses)</td>
<td>4</td>
</tr>
<tr>
<td>(3) Seminars and tutorials</td>
<td>3</td>
</tr>
<tr>
<td>(4) Films</td>
<td>3</td>
</tr>
<tr>
<td>(5) Molecular models (organic courses)</td>
<td>2</td>
</tr>
<tr>
<td>(6) Problem classes using data obtained from literature</td>
<td>1</td>
</tr>
<tr>
<td>(7) Specimen data for interpretation</td>
<td>1</td>
</tr>
<tr>
<td>(8) Programmed books</td>
<td>1</td>
</tr>
<tr>
<td>(9) Photographs of apparatus assembly</td>
<td>1</td>
</tr>
<tr>
<td>(10) Question sheets</td>
<td>1</td>
</tr>
<tr>
<td>(11) Preliminary questions to be answered before starting experimental work</td>
<td>1</td>
</tr>
<tr>
<td>(12) Introduction by library staff in literature searching</td>
<td>1</td>
</tr>
<tr>
<td>(13) Compilation of a literature survey on a set topic</td>
<td>1</td>
</tr>
</tbody>
</table>

3.3.4. Recent changes and developments

Recent changes and developments in laboratory work were investigated in two ways as described in Section 3.1.

The responses from the Heads of Departments in universities and polytechnics and from academic staff show similar trends and are grouped together in the following analysis. The number of responses included in the analysis is:

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heads of Department (or Coordinator of Lab. work)</td>
<td>31</td>
</tr>
<tr>
<td>Members of staff</td>
<td>61</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>92</strong></td>
</tr>
</tbody>
</table>
3.3.4.1. Content

(1) The strongest trend in undergraduate chemistry laboratory courses (29 respondents) is the inclusion of more instrumental techniques, particularly spectroscopic techniques, throughout the degree course.

(2) 14 respondents mentioned changes in the subject matter covered by the laboratory courses:
   (a) to reflect advances in chemistry (5 respondents)
   (b) to reflect changes in the lecture courses (4 respondents)
   (c) to include more statistical treatment of errors (3 respondents)
   (d) to include more biochemistry (2 respondents).

(3) 9 respondents said that there was now closer integration or correlation between the laboratory and theory courses.

(4) 11 respondents said that their laboratory courses had been reorganised in order to lessen the distinctions between the traditional branches of chemistry and in order to present chemistry as an integrated subject in the laboratory. This mainly took place in first year courses (see Section 3.3.3.11).

Four of the respondents reported that their courses had been changed back to a more traditional pattern. One of the respondents said that this had arisen because it seems to be the only way to ensure that all the students do cover most of the practical skills required in the overall degree programme. Another respondent pointed out that the lecture courses had not been integrated therefore got 'out of phase' with the lecture courses which was unsatisfactory.
(5) 7 respondents said that they had produced courses where the different parts were linked together more coherently in integrated sequences'.

3.3.4.2. Changes in the style of laboratory courses

(1) Projects

10 respondents reported an increase in the amount of project work used in the laboratory programme and 4 of these noted an increase in the use of project work in pre-final years.

(2) Open or problem solving work

10 respondents reported an increase in the amount of open or problem solving work. 4 of them specified that more open work was being used in the first 2 years.

The findings in (1) and (2) are in agreement with the trends noted in the literature survey in Section 3.2.1.1.

3.3.4.3. Changes in the teaching methods and materials used within the courses.

Five respondents said that efforts had been made to streamline their laboratory courses so that students got the maximum benefit out of the time spent in the laboratory.

A further 4 respondents reported a reduction in the amount of time
available for laboratory work whilst one reported that more time had been allotted to his laboratory course. It would appear from the paucity of comments about this issue that the trend to reduce laboratory time noted between 1966 and 1972 (see Section 3.2.1.4) has now slowed or stopped.

Other changes are as follows:

(1) 5 respondents had introduced computer assisted learning into the laboratory. Interactive computer terminals were being used to assist students in revising theory for experiments, in planning experiments and in working out results.

(2) 5 respondents had made calculating facilities available to the students to assist in working out results. Calculating facilities included desk top computers and calculators, on line computing facilities with a terminal in the chemistry department and use of a central university computer.

(3) 6 respondents mentioned increased use of audio-visual materials particularly videotapes and tape-slide.

(4) 6 respondents, 5 of them teaching on first year courses, said that the manipulative ability of students entering their courses was now very low and so more emphasis had to be placed in this area. One of them used videotapes in order to teach basic skills and techniques.

(5) 4 respondents had introduced tutorials or seminars related to the
practical work; 3 of them so that students could present and
discuss their results and conclusions and one of them in
order to introduce the practical work for each session.

(6) 3 members of staff had introduced group experiments. In two
of the courses students pooled their results whereas in the
third, students planned, discussed and carried out their
experiments as a group.

(7) 6 respondents had reduced the length of the write-up required
from students. 5 of them had produced instruction sheets or
manuals which left a space for students to fill in their
results, calculations and discussion of the results. One
respondent, however, was proposing to go back to the previous
scheme of insisting that students write up a full account of
each experiment in order to improve students' ability to
communicate.

(8) Respondents from 4 polytechnics said that they had replaced
practical exams by continuous assessment. Clearly the move
away from practical exams which was reported in Section 3.2.1.3
is continuing.

3.3.4.4. Summary

The main changes in undergraduate chemistry laboratory courses have
been in their content. This has changed in order to keep up with
advances both in the theoretical and in the practical and technical
aspects of chemistry. There is also more emphasis on relating the
laboratory and theoretical courses.

The trend towards more open, problem solving and project work continues. This would be expected considering the dissonance between the aims of an ideal courses noted in Section 3.3.2.5. More use is being made of technical aids to teaching i.e. calculators, computers and audio-visual materials.

3.4 Conclusions, Discussion and Recommendations

3.4.1 Relationship between aims and laboratory style

This section explores the relationship between different aims and the methods used to achieve them.

Many of the differences in emphasis between the aims in the present courses and the aims of ideal courses can be accounted for by the limitations of the particular laboratory styles being used (Section 3.3.2.5). It would therefore seem reasonable to make the assumption that the emphasis put on the aims is affected by the likelihood of these aims being achieved. If this assumption is made it is possible to draw conclusions about the types of aims that staff feel can be achieved in different styles of laboratory courses.

Table 3.28 outlines the relationship between aims and the overall laboratory style being used to achieve them. Also given in Table 3.28 are the years in which the laboratory styles were mainly used.
The aims included above are those which are considered to be important in the present courses (see Section 3.3.2.3).

The following conclusions can be drawn from Table 3.2 8:-

1. The relationship between laboratory styles and aims is confused by the fact that there is a progression of laboratory styles through the different years of the courses. Some of the aims are therefore more obviously related to the year of the course, rather than the style of the course:

   a. Aim 31 (and possibly Aim 28) is obviously more important earlier in the course when staff and students do not know one another very well.
(b) Aims 6, 7 and 17 are not emphasised in projects, presumably because it is felt that such basic skills should have been taught earlier in the degree course.

(2) There are no aims (with the possible exception of aim 28) which staff feel can only be achieved by traditional laboratory work.

A problem of using traditional courses to illustrate lecture materials (aim 2) was mentioned by 5 members of staff in interviews and is also mentioned in the literature. Students often tend to work mechanically in the laboratory simply following instructions without thinking. This problem seems to be intrinsic to the nature of traditional laboratory work:

five of the staff interviewed mentioned that if an experiment 'did not work' or students had difficulties with it they would alter the experiments to make it 'foolproof'. It appears that experiments that are designed specifically not to go wrong often require little thought in their execution. This problem is examined in more detail in the case studies in the next chapter (See also Sec. 2.2.2.1.2.).

(3) Staff feel that aims 18, 19 and 26 are underemphasised in year group 1 traditional courses (Section 3.3.2.5, Table 3.10), indicating a possible weakness of traditional courses in these areas.

(4) Most of the aims which are underemphasised in area C occur in traditional courses and clearly require open or problem solving work to achieve them e.g. aims 11, 16, 14 and 15.
(5) Staff feel that projects are particularly suitable for attitudinal aims. This is the only style of laboratory work in which it is felt that they are not underemphasised.

(6) One aim which is felt to be underemphasised in the final year is aim 23. This is not important in any of the three laboratory styles.

It appears that a shift of emphasis to areas C and D would be possible without lessening the emphasis on aims that are already considered to be important by using more open, problem solving and project work.

More open kinds of practical work, however, have more favourable student: staff and demonstrator ratios (Section 3.3.3.2). It is probably significant that in the years when there is more open work the quality of supervision is also improved with postgraduate demonstrators being used less and staff being used more (Sections 3.2.2.2 and 3.3.3.1).

It appears that 'open' types of practical work therefore demand more in terms of both amount of staff to student contact and in the quality of that contact. In order that more 'open' work can be introduced into laboratory courses, they will have to be run more efficiently.

3.4.2 Possible ways of improving the efficiency of laboratory courses

This survey was designed mainly to elucidate the staff's perception
of aims of chemistry laboratory courses and how the courses are organised. The variety of methods used within the three basic laboratory styles, however, do suggest a number of possible ways of improving the efficiency of both traditional and open types of laboratory courses.

The suggestions below are related to three areas:

(1) Improving the quality of contact between students and staff and postgraduate demonstrators by (a) improving the preparation of the teachers on the courses particularly the postgraduate demonstrators, and (b) relieving the staff and demonstrators of some of the more routine instruction by using alternative methods.

(2) Using methods of teaching and learning which will encourage the development of the skills which are not encouraged by present methods (particularly aims in Area C).

(3) Using methods which allow the laboratory and theory courses to be more closely related.

3.4.2.1 Improving the quality of contact between students and staff and postgraduate demonstrators

(a) One of the most important factors limiting the effectiveness of present courses is the quality of teaching given by postgraduate demonstrators. Short training programmes could be instituted within
departments that would both familiarise postgraduate demonstrators with the content of the courses and with the basic pedagogical skills needed in the laboratory. The latter aspect is of considerable importance in open or problem solving experiments where postgraduate demonstrators can encourage the students to solve the problems for themselves, rather than simply supply answers to questions.

In many university departments postgraduate students spend in the region of 200 or 300 hours demonstrating over 3 years. It would seem that a short time spent in initially training the postgraduate demonstrators would be amply repaid by the increased effectiveness of their teaching.

(b) The quality of the interactions between students and staff and demonstrators could also be improved by relieving the staff and demonstrators of much of the routine teaching. The following methods are currently in use in chemistry laboratories in the U.K.:-

(1) Computer assisted learning is being used both to relate the theory to the experimental work (aims in area A, particularly Aim 2) and to help students to plan experiments for themselves (aims in area C, particularly Aims 11, 12, 15 and 16). ¹

(2) Programmed learning and audiovisuial materials, particularly videotapes and tape-slides are being used to

¹ Computer assisted learning at Sheffield Polytechnic, North London Polytechnic, Trent Polytechnic and Herriot Watt University.
introduce the relevant theory (aims in area A, particularly Aim 2).  

(3) Audiovisual materials are also being used to replace individual instruction by staff and demonstrators about basic practical skills and techniques (aims in area B, particularly 6 and 7).

(4) Prelaboratory lectures, demonstrations and tutorials are also being used instead of individual instruction by staff and demonstrators to discuss the theory of the experiments and the techniques being used in the experiments (aims in areas A, B and C).

(5) Some departments are reducing the length of the write-up required from students. Some have produced instruction sheets or manuals which left a space for students to fill in their results, calculations and discussion of the results. This inevitably means that the quantity of marking is reduced.

3.4.2.2 Encouraging the development of specific skills

One aspect of the instructional environment of which little use is made at present is the help that students give one another. Pairs and

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2 Programmed learning at Sheffield University, St Andrews University Audiovisual aids e.g. at Sheffield Polytechnic, St Andrews University, Swansea University.

3 Audiovisual aids e.g. at Sussex University, Leeds University.

4 Lectures: Essex University, Belfast University, UMIST, Dundee University, Imperial College London, Keele University, Herriot Watt University.

Demonstrations:- Huddersfield Polytechnic

Tutorial: York University, North East London Polytechnic
groups usually appear to be used in practical work when there is insufficient apparatus or space for students to work individually (Section 3.3.3.1 2) and staff feel that the amount that students learn from one another is relatively unimportant (Section 3.3.3.3). In a small number of departments post-laboratory seminars or tutorials e.g. Universities of St Andrews and Exeter, are used. These would be particularly useful for achieving aims to do with data processing (area C, Aims 16, 19, 20, 21, 23) in addition to reinforcing the theoretical aspects of the work (area A).

Another method used to emphasise data processing is to supply students with specimen data to process (e.g. UMIST, Queen Mary College London, North East London Polytechnic). If students perform an experiment as a group this will obviously help to achieve aims in area E (Aims 32 and 33) as well as necessitating discussion of the experiments and results (Aim 23, area C).

3.4.2.3 More relationship between laboratory and theory courses

It is apparent that the integration of laboratory and lecture courses is difficult, especially at higher levels, and must limit the effectiveness of the laboratory for illustrating the lectures (Aim 2) (see Section 3.3.3.2 2). Two courses have shown, however, that more integration is possible if a wide variety of teaching materials is used or if the timetabling for the laboratory and theoretical components of the course is radically restructured (Section 3.3.3.2 2).

The growth in the use of individualised learning materials e.g. audio-
visual materials and computer assisted learning, in the laboratory could well help to produce more integration between lecture and laboratory courses: Individualised learning would enable students to synchronise their theoretical and practical work more: When students are taught as groups synchronisation is usually restricted by timetabling difficulties.
CHAPTER 4

EVALUATIONS OF UNDERGRADUATE CHEMISTRY LABORATORY COURSES -

SIX CASE STUDIES
This chapter describes evaluations of six chemistry laboratory courses. First the methodology of the evaluations is discussed and then the six evaluations are described in chronological order of the evaluations being carried out. The details of the methods of evaluation used are described in each evaluation report.

4.1 A paradigm for laboratory course evaluations

4.1.1 The types of data being collected

The lack of data about the different ways in which laboratory courses are organised, means that it was impossible, at the start of this study to define the important variables affecting student learning in the laboratory. Gross differences between laboratory courses, such as the differences between traditional and open laboratory courses, have been described in the literature but the subtle effects of the large number of variables within the courses have not been described.

In this study it was decided to study a small number of laboratory courses in depth, in order to describe the effects of the variables, within the different laboratory styles, on student learning. It was also decided to study a number of completely different laboratory styles in order to examine in detail the effects of the gross differences between the courses. In addition, courses in different institutions were studied in order to gain an understanding of the effects of institutional constraints on the courses.

The aim was to produce descriptive reports which explained why
different laboratory courses were successful or unsuccessful. There was no question of sampling courses because the large number of variables would make this meaningless and there was no attempt made to control the different parameters within the courses.

The courses studied are briefly characterised below.

<table>
<thead>
<tr>
<th>Type of lab. course</th>
<th>Described in section</th>
<th>Code no</th>
<th>Type of students</th>
<th>Subject area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open 4.2 I Chem.II</td>
<td>4.2</td>
<td>I</td>
<td>Chem.II</td>
<td>Inorganic</td>
</tr>
<tr>
<td>Traditional 4.4 III</td>
<td>4.4</td>
<td>III</td>
<td>Chem. I</td>
<td>Inorganic</td>
</tr>
<tr>
<td>Open (groups) 4.5 IV</td>
<td>4.5</td>
<td>IV</td>
<td>Chem.Eng.I</td>
<td>Org.+inorg.</td>
</tr>
<tr>
<td>Traditional 4.6 V</td>
<td>4.6</td>
<td>V</td>
<td>Chem. II</td>
<td>Physical</td>
</tr>
<tr>
<td>Traditional (unit lab.) 4.7 VI</td>
<td>4.7</td>
<td>VI</td>
<td>Chem.I+II</td>
<td>Integrated Chem.</td>
</tr>
</tbody>
</table>

It is envisaged that staff reading the reports would be able to use them in two ways:

(i) Staff with similar courses would be able to examine the findings of the evaluations to gain insight into how students learn in that kind of course. They would be able to see why certain aspects of the course promote learning and why other parts inhibit learning and they would gain some insight into the effects of changing some variables within the course.

(ii) Staff who are not familiar with this kind of course would get

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1 c.f. Smith and Pohland (152), section 2.3.1.3
an idea of how this kind of course runs and what it achieves. In addition, by comparing the evaluations it was hoped to provide some summative information about the different types of laboratory courses available for achieving different groups of aims.1

In order to produce the appropriate descriptive evaluation reports, it was decided to collect data in many of the areas outlined by Stake's (156) data matrix. The evaluations concentrate on the 'transactions' and 'outcomes' part of the matrix, but some information was also collected about 'antecedents'.

(a) Antecedents
In the study of the observed transactions it was found that some of the antecedents had an important effect on the quality of teaching and learning in the laboratory and where this was true, these antecedents were studied. Examples of antecedents of this type were (i) whether students had sufficient preknowledge to cope with the experiments and (ii) whether P.G. demonstrators were well enough prepared for their role in the laboratory.

(b) Transactions
The evaluations study how the courses were organised and the opinions of the participants were sought in order to find out the extent to which the way the course is organised, reflects the aims and to elucidate factors which promote or inhibit the achievement of the aims.

---

1 Kemmis (84a) describes this as a surrogate experience of the course
2 See section 2.3.1.3
The evaluations have identified the aims of the courses and also what aims staff would like to achieve in an ideal situation. Information has therefore been collected about intended outcomes and judgements about the adequacy of these aims, but, because of the imprecise nature of these aims, it was difficult to collect data relating to observed outcomes and the standards by which these outcomes were judged. It was, however, possible by examining the transactions to identify factors which were affecting the achievement of the aims.

In order to understand the data collected in these areas it was necessary to seek for relationships between the different items of data and to explain these relationships. The methodology embodied in illuminative evaluation offered a suitable means of investigation.

4.1.2 A strategy for data collection

The evaluations were carried out in four stages, based on those outlined by Parlett and Hamilton (129) and Becker (9). The four stages are:

(i) The evaluator becomes knowledgeable about the scheme. He collects data to define the problems and concepts to be investigated.
(ii) The evaluator inquires further. He seeks more evidence to support of refute data collected in (i). He seeks to quantify the qualitative data collected in stage (i) and he looks for relationships between different areas of data.
(iii) The evaluator seeks to explain his observations in stages (i) and (ii). He builds up a theoretical model of the laboratory course.

(iv) In the fourth stage the evaluator analyses the results and rechecks and rebuilds the theoretical models by cross-checking all the data available.

These stages do not necessarily occur in sequence because an evaluator may still be seeking basic data about one area of the course whilst he is already building theoretical models about other areas. In addition, the four stages may not necessarily occur within one laboratory course: The data gained from one laboratory course may be used as the basis for investigations in a later course.

The stages embody the concept of progressive focussing. As the evaluation moves from the exploratory observations to further enquiries, it focusses progressively on important issues, thereby narrowing the width of the study and allowing important issues to be studied in depth.

Each stage will now be considered in more detail.

4.1.2.1 Stage (i)

Some data was collected before going into the laboratory. First the educational literature about laboratory courses was studied so as to define initial areas of enquiry\(^1\). All the available

---

\(^1\) Smith and Pohland (152), see section 2.3.1.1
documentary evidence about each course was studied, such as instruction sheets given to students and in courses IV and VI minutes of meetings in which the setting up of the courses was discussed.

On entering the laboratory, basic data about the course was gathered by (a) observation  
(b) discussion and interviews  
(c) questionnaires

(a) Observations

Two strategies for observation were used:  
In course I, the evaluator attended the course first as a participant observer as a student, and then when the course ran for a second time as a demonstrator. In courses II and IV the evaluator attended the course as a demonstrator. In all these courses the dual role of the evaluator, i.e. as evaluator and participant, was known to the participants. Although the role of participant observer gave the evaluator valuable insight into the organisation of the course and enabled him to quickly establish rapport with the participants, it was very demanding in terms of time and limited the depth into which some topics could be investigated.

The second strategy for observation is what Schatzman and Strauss (146) describe as 'active control'. The evaluator attended courses III, V and VI as a researcher. As well as observing he engaged the participants in conversation in order to obtain their opinions of the courses.

1 c.f. Schatzman and Strauss (146), see section 2,3,2.2
(b) Interviews and discussion

Basic data about the courses were also collected by interviews and
discussions, although interviews and discussions tended to concentrate
on stages (ii) and (iii).

(c) Questionnaires

Questionnaires were used to obtain data about predefined issues:
(i) In each course an aims questionnaire was given to staff and students.

(ii) Feedback sheets were also used extensively to find out students'
opinions of the interest, difficulty and relevance to the lecture
courses of specific experiments and to find out what difficulties
they had with the experiments.

(iii) Other questionnaires were designed to find out specific pieces
of information, e.g. feedback sheets about audiovisual aids.

4.1.2.2 Stage (ii)

The data collection in this stage was based on three data sources:
(a) observation
(b) discussions and interviews
(c) ad hoc questionnaires

1 Much of the information collected by these feedback sheets was
suitable for improvement of individual experiments, but is not
relevant to the summative reports described in this chapter.
Only relevant information has been included.
(a) Observation

In courses I and II the relationships between students and staff/demonstrators and amongst students was found to have an important effect on the success of the courses. In courses III, V and VI observation was therefore used to quantify student, demonstrator and staff activities in the laboratory.

At intervals of about half an hour or an hour observations were made of what all the different people in the laboratory were doing and of the types of interaction between the different people in the laboratory.

(b) Discussion and interviews

Discussions and interviews fell into two types:

Type 1: These interviews lasted about half an hour to an hour and covered a wide range of issues. Staff interviews were usually held in their rooms and student interviews in informal gathering places such as coffee bars. The interviews were mainly non directive so that interviewees would reveal issues in the courses which were important to them. An interview schedule was used but interviewees were only asked specific predefined questions if the discussion had not included them. The interviews were therefore used to focus the attention of the evaluator on issues which were important to the participants and to seek for relationships between specific items of data. This type of interview was also used to provide data for stage (iii).
Type 2: These interviews or discussions were shorter, lasting less than 15 minutes and were much more specific in content. They were usually held in the laboratory at times convenient to the interviewees and were held with staff, demonstrators, technicians and students. This type of interview sought clarification of specific activities and sought quantification of data in small areas of the evaluations.

Most of the interviews in the evaluations were of type 1. Almost all interviews were tape-recorded.

In course V due to the poor response rate to questionnaires interviews replaced questionnaires as the primary data source for quantification.

(c) Ad hoc questionnaires

These questionnaires were designed to obtain data about issues which had already been defined in earlier parts of the evaluations, e.g. interviews, and in earlier evaluations. The questionnaires sought to quantify the data and to seek for relationships between the data.

Some questions were designed to cross-check the validity and reliability of data found in other parts of the evaluation and other open questions were designed to check the validity of the focusing taking place, to make sure that all the important issues were being studied.

Some data for stage (i) were also gathered by these questionnaires but this was not their primary function.

Ad hoc questionnaires were also used for stage (iii).
4.1.2.3 Stage (iii)

In this stage the evaluator sought to explain the relationships between items of data and to build up a theoretical model of the laboratory course. Participants were therefore asked to explain their actions and opinions in type 1 interviews and in ad hoc questionnaires.

The emphasis in the data collection gradually shifted from stage (i) to stage (iii) as the evaluations succeeded one another and as the process of focusing became more advanced.

4.1.2.4 Stage (iv)

During the evaluations the evaluator made judgements about the choice of issues to be investigated. The choice of issues was dictated by the kind of information required from the evaluation and by the views of the participants of the important issues affecting the teaching and learning process in the laboratory.

Having selected the issues to be investigated the evaluator then collected data from which he could start to build theoretical models. Stage (iv) was used to test the validity of the conclusions reached and to present the reader with a descriptive report in which an account is given of the data on which the conclusions are based.

Much of the data used in the evaluations was subjective and based on small numbers of respondents. Some individual items of data
are therefore unreliable if they are examined by themselves. The importance of stage (iv) is to link these individual items of data into a coherent whole, so that items of data from different sources can be cross-checked against one another\(^1\).

The first part of stage (iv) was, therefore, to arrange the data in an accessible form so that all the data relevant to a particular theory or concept could be scrutinised and cross-checked.

The second part of stage (iv) was to report the findings in such a form that the data on which the conclusions are based are subject to scrutiny. In order to do this, the sources and strength\(^2\) of the data used have been supplied in the evaluation reports.

The strength of illuminative evaluation lies in the ability of the evaluator to make pragmatic decisions about the issues to be investigated and the methods of investigation. The decision making capacity of the evaluator does mean, however, that there is a possibility of evaluator bias in the selection of data for inclusion in the evaluation report and the interpretation of the data. Two safeguards exist in stage (iv) to reduce observer bias:

(a) The reader is able to scrutinise the data and the conclusions reached in the report.

(b) Opinions of staff involved in the course about the evaluation

---

1 This is called triangulation by Webb et al (173)

2 e.g. the strength of the data may be indicated by the number of students giving a particular opinion expressed as a percentage of those asked a particular question.
reports can be sought. In all cases staff felt that the evaluation gave a fair description of the courses.
4.2 An evaluation of a second year inorganic laboratory course
   - Course I

This is the first of the six case studies described in this chapter. As far as possible the method of reporting the case studies has been standardised so as to make comparison between different case studies easier. At the beginning of each case study there is an index as to its contents.

Index

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<th>Page</th>
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<td>4.2.4.3 Some possible improvements</td>
<td>201</td>
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</table>
At the time of the evaluation in the 1973/74 academic year the course had been running for three years and was novel in that it was an open or problem solving course.

In the second year of the chemistry degree course students were divided into two groups. Each of the groups studied a physical, an inorganic and an organic chemistry laboratory course but in a different order from the other group. It was thus possible to evaluate the inorganic laboratory course first during the autumn term of 1973 and then again in the latter part of the spring term and the early part of the summer term of 1974.

4.2.1 Methods of evaluation

The sources of data for the evaluation, the times when the particular data sources were used and the stages in the evaluation to which they are mainly related, are outlined below. All relevant questionnaires and interview schedules are included in Appendix A.4.2.
**Autumn 1973**

Total number of students attending course = 16
Total number of staff attending course = 3
Total number of P.G. demonstrators attending course = 3

<table>
<thead>
<tr>
<th>Data source</th>
<th>Time of use</th>
<th>Response</th>
<th>Stage of evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Documentary evidence</td>
<td>prior to and during course</td>
<td>-</td>
<td>(i)</td>
</tr>
<tr>
<td>Instruction sheets given to students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Observation</td>
<td>throughout course</td>
<td>-</td>
<td>(i)</td>
</tr>
<tr>
<td>Participant observation as student</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Interviews (type 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) 3 staff (100%)</td>
<td>from middle of course</td>
<td>all</td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>(b) 3 P.G. demonstrators (100%)</td>
<td>to end</td>
<td>all</td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>(c) 16 students (100%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Students

(a) aims questionnaire | beginning course | 16 16 100 | (i) |
(b) aims questionnaire | end of course | 16 16 100 | (i) |
(c) ad hoc questionnaire | end of course | 16 16 100 | (i)(ii)(iii) |

Staff and demonstrator aims questionnaire | end of course | 6 5 83 | (i) |

1  See section 4.1.2
Total number of students = 19

<table>
<thead>
<tr>
<th>Data sources</th>
<th>Time of use</th>
<th>Response</th>
<th>Stage of evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Documentary evidence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Instruction sheets given to students</td>
<td>throughout course</td>
<td>-</td>
<td>(i) 1</td>
</tr>
<tr>
<td>(b) Marking schedules for 2 experiments</td>
<td></td>
<td></td>
<td>(i)(ii)</td>
</tr>
<tr>
<td>(2) Observation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant observation as demonstrator</td>
<td>throughout course</td>
<td>-</td>
<td>(i)</td>
</tr>
<tr>
<td>(3) Interviews (type 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 students (47%)</td>
<td></td>
<td></td>
<td>(ii)(iii)</td>
</tr>
<tr>
<td>(4) Questionnaires</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) aims questionnaire</td>
<td>beginning course</td>
<td>19</td>
<td>74</td>
</tr>
<tr>
<td>(b) aims questionnaire</td>
<td>end of course</td>
<td>19</td>
<td>47</td>
</tr>
<tr>
<td>(c) feedback sheets</td>
<td>after each experiment</td>
<td>83</td>
<td>49</td>
</tr>
</tbody>
</table>

1 See section 4.1.2.1
4.2.2 Aims

4.2.2.1 Aims of the actual course

The stated aims of the course were:
(i) To bridge the gap between the individual training of the first year and the research requirements of the industrial year and final year chemistry.

(ii) Where possible, to supplement the second year lecture course.

The aims questionnaire gives a good indication of what these aims meant in practice to the participants. The staff and students were in quite good agreement about the aims of the course. The main emphasis was on areas B and C and to some extent E.

Area B

Aim 6: To teach basic practical skills and techniques
Aim 7: To familiarise students with some important instruments and devices

Area C

Aim 19: To develop students' ability to make deductions from

---

1 An aims questionnaire was used to evaluate opinions about the aims of the course. After the experience gained in this evaluation the aims questionnaire was modified and where possible the aims are numbered according to the modified questionnaire: This is the aims questionnaire included as a fold out in Chapter 2.

2 Out of the 27 aims there was only one statistically significant difference (at the 0.05 level) between the mean ratings of the two groups of students. This would be expected randomly anyway and so the two groups have been aggregated for this comparison.
Aims of present course

The aims are numbered according to the modified questionnaire.
The crosses which are circled are numbered according to the unmodified course I questionnaire.
Aim 22: To train students in writing reports on experiments

Area E
Aim 31: To provide closer contacts between students and academic staff.

Other aims in areas B (e.g. aim 8), C (e.g. aim 11) and D (e.g. aim 24, 25) were also considered to be quite important (see graph 4.3.1).

There were some differences between the staff and students' perceptions of the course:

Students thought that the course was trying to teach theoretical material not included in lectures and tutorials (aim 1) and found the problem-solving aspects of the course more challenging than was realised by staff (aims 11 and 16).

Staff thought that an important aim of the course was to stimulate the students' interest, but students did not see this as being so important.

4.2.2 Aims of an ideal course

Staff and students were generally agreed that the aims of the present course were the right ones and that they should be emphasised strongly in an ideal course (Graph 4.2.2). In addition staff and students felt that several aims in area C should be emphasised more strongly. Staff thought aims 12, 16 and 18 should be emphasised more strongly and students thought aims 10, 11 and 16 should be emphasised more
Aims of ideal course

Graph 4.22

X = Modified questionnaire
O = Original course I questionnaire
Staff dissonance between ideal and actual aims

Graph 4.23

X = Modified questionnaire
Ø = Original course I questionnaire
Students dissonance between ideal and actual aims

Graph 4.24

Key
X I-A is positive
O I-A is negative
□ I-A is positive but the number of the aims is according to the original course I questionnair
4.2.3.1 How was the course structured?

The course lasted for 8 weeks with three sessions of 3 hours per week. The course ran twice in the 1973/74 academic year. The first course in the Autumn term was attended by 16 students and the Spring/Summer term course was attended by 19 students. Three staff and 3 P.G. demonstrators demonstrated on the course, two for each practical session.

4.2.3.1.1 Course content

The course was divided into seven experiments which were to some extent interdependent. Each contained a proportion of preparative, analytical and general chemistry, and some involve instrumental measurements.

4.2.3.1.2 Resources

(a) Written materials

The students were issued with an assignment sheet for each experiment.
Most assignment sheets were divided into six sections:

(i) Introduction

(ii) Aims, e.g. - to study the preparation of the dextro isomer of an octahedral chelate complex and measure its optical activity;
- to become aware of the property which enables a resolution of isomers to be made;
- to scale down a published experimental method.

(iii) Experimental
This gave an experimental instruction such as 'Prepare 2g of dextro-tris (ethylene diamine) cobalt (III) iodide', but usually gave no specific experimental details.

(iv) Discussion
This gave an outline of what theory should be included in the report on the assignment.

(v) References
The references to books or periodicals in the library contained experimental details and the theory needed to interpret and discuss the experiment.

(vi) Notes
These gave a bit more guidance on what to write in the report on the experiment.
(b) People

Students could consult staff or P.G. demonstrators when they were available. The staffing ratios were

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Spring/Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>student : staff</td>
<td>16:1</td>
<td>19:1</td>
</tr>
<tr>
<td>student : demonstrator</td>
<td>16:1</td>
<td>19:1</td>
</tr>
<tr>
<td>student : staff + demonstrator</td>
<td>8:1</td>
<td>10:1</td>
</tr>
</tbody>
</table>

(c) Apparatus

Students were provided with basic glassware but other items were available from the store on request. Much of the instrumentation used was in laboratories adjacent to the second year teaching laboratories.

4.2.3.1.3 Activities

Before starting each experiment students often had to consult the literature to derive appropriate experimental procedures. After carrying out the practical work in the laboratory they had to write a full report on each experiment which included a discussion of the results, for which it was again necessary to consult references in the library.

Staff and P.G. demonstrators divided their time between the following activities:
(i) Supervising the students in the laboratory
(ii) Discussing experiments with the students
(iii) Teaching the students how to operate various instruments
(iv) Marking students' reports
(v) Discussing students' reports with them.

4.2.3.1.4 Assessment

The students were assessed on the basis of written reports. For two experiments there were objective marking schemes but these were only used by three staff/demonstrators. Most marking was therefore subjective.

4.2.3.2 How did the participants react to the course?

4.2.3.2.1 Reactions of students

(a) Interest

The end of course questionnaire showed that students(I)\(^1\) found the course interesting and more interesting than previous courses\(^2\). A similar level of interest is indicated by students (II) in the feedback sheets:

---

1 Throughout this section students who did the course in autumn 1973 will be referred to as students I and those who did it in spring/summer 1974 as students II.

2 In the questionnaire 10 students (63\%) said that they found the course either quite interesting or stimulating and in interviews 10 thought it was more interesting than previous courses.
### TABLE 4.2.1

<table>
<thead>
<tr>
<th>Experiment</th>
<th>B</th>
<th>A2</th>
<th>3</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>19</td>
<td>3</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Response rate</td>
<td>14</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>% response rate</td>
<td>74</td>
<td>-</td>
<td>32</td>
<td>42</td>
<td>37</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$\bar{x}$</th>
<th>$\sigma$</th>
<th>$\bar{x}$</th>
<th>$\sigma$</th>
<th>$\bar{x}$</th>
<th>$\sigma$</th>
<th>$\bar{x}$</th>
<th>$\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty</td>
<td>2.7</td>
<td>0.8</td>
<td>2.0</td>
<td>-</td>
<td>2.7</td>
<td>0.9</td>
<td>3.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Interest</td>
<td>3.1</td>
<td>0.8</td>
<td>4.5</td>
<td>-</td>
<td>3.5</td>
<td>0.5</td>
<td>3.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Relevance</td>
<td>3.4</td>
<td>0.5</td>
<td>4.0</td>
<td>-</td>
<td>2.5</td>
<td>0.8</td>
<td>4.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

$\bar{x}$ = Mean of ratings  
$\sigma$ = Standard deviation

Experiment A2 was only done by 3 students.

The level of interest of the experiments varied. Students (I) were asked which experiments they found most interesting and which they found least interesting. The results are shown below in Table 4.2.2.

### TABLE 4.2.2

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Most interesting (no. of students)</th>
<th>Least interesting (no. of students)</th>
<th>No. of students having difficulties</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>A4</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

1 The course was modified for students (II). Experiments A1 and A4 were combined to form experiment A2.

2 Questions 2, 3, 6 in questionnaire
Students found experiment A1 uninteresting because no thought was required whereas some students found experiment A4 uninteresting because they had studied the work before at school\footnote{1}.

Students on the whole found experiments 3 and 5 most interesting. Students\footnote{2} liked the variety of experimental work included in these experiments, i.e. preparations, analyses and the use of instrumentation. They found the content interesting\footnote{3} and enjoyed using instruments and techniques which were new to them\footnote{4}.

Experiment 3 was not as closely related to the lecture courses as experiment 5. This, together with the fact that the instruction sheets were not very clear for experiment 3 led to some students (I) having difficulties with this experiment (Table 4.2.2). Three students, however, found studying the literature for this experiment most interesting and found it interesting to examine contradictory theories in the literature in the light of their experimental results.

As a result of the criticisms of experiment 3 by students (I) the instruction sheets were modified for students (II) and there were no complaints from students (II) about the instruction sheets.

\begin{itemize}
\item \footnote{1} Questionnaire, question 3: 6 students (33%)
\item \footnote{2} Questionnaire, question 2, Experiment 3: 2 students; Experiment 5: 3 students
\item \footnote{3} Questionnaire, question 2, Experiment 3: 4 students; Experiment 5: 4 students
\item \footnote{4} Questionnaire, question 2, Experiment 3: 1 student; Experiment 5: 5 students.
\end{itemize}
(b) Relevance to lectures
Most students\(^1\) thought that the laboratory course was not closely related to the lecture courses and staff and students were agreed that there should be closer links between the laboratory and lecture courses\(^2\). Some students\(^3\) thought that this would give them a better understanding of what they were doing in the laboratory.

The course organiser agreed that ideally there should be a closer relationship between the laboratory and lecture courses, but thought that this was very difficult to achieve in practice\(^4\).

The open nature of the course, however, meant that students got results that they could not necessarily have predicted and that a lot of background reading had to be done to meaningfully interpret the results. Students therefore had to study the relevant theoretical material on an individual basis. This was one factor which contributed to the write-up taking such a long time (see section 4.2.3.2.3).

(c) Lack of time
A problem which seems to have detracted from the success of experiments 3 and 5 in particular, is that there were some organisational problems with the use of the chemical instruments. Students tended to do the experiments in roughly the same order and consequently needed to use

---

\(^{1}\) Students (I): Questionnaire, question 12: 9 students (56%)
Students (II): Feedback sheets; see Table 4.2.1

\(^{2}\) Section 4.2.2.2

\(^{3}\) Questionnaire, question 13: 4 students (25%)

\(^{4}\) Interview
the instruments at about the same time as one another. This led to long queues and for the U.V. spectrophotometer students had to wait on average 1 or 2 practical sessions before they could use it\textsuperscript{1}.

Most of students (I)\textsuperscript{2} complained that there was not enough time to do the experiments properly. This meant that if the students obtained poor results, they did not have enough time to repeat the experiment and instead they 'fiddled' their results\textsuperscript{3}.

It can thus be seen that the achievement of some of the important aims of the course, such as aim 11, 'to develop students skill in problem-solving by experimental work', was being limited by organisational problems coupled with a high workload.

Students (II)\textsuperscript{4}, however, said that they had enough time to do the experiments to their satisfaction. Three factors may have contributed towards this different reaction to the course: (i) Some of the experiments had been modified to iron out difficulties encountered by students (I). (ii) Students (II) were able to consult students (I) who had already done the course. (iii) Students (II) did the course at the end of their second year, whereas students (I) did it at the beginning. Students (II) had therefore spent more time doing both experimental and theoretical work.

\begin{itemize}
  \item[1] Observation
  \item[2] Interviews: 12 students (75%) 
  \item[3] All students (I) interviewed admitted to fiddling at least one of their results
  \item[4] 7 out of 9 students interviewed
\end{itemize}
4.2.3.2.2 Staff and demonstrators

In an open or problem solving course of this type it is necessary for staff and demonstrators to be available to discuss the experiments with students and to help them with their problems. Staff, P.G. demonstrators and students were therefore agreed that aim 31 was an important aim of the course: Aim 31: 'To provide closer contacts between students and academic staff'. (see section 4.2.2.1).

Most of students (I)\(^1\) did in fact find the staff and demonstrators to be helpful. There were, however, some problems:

(i) Both staff and students\(^2\) thought that staff had insufficient time in the laboratory to cope with all the students' problems. Staff said that teaching students how to operate the various instruments used in the course was very time consuming and also that vast amounts of time had to be spent marking. As a result students tended to consult one another instead of staff and demonstrators\(^3\).

(ii) Students could consult staff and demonstrators when they wished. Some students, however, felt uneasy about asking staff and demonstrators to explain how to use the chemical instruments. They felt that the staff thought that the students should know how to use

\(^1\) Questionnaire, question 10: 12 students (I) (75%)

\(^2\) Staff interviews; Student interviews: 6 students (I) (38%), 4 students (II) (44%)

\(^3\) Questionnaire, question 17, Students (I) interviews: 7 students (II) (78%)
the instruments and therefore asked other students how to use them\(^1\).
This was not always satisfactory as some students never learnt how
to use the instruments properly\(^2\).

(iii) Some staff, P.G. demonstrators and students thought that the
P.G. demonstrators were insufficiently well prepared for the course
and that they did not know enough about the experiments to be
marking them\(^3\). Students also found that P.G. demonstrators did
not know the answers to many of the questions which they were asked\(^4\).

4.2.3.2.3 How students coped with the open course?

(a) Doing the experiment
In order to derive suitable experimental details each student had
to study the instruction sheets and sometimes some of the references
and to consult the various people available in the laboratory.
The table below shows the factors affecting the choice of
experimental methods for students (I)\(^5\).

<table>
<thead>
<tr>
<th>TABLE 4.2.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
</tr>
<tr>
<td>(a) Using a method someone has already used</td>
</tr>
<tr>
<td>(b) Weighing up the different possibilities in your mind</td>
</tr>
<tr>
<td>(c) Discussion with friends</td>
</tr>
<tr>
<td>(d) Discussions with staff/demonstrators</td>
</tr>
</tbody>
</table>

1 Interviews: 5 students (I) (31%)
2 Observation
3 Interviews: 2 staff, 1 P.G. demonstrator, 6 students (I) (38%)
4 Interviews: 6 students (I) (38%)
5 Questionnaire, question 17
It can be seen that students usually used a method that had already been used by some one else, but that in deciding whether to use a particular method, students thought that discussion with friends was important and that discussion with staff or demonstrators was rather less important. Students also attached some importance to weighing up the different possibilities in their minds.

On the whole, however, students did not feel that they had to use their initiative very much\(^1\).

(b) The write-up and assessment

Having done an experiment in the laboratory students then had to write a report about the experiment which was used to assess their work. Students were initially given little guidance about what to write and several students commented that they did not know how much they were expected to write for the first experiment\(^2\).

Although students did not usually feel that they were in a position to judge what grade should be awarded for each experiment, some students\(^3\) felt that the grade that they had been given for their first experiment was too low. This again indicates that students did not know what to write.

After each experiment had been marked there was usually some discussion between staff/demonstrators and each student. Students\(^4\) found this

---

1 Questionnaire, question 18, Students (I) 15 students (94%)
2 Feedback sheets: 3 students (II) (15%); Questionnaire, question 6, 6 students (I) (38%)
3 Interviews: 4 students (I) (25%)
4 Interviews: 16 students (I) (100%)
discussion useful and thought that they had a better idea of what to write after they had had their first experiment marked.

There was, however, some disagreement amongst staff\(^1\) about the importance of different aspects of the report. Some staff thought that not enough emphasis was placed on getting accurate results, whereas others thought that it was more important to be able to interpret the results. This disagreement was reflected in the uncertainty amongst students about the importance of these aspects of the experiment. Some of the students (I) thought that making accurate experimental readings was a very important aim of the course, whereas other students thought it was only moderately important\(^2\). Similarly, students (II) disagreed with one another about the importance of accurate results in the marking of an experiment\(^3\).

Marking schemes had been made up for two of the experiments, but these were only used by two P.G. demonstrators and one member of staff. More extensive use of marking schemes would have helped to standardise the assessment.

The majority of the staff and students thought that the length of the reports on the experiments should be reduced\(^4\). The table below shows the length of time spent in the laboratory and the length of

<table>
<thead>
<tr>
<th>Rating</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>very important</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of students</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>1</td>
<td>5</td>
<td>----------------</td>
</tr>
</tbody>
</table>

---

1. Staff interviews and aims questionnaire
2. Aims questionnaire (Aim 8 = Aim 16 of survey questionnaire)
3. Interviews: Estimates of the proportion of marks given for results varied from 35 to 65%
4. Interviews: 12 students (I) (75%), 7 students (II) (78%)
   4 staff/demonstrators (67%)
time spent doing the write-up\(^1\).

**TABLE 4.2.4**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>No. of students responding</th>
<th>Time spent in the lab (hrs)</th>
<th>Time spent writing-up (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(\bar{x})</td>
<td>(\sigma)</td>
</tr>
<tr>
<td>A2</td>
<td>2(^3)</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>14</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

It can be seen that students spent almost as long writing up the experiments as they spent in the laboratory.

Students spent a lot of time writing-up the experiments in the library. Most of students (I)\(^2\) looked up all or most of the references given in the instruction sheets and the remainder of the students tended to look up alternative references. Half of the students (I) said that they had difficulty in finding the books given as references in the library, because they had been taken out and half the students found some of the references either irrelevant or of no use in helping them to write-up the experiments. As a result of the comments of students (I), one reference, which was used as the basis for the experimental method of experiment 3, was photocopied for students (II), thus

---

1 Information from feedback sheets
2 Questionnaire, question 14: 13 students (80%)
3 Only three students did this experiment
relieving some of the congestion in the library.

Two members of staff\(^2\), however, suggested that the amount of time spent in the library should be reduced by half.

As has been pointed out, it was not made clear to the students how much they were expected to write and so students\(^1\) tended to write a lot in order to include everything which they thought might be relevant. This meant that reports were very lengthy and that as well as taking the students a long time to write, they also took staff and demonstrators a long time to mark. This had the effect that staff and demonstrators had insufficient time for all their other activities in the laboratory and that staff also found themselves having to do a lot of marking outside the laboratory.

4.2.4 Achievement of aims

4.2.4.1 Factors affecting achievement of aims

This section examines some of the factors which have been found to be affecting the success of the course.

(a) The fact that the course was an open one meant that it was possible to achieve a wide variety of aims and that on the whole the staff and students were satisfied with the width of the aims of the course.

---

1 Interviews: 3 students (II) (33%) thought that credit was given for writing a lot. 4 students (II) (44%) did not know how much to write.

2 Staff interviews
Students generally found the course interesting and enjoyed the variety of practical and theoretical material included in the course.

(b) Staff and P.G. demonstrators had to be available to discuss the experiments with students. Since the experimental methods for the experiments were not fixed, the range of questions and the range of difficulties which students encountered was greater than in a traditional course. Staff and P.G. demonstrators therefore needed a great deal of expertise in practical chemistry and also the pedagogical expertise to guide students through their experiments. Students, however, found that P.G. demonstrators did not have the necessary expertise.

(c) The wide variety of aims also meant that it was difficult for staff, demonstrators and students to decide what were the most important aspects of the experiments. This led to students having problems knowing what to write in their reports and in the students producing reports which were very long and took a long time to mark. In addition, there was some disagreement amongst the staff and demonstrators as to what aspects of the report were most important.

(d) In addition to guiding students through experiments and marking students' reports, staff and demonstrators had to teach students how to use the various instruments. Since the course was an open one, students worked at their own pace and needed to be taught how to use the instruments at different times from one another. Staff and demonstrators therefore gave individual instruction in the use of instruments.
(e) Staff and demonstrators found that demands on their time were very high and as a result, students were sometimes unable to consult them. This led to some students not learning how to use the instruments properly as they received inadequate instruction from other students.

In addition students relied a lot on one another when deciding what experimental method to use. The openness of the course was therefore not as great as would seem from the instruction sheets, because where students might have been expected to use their initiative, they often consulted other students. Nevertheless, students had to make many more decisions about the experimental methods than in a traditional course.

Another factor which detracted from the problem solving nature of the course was the fact that students (I) had insufficient time to repeat experiments when they obtained poor results. Instead they 'fiddled' their results.

(f) Students were allowed to do most of the experiments in any order, but usually did them in the same order as one another, perhaps because they got help from one another. This led to organisational problems with too many people wanting to use the same instruments and the same books and periodicals at the same time.

4.2.4.2 Extent of achievement of aims

(a) Students had practice in using various skills, techniques and instruments, but success in achieving aims in area B was limited by the lack of staff/demonstrator time.
(b) Aims in area C to do with problem-solving in the laboratory were only partially achieved because of students consulting one another and because they had insufficient time.

(c) The large amount of time that students spent making deductions from experimental data, interpreting experimental data and writing-up their experiments meant that the achievement of aims in area C, related to these skills, was quite high.

(d) The course was quite successful in interesting the students and required them to use their initiative to a limited extent and was therefore quite successful in achieving the main aims of the course in area D.

(e) Achievement of aim 31 in area E was limited because the staff and demonstrators were very busy but the students generally found the staff and demonstrators to be helpful.

4.2.4.3 Some possible improvements

4.2.4.3.1 Use of staff and demonstrators

Two changes could be made to reduce the workload of the staff and demonstrators:

(a) Time could be saved in teaching instrumental skills. Either groups of students could be taught how to use the instruments at the beginning of the practical sessions, thus avoiding the necessity for repetitions to individual students, or students could be taught
instrumental skills on an individual basis by audio-visual material, such as videotapes.

(b) The amount of time assessing students' work could be reduced by reducing the length of students' write-ups.

(c) The efficiency of P.G. demonstrators could be improved by giving them some form of training to prepare them for their role in the laboratory.

4.2.4.3.2 The write-up and assessment

Staff should agree what is required for the reports of the experiments and what weighting should be given to the different aspects of the reports. Students should then be given some explicit guidance about what to write. This would help to reduce confusion amongst students about what and how much to write and would hopefully make reports more concise and easier to mark.

For some experiments, shortened reports coupled with discussions between staff/demonstrators and students could be used.

4.2.4.3.3 Order of experiments

Various organisational problems arose from the fact that students preferred to do the experiments at the same time as one another. This could be overcome by restricting student choice as to the order in which they did experiments. It is difficult to predict, however, what effects this would have on other aspects of the course, e.g.
the amount of help given by students to one another and the demands made on staff and demonstrator time.

4.2.4.3.4 Encouraging an investigative approach

In order to encourage problem solving in the laboratory sufficient time should be given for students to repeat experiments and to investigate problems. Students should also be given credit for their efforts at problem solving as well as for their final report.
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<th>Index</th>
<th>Page</th>
</tr>
</thead>
<tbody>
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<tr>
<td>4.3.2 Aims</td>
<td>206</td>
</tr>
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<td>4.3.2.1 Aims of the present course</td>
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</tr>
<tr>
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<td>229</td>
</tr>
</tbody>
</table>
The course was evaluated in the Spring term of 1974. The course was part of the chemistry teaching given to first year chemical engineers. It included organic and inorganic chemistry and was organised by two members of staff, one who gave organic and the other who gave inorganic lectures to chemical engineers.

The course had remained unchanged for several years, but this year's course was modified in order to make it more relevant to chemical engineers. One of the purposes of the evaluation was to monitor the effects of the changes. Further changes were made for the 1975 course and this course is described separately in section 4.5.

### 4.3.1 Methods of evaluation

Details of the methods of evaluation used are given below.

- Total number of students attending the course = 22
- Total number of staff attending the course = 2
- Total number of P.G. demonstrators attending the course = 1

<table>
<thead>
<tr>
<th>Data source</th>
<th>Time of use</th>
<th>Response</th>
<th>Stage of evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Documentary evidence</td>
<td>prior to and during course</td>
<td>-</td>
<td>(i)</td>
</tr>
<tr>
<td>Instruction sheets given to students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Observation</td>
<td>throughout the course</td>
<td>-</td>
<td>(i)</td>
</tr>
<tr>
<td>Participant observation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>as a demonstrator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Interviews</td>
<td>before, during and after the course</td>
<td>-</td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>(a) 2 staff - interviews</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>took the form of frequent informal discussion (types 1+2 interviews)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) 4 students (18%)</td>
<td>near end of course</td>
<td>100%</td>
<td>(ii)(iii)</td>
</tr>
<tr>
<td>(type 1 interviews)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 See section 4.1.2
4.3.2 Aims

4.3.2.1 Aims of the present course

The stated aims of the course were:

(a) To illustrate certain topics connected with the lecture courses.
(b) To familiarise the students with laboratory apparatus and instrumentation.
(c) To study some aspects of chemistry in depth.
(d) To become familiar with laboratory scale experiments within the context of the research and development requirements of chemical engineers.

In their responses to the aims questionnaire staff and students showed that they were in quite close agreement about the aims which were emphasised most strongly in the present course (see Graph 4.3.1). These

1 As for course I in section 4.2 the aims questionnaire used in the evaluation was subsequently modified. The aims in this evaluation have been numbered according to the modified questionnaire wherever possible. Aims numbered according to the original aims questionnaire have been given the superscript o (e.g. 28o) in the text and have been placed in brackets on graphs.
Aims of present course

Graph 4.31

Mean rating of students

Mean rating of staff

Numbers not in brackets refer to the modified aims questionnaire

Numbers in brackets refer to original aims questionnaire
aims correspond closely with the stated aims of the course. The emphasis is clearly on areas A (aims 2 and 3) and B (aims 6, 7 and 9) and on aims specifically related to chemical engineering (aims 28° and 29°). Some aims in area C (i.e. aims 17 and 19) were also thought to be important.

There were some differences between staff and students' perceptions of the course. Staff thought that stimulating students' interest was an important aim of the course, whereas students did not. Students thought that more emphasis was placed on illustrating material taught in lectures (aim 2) and problem-solving (aim 11), than did staff.

4.3.2.2 Aims of an ideal course

Students were given an aims questionnaire at both the beginning and end of the course and were asked to rate the importance of each aim for an ideal course. The mean of the ratings for each aim in the two questionnaires have been compared and none of the differences is significant at the 0.05 level.

Graph 4.3.2 is a plot of the mean ratings for an ideal course of students (at the end of the course) against staff ratings. Staff and students agreed that the main emphasis of the present course is right and they would like the course to continue to emphasise aims in areas A and B and aims specifically related to chemical engineers.

There is some desire, however, by both staff and students, to put more emphasis on aims in areas C and D (see Graphs 4.3.3 and 4.3.4). The more important discrepancies between the aims of an ideal course
Aims of ideal course

Graph 4.32
Staff Dissonance between Actual and Ideal Aims

Graph 4.3.3

Only aims with dissonance values 70.5 have been plotted
Students dissonance between actual and ideal aims

Graph 4.3.4

Only aims with dissonance values > 0.5 have been plotted
and the present course, for staff and students, are listed below in Table 4.3.1.

**TABLE 4.3.1**

Aims for which the mean rating for an ideal course is $\geq 3.0$ and for which the dissonance value is $> 0.9$.

<table>
<thead>
<tr>
<th>Area of aims</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff</td>
<td>2</td>
<td>8,9</td>
<td>18,19,22,23</td>
<td>24</td>
<td>-</td>
</tr>
<tr>
<td>Students</td>
<td>-</td>
<td>-</td>
<td>12,16,23</td>
<td>24,25</td>
<td>-</td>
</tr>
</tbody>
</table>

The students, and to some extent the staff, thought that the course should be more open allowing students more freedom to think independently and become more involved in the planning of experiments and in problem-solving.

The staff were particularly concerned that more emphasis should be placed on keeping a day to day laboratory notebook, on making deductions from experimental data and interpreting experimental data and on communicating experimental findings both orally and in written form.

---

1 These graphs plot the dissonance values (i.e. the difference between the mean rating for an ideal course and for the actual course) against the mean rating for an ideal course. The aims where the dissonance values are most significant lie in the right-hand corner of the graphs.
4.3.3 How did the course go about achieving the aims?

4.3.3.1 How was the course structured?

The course lasted for 10 weeks with one session of 3 hours per week and ran in the Spring term of 1974. It was attended by 22 students, 2 members of staff and 1 P.G. demonstrator who was also the evaluator.

4.3.3.1.1 Course content

The course consisted of six experiments some of which had been used in previous years. The table below gives brief details of each experiment.

TABLE 4.3.2

<table>
<thead>
<tr>
<th>Title</th>
<th>Change, if any, from previous years</th>
<th>style of experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Carbonyl compounds</td>
<td>Modified - new script</td>
<td>Traditional</td>
</tr>
<tr>
<td>(2) Coordination compounds</td>
<td>Unchanged</td>
<td>Traditional</td>
</tr>
<tr>
<td>(3) Acetanilide</td>
<td>Radically redesigned</td>
<td>Open</td>
</tr>
<tr>
<td>(4) Impurities in water</td>
<td>Modified - new script</td>
<td>Traditional</td>
</tr>
<tr>
<td>(5) Radioactivity</td>
<td>New experiment</td>
<td>Traditional</td>
</tr>
<tr>
<td>(6) Ethyl acetate</td>
<td>Unchanged</td>
<td>Traditional</td>
</tr>
</tbody>
</table>

Students worked individually for all experiments except experiment 3 in which they worked in groups.

The order in which it was proposed that the experiments should be done
and the approximate time needed for each experiment are set out below.

1 (2 sessions)

2 (1 session)

3 (3 sessions)  ANY ORDER  4 (1 session)  5 (1 session)

6 (2 sessions)  1 session = 3 hours

4.3.3.1.2 Resources

(a) Written materials
Students were issued with instruction sheets containing step-by-step instructions for all the experiments except experiment 3. For experiment 3 a flow sheet was issued to the students. This outlined the aims of the experiment and the various practical and instrumental skills they would need to learn during the experiment. In addition, the experiment was preceded by a talk to explain the flow sheet in more detail.

(b) People
Students could consult staff or P.G. demonstrators when they were available. The staffing ratios were:

\[
\begin{align*}
\text{student} : \text{staff} & \quad 11:1 \\
\text{student} : \text{demonstrator} & \quad 22:1 \\
\text{student} : \text{staff} + \text{demonstrator} & \quad 7:1
\end{align*}
\]

1 See Appendix A.4.3
(c) Audiovisual materials
This course was used to experiment with the use of three kinds of audiovisual material for individual learning in the laboratory, i.e. videotapes, tape-slides and film-loops. Unfortunately the film-loop was shredded by the projector on the first showing to students and so only videotapes and tape-slides were used.

(d) Apparatus
Each student was supplied with a set of glassware with which he could perform all the experiments. Various chemical instruments were also available for use.

4.3.3.1.3 Activities

Students were involved in four main types of activity.

(a) For most of the experiments students worked alone at the bench, following step-by-step instructions.

(b) For experiment 3 students were required to cooperate with 3 or 4 other students in order to find the optimum conditions for preparing some acetanilide. At the beginning of this experiment, in the fourth week of the course, the students were brought together for an explanation and discussion of experiment 3 and were organised into groups.

(c) Students had to use various instruments in the teaching laboratory and in adjacent laboratories, mainly for experiments 3 and 6.
(d) When they wished, students were able to consult a videotape which demonstrated various methods of filtration used in experiment 2 and a tape-slide which gave some background information related to experiment 4.

The staff and demonstrators spent most of their time in the laboratory, discussing experiments with students and teaching them how to use various instruments.

4.3.3.1.4 Assessment

Students were required to write a report on each experiment. Students were not compelled to write-up the experiments immediately and most left the write-ups until the end of the course. The reports were marked subjectively.

4.3.3.2 How did the students react to the course?

4.3.3.2.1 General reactions

Table 4.3.3 shows the mean ratings from the feedback sheets for the 6 experiments.

Students thought that most of the experiments were quite interesting, particularly experiment 3, were quite closely related to the lecture courses and were of about the right level of difficulty. Experiments 1 and 5, however, were thought to be rather too easy and experiment 1 was also rather uninteresting.
### TABLE 4.3.3

<table>
<thead>
<tr>
<th>Experiment</th>
<th>no. given out</th>
<th>no. returned</th>
<th>% response</th>
<th>Difficulty</th>
<th>Interest</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$\bar{x}$</td>
<td>$\sigma$</td>
<td>$\bar{x}$</td>
</tr>
<tr>
<td>(1) Carbonyl compounds</td>
<td>19</td>
<td>19</td>
<td>100</td>
<td>2.3</td>
<td>0.6</td>
<td>2.1</td>
</tr>
<tr>
<td>(2) Coordination compounds</td>
<td>19</td>
<td>12</td>
<td>63</td>
<td>2.9</td>
<td>0.5</td>
<td>2.9</td>
</tr>
<tr>
<td>(3) Acetanilide</td>
<td>19</td>
<td>10</td>
<td>53</td>
<td>3.2</td>
<td>0.4</td>
<td>3.7</td>
</tr>
<tr>
<td>(4) Impurities in water</td>
<td>19</td>
<td>10</td>
<td>53</td>
<td>3.2</td>
<td>0.8</td>
<td>3.5</td>
</tr>
<tr>
<td>(5) Radioactivity</td>
<td>19</td>
<td>16</td>
<td>84</td>
<td>2.0</td>
<td>0.4</td>
<td>3.1</td>
</tr>
<tr>
<td>(6) Ethyl acetate</td>
<td>17</td>
<td>12</td>
<td>71</td>
<td>2.9</td>
<td>0.9</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Rating scales:

- **Difficulty**: 1 = too easy, 5 = too difficult, $\bar{x}$ = mean
- **Interest**: 1 = boring, 5 = stimulating, $\sigma$ = standard deviation
- **Relevance to lecture course**: 1 = unrelated, 5 = closely related

The four students interviewed gave favourable overall comments on the course and three of them spontaneously commented that they thought the course should have been longer.

#### 4.3.3.3.3 The sequential nature of the course

It was intended that after the students had completed the first two experiments they should be able to do either experiment 3, 4 or 5 next. It was, however, convenient to brief all the students together, about the open experiment, experiment 3. Having been briefed about the experiment students wanted to start it immediately. Students, there-
fore, tended to do the experiments in the same order. The fact that students were all doing the same experiments at the same time led to a number of problems.

(i) In experiment 1 there were insufficient bottles of chemicals and chemicals often ran out.\(^1\)

(ii) In experiment 3 all the students wanted to use the limited number of chemical instruments (I.R., U.V. and G.L.C) at the same time. This led to queues forming and time being wasted\(^2\). Some students did start other experiments whilst waiting but nevertheless a lot of time was wasted.

In addition, students had to be taught how to use the chemical instruments. Although students found that the staff and demonstrators were generally helpful and were available when needed\(^3\), this was not so during experiment 3. This was because of the heavy demands made on staff and demonstrator time, both for teaching students how to use chemical instruments and for guiding the students through this open experiment. As a result some students were never taught by staff or demonstrators how to use some of the instruments (see section 4.3.4).

---

1 Feedback sheets : 6 students ) 8 students in all (42%)
Questionnaire : 3 students )

2 Questionnaire : 5 students ) 6 students in all (31%)
Feedback sheet : 1 student )

3 Questionnaire, question 10; 4 students - very helpful, 8 students helpful most of the time; question 11 mean rating = 4.1
4.3.3.2.2 Audio-visual materials

(a) Videotapes

In experiment 2, students viewed a videotape demonstrating the use of a Buchner funnel, when they reached the relevant part of the experiment. At first students viewed the whole videotape, but large parts of it were irrelevant to the needs of students in this course and so later students only viewed the relevant parts.

Staff thought that the videotape was rather longwinded and boring\(^1\) but that it included most of the points which they wanted to teach.

Students found the videotape to be relevant to the experiment and thought that it was quite an effective method of teaching them the skill, but did not find it very interesting\(^2\). Seven students said that they wanted to see more videotapes included in the course, whereas four students did not. In an interview one student pointed out that videotapes are a quick way of teaching laboratory skills and save staff time.

(b) Tape-slide

The tape-slide sequence was an explanation of the theory of analysis by atomic absorption and was intended to be linked with experiment 4. Unfortunately constraints of time prevented experiment 4 from being

\[\begin{array}{lll}
\text{Relevance} & 4.0 & 1 = \text{not related} \\
\text{Interest} & 2.7 & 1 = \text{boring} \\
\text{Effectiveness} & 3.6 & 1 = \text{not effective} \\
\end{array}\]

1 Staff interviews
2 mean rating
   5 = closely related
   5 = stimulating
   5 = very effective
expanded to include this technique and so it was not directly relevant to the experiment. Nevertheless, students found it quite interesting, thought that it was well presented\textsuperscript{1} and was relevant to the course\textsuperscript{2}. Students were, however, equally divided as to whether or not more tape-slides should be included in the course.

(c) General comments

One problem with using audio-visual materials was the positioning of the equipment. Placing the equipment in the laboratory caused problems because students were distracted by what was going on around them. It was eventually decided to transfer all the audio-visual materials to an adjacent laboratory which happened to be free when the course was running.

The experimental nature of the course meant that all the audio-visual hardware had to be borrowed and transported from other parts of the campus for each laboratory session and then had to be returned afterwards. This took up so much time as to be impracticable, and therefore necessitated a choice being made as to the most appropriate audio-visual medium for use in the laboratory. On the basis of the findings above, it was decided to use videotapes for the future\textsuperscript{3}.

---

1 Feedback sheet on atomic absorption
2 Questionnaire question 14
3 The more extensive trials of videotapes in the 1975 course are reported in section 4.5.
4.3.3.2.4 Comments on specific experiments

This section examines detailed comments on particular experiments.

Experiment 1

Two factors appear to have contributed to the low level of interest of this experiment\(^1\). Firstly, there were insufficient bottles of chemicals and students wasted time waiting for them. Secondly, although the experiment was easy to perform in the laboratory, students did not understand the reactions involved very well: 3 students said that they had forgotten their chemistry and did not really know what they were doing, 3 students said that they got unexpected results and 2 students said that they had difficulties finding explanations of the reactions in textbooks (a total of 8 students (42\%)). This poor understanding of the chemistry of the reactions could also account for the low mean rating for the relevance to the lecture course\(^1\).

Experiment 3

The mean ratings from the feedback sheets\(^1\) show that the students thought that this experiment was the most interesting one and was closely related to the lecture courses. This was reinforced by comments from 4 students in the free-response section of the feedback sheets, such as 'a very good experiment', 'a useful experience' and 'obviously related to chemical engineering'.

\(^1\) See Table 4.3.3
Two factors appear to have been important in determining the success of this experiment:

(i) In the aims questionnaire students expressed a desire for more open types of experiments. This experiment was an open one.

(ii) Students thought that it was worthwhile to learn the variety of chemical techniques and the use of the instruments included in this experiment\(^1\).

A number of factors, however, detracted from the success of the experiment:

(i) Students spent a lot of time waiting to use instruments (see section 4.3.3.2.2).

(ii) Students had difficulties writing-up the experiment. Much of the data for the evaluation was collected before this experiment had been written-up. Nevertheless, 2 students commented that they had difficulties writing-up the experiment\(^2\) and 3 students said that they had difficulties coordinating their results with other students\(^3\). Clearly, there is a need for a meeting of each of the groups at the end of the experiment in order to have a final discussion.

Experiment 4

Nine students (90\%)\(^4\) said that they were not able to titrate to the

---

1 Feedback sheet: 1 student; Interviews: 2 students
2 Feedback sheet: 1 student; Interview: 1 student
3 Feedback sheets: 1 student; Interviews: 2 students
4 Feedback sheets
high degree of accuracy required or that it was difficult to detect the end-point or get an accurate titration result.

In addition, 3 students thought that they were given the wrong grade for this experiment. This is probably because they lost marks for inaccurate titrations.

This points out the need for more help to be given to the students so that they can obtain more accurate titration results and for more information to be given about the criteria used for assessing this experiment.

Experiment 6

There were a number of problems with this experiment:

(i) Safety was a problem. Of the 17 students doing this experiment, 3 students' experiments blew up. An examination of student ratings for the importance of aim 9 in the present course reveals a far from normal distribution:

The distribution indicates that some students were aware of the problems
placed on the safety aspects of the experiments.

(ii) There were again problems with queues forming to use the I.R. spectrophotometer.

(iii) Members of staff commented that this experiment was superfluous as it included no more than was included in experiment 3. The experiment was, therefore, not included in subsequent courses.

4.3.3.3 An analysis of course content

The laboratory course was designed both to illustrate lecture material (aim 2) and to teach practical skills, techniques and the use of chemical instruments (aims 6 and 7). In order to guide the choice of laboratory course content a matrix has been drawn up (Table 4.3.4).

The matrix shows the 'theoretical' topics covered in the lecture courses down the left hand side and the 'practical' topics across the top. In addition, a number of practical skills and techniques that were considered to be important by the staff have been added to the list at the top of the table: These are shown in brackets. The examination papers for 1970, 1971, 1972 and 1973 have been analysed and each time a question occurred on a particular topic in the matrix; that topic was starred. The numbers in the matrix represent the experiments, showing which topics they included.

It can be seen that the laboratory course includes most of the practical skills, techniques and instrumentation considered to be
<table>
<thead>
<tr>
<th></th>
<th>Titration</th>
<th>Solvent extraction</th>
<th>Ion exchange</th>
<th>Molecular sieves</th>
<th>Chemical analysis</th>
<th>Infra-red</th>
<th>Ultra-violet</th>
<th>Atomic absorption</th>
<th>Chromatography</th>
<th>Radiation counters</th>
<th>Refractive index</th>
<th>Calorimeters (Distillation)</th>
<th>Re-fluxing</th>
<th>Filtration</th>
<th>Recrystallisation</th>
<th>Weighing</th>
<th>No specific lab skills</th>
</tr>
</thead>
</table>
important with the exception of molecular sieves. A useful area for development of the course would be some organic experiments including a study of either alkane, alkenes or benzene compounds and also including the use of infra-red spectroscopy and chromatography.

4.3.4 Outcomes

This section examines how successful the course was in achieving its aims.

(i) Area A: aims 2 and 3

The data in Table 4.3.3 in section 4.3.3.2.1 indicate that the laboratory course was quite closely related to the lecture courses.

(ii) Area B: aims 6, 7 and 9.

(a) Laboratory skills and techniques.

Table 4.3.4 shows mean student ratings for success of the course in teaching specific skills.

| TABLE 4.3.4 |
|-----------------|-----------------|-----------------|-----------------|
|                | Number who could | Number who could | Mean rating for |
|                | perform the skill | not perform the  | success in      |
|                | before the course| skill before course| teaching skill  |
| (1) Filtration using a Buchner funnel | 9 (69%) | 4 (31%) | 4.0 |
| (2) Titration | 11 (85%) | 2 (15%) | 2.0 |
| (3) Distillation using quickfit. app. | 8 (62%) | 5 (38%) | 4.0 |
| (4) Recrystallisation | 6 (41%) | 7 (59%) | 3.6 |

1 Questionnaire questions 1 and 2
The mean ratings are for those students who could not perform the skill before the course.

Rating scale: Not at all successful = 1
Very successful = 5

The course was thought to be quite successful in teaching all four laboratory skills except for titration. It was assumed by the staff that all the students would be able to titrate and so this skill was not systematically taught to the students.

(b) Use of instruments

Table 4.3.5 shows the mean ratings for success in teaching the use of instruments.

<table>
<thead>
<tr>
<th>Instrumental skill</th>
<th>n=13 Success in teaching (mean rating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Melting point apparatus</td>
<td>4.7</td>
</tr>
<tr>
<td>(2) I.R. spectrophotometer</td>
<td>4.3</td>
</tr>
<tr>
<td>(3) U.V. spectrophotometer</td>
<td>2.8</td>
</tr>
<tr>
<td>(4) G.L.C. machine</td>
<td>3.8</td>
</tr>
<tr>
<td>(5) Refractive index apparatus</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Detailed examination of the ratings shows that two different students on each occasion rated (2), (4) and (5) as either 1 or 2 and four students rated (3) as 1 or 2. This indicates that these students missed the individual training from the staff or demonstrators due

1 Questionnaire question 3
to shortage of instruments or staff and demonstrator time (section 4.3.3.2.2). On the whole, however, the course was thought to be successful in teaching the use of the instruments.

(c) Safety factors
The problems with safety are mentioned in section 4.3.3.2.4, experiment 6. It should be noted, however, that special attention was given to safety in experiment 3, with details of toxicity, flammability, etc. of the chemicals being given to the students.

(iii) Area C: aims 17 and 19.
These aims were not included in the stated aims of the course and no attempt was made to evaluate how successful the course was in achieving the aims.

(iv) Aims related to chemical engineering: aim 28° and 29°.
(a) Aim 28°
Students were asked how successful experiment 3 was in achieving this aim. The mean rating on a five point scale was 3.5. This experiment was, therefore, thought to be quite successful in achieving this aim, although there were problems with the write-up, as mentioned in section 4.3.3.2.4.

Seven students also mentioned other experiments which they thought achieved this aim.

(b) Aim 29°
The four students interviewed said that they thought experiment 3 and perhaps experiments 4 and 5 were orientated towards chemical engineers

---

1 Questionnaire questions 6 and 7
but that experiments 1 and 6 were definitely not.

4.3.5 Conclusions and recommendations

(1) Although staff and students feel the main aims of the course are the right ones, they feel that there should be more emphasis on aims in areas C and D. The open nature of experiment 3 allowed more emphasis to be placed on aims in areas C and D during this experiment. Students also thought that experiment 3 was the most interesting one in the course. It would, therefore, seem desirable to either expand experiment 3 or include another experiment of similar style.

(2) The open nature of experiment 3 and the extensive use of chemical instruments led to heavy demands on staff and demonstrator time during this experiment. If the use of this type of experiment is to be extended, additional teaching resources will need to be made available. The results from this evaluation indicate that a suitable way of supplementing the teaching given by staff and demonstrators would be to use videotapes for teaching basic practical skills and techniques and how to use specific chemical instruments.

The use of videotapes would also enable students to learn skills and techniques when they wanted to, thus giving them more flexibility in when they used particular instruments. This should help to reduce queues for instruments. It would also overcome the problem of students missing instruction.

(3) Various organisational problems must be overcome in order to reduce wastage of students' time. For example, more reagent bottles
could be provided for experiment 1 and the use of chemical instruments in experiment 3, could be staggered.

(4) Students need more guidance in the writing-up of experiment 3. Students from each group need to meet at the end of this experiment in order to collate all the data they have collected and in order to discuss their conclusions either with a member of staff or a demonstrator. Such a meeting would also be a valuable opportunity for staff or demonstrators to explain to the students the criteria used for assessing their work.
# An evaluation of a first year inorganic laboratory course
- Course III

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<th>Section</th>
<th>Page</th>
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</thead>
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<td>233</td>
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<td>261</td>
</tr>
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<td>4.4.5</td>
<td>Conclusions and recommendations</td>
<td>263</td>
</tr>
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The course was evaluated in the Spring term of 1975. It constituted one third of the practical work of 1st year chemistry students, the other two thirds being in courses of physical and organic chemistry.

The course was traditional in style and had remained unchanged for several years. The purpose of the evaluation was to examine the effectiveness of a traditional course that was primarily orientated towards students acquiring practical skills and techniques in order to be able to compare it with the more innovative courses evaluated in section 4.2 and 4.3.

.. 4.4.1 Methods of evaluation

Details of the methods of evaluation are given below:

Total number of students attending course = 28
Total number of staff attending course = 1
Total number of P.G. demonstrators attending course = 4

| TABLE 4.4.1 |

<table>
<thead>
<tr>
<th>Data source</th>
<th>Time of use</th>
<th>Response</th>
<th>Stage of evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Documentary evidence</td>
<td>Prior to and during course</td>
<td>-</td>
<td>(i)</td>
</tr>
<tr>
<td>Instruction sheets given to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Observation as a researcher</td>
<td>Throughout course</td>
<td>-</td>
<td>(i)</td>
</tr>
<tr>
<td>(a) General observation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Observation of staff,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>demonstrator and student</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>activities at intervals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Interviews (type 1)</td>
<td>Before course</td>
<td>-</td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>(a) The member of staff</td>
<td>Towards end of course</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(b) 2 P.G. demonstrators (50%)</td>
<td>Middle to end of course</td>
<td>-</td>
<td>(ii)(iii)</td>
</tr>
<tr>
<td>(c) 6 students (21%)</td>
<td></td>
<td></td>
<td>(i)(ii)(iii)</td>
</tr>
</tbody>
</table>

1 See section 4.1.2
### 4.4.2 Aims

#### 4.4.2.1 Aims of the actual course

There was quite good agreement between the member of staff in charge of the course and the students about many of the more important aims of the course (see Graph 4.4.1).

The member of staff and students were agreed that the emphasis of the course was in area B (aims 6, 7 and 8) with some emphasis on area C (aims 17, 19 and 22).

The member of staff thought that aims in area A (aims 1, 3 and 4) were more important than did students indicating that the member of staff was able to relate the practical course to other areas of

---

1 This was a trial of this type of questionnaire and it was therefore used with half the students for experiment 3 and the other half of the students for experiment 6, instead of feedback sheets.
Aims of actual course

Graph 4.4.1
chemistry, whereas the students were not. The member of staff also thought that aim 16 was more important.

Students thought that aim 11 was more important indicating that the students found the course more intellectually biassed than was intended by the member of staff.

The emphasis on area B was confirmed in staff and student interviews, in the feedback sheets and in the assessment questionnaire.

The member of staff said that 'the main purpose of the course is to bring the students to a standard where they can handle apparatus in a way which will give them reasonable results and so that they can do the calculations which follow'.

In interviews students said that they saw the aim of the course as being to give them more practical experience in order to improve their practical skill and accuracy and to introduce them to new techniques and pieces of chemical equipment.

In the feedback sheets 29% of the students' comments on the aims of the experiments were connected with acquiring practical skills and techniques, with a further 29% being connected with acquiring knowledge related to the practical skills:

e.g. 'To gain knowledge of the apparatus and how to find its accuracy'

'To gain knowledge of the applications of gravimetric analysis'..

Another 10% of the students saw the practicals simply as a process which they had to go through:
e.g. 'To prepare a coordination compound'

'To determine the concentration of phosphate in an unknown phosphate'.

A further 10% of the students said that they did not know what the aims of the particular experiments were.

Information obtained from assessment questionnaires confirmed the emphasis described above. Students thought that two items should be given significantly more marks in the assessment of experiments than the other six items.¹

Item 3: Accuracy of results and quality of samples.
Item 4: Organisation of data and references drawn from data.

4.4.2.2 Aim of an ideal course

4.4.2.2.1 Agreed aims of an ideal course

The members of staff and students were agreed that the main emphasis of the course should lie in area B (aims 6, 7, 8) with some aims in other areas also being emphasised, i.e. area A, aims 3 and 4; area C, aim 19; area D, aim 25.²

4.4.2.2 Areas of disagreement

There was considerable disagreement between staff and students about the importance of some aims (see Graph 4.4.2). Students thought

---

¹ The mean number of marks allocated to these two items was more than one standard deviation greater than the means of the other items.

² Aims 6, 7, 8, 19 and 25 were rated as 4.0 or above by staff and students and aims 3 and 4 as greater than 3.5.
Aims of an ideal course - Differences between Staff & Students

Graph 4.4.2

X Staff rated aim as more important
O Students rated aim as more important

Mean rating of staff (X) or students (O)

Difference between staff and students ratings
that the emphasis of the course should be much wider than did the member of staff. Aims which students felt should be more important (by 2 or more points on the rating scale) than did the member of staff were:

Area A: aim 2
Area C: aims 10, 13, 14, 30
Area D: aims 24, 29
Area E: aims 33, 32

Three themes emerge clearly from these discrepancies:

(i) Students would like more emphasis on the aims which would make the experiments more open, allowing them to experiment for themselves and have more control over what they do in the laboratory (areas C and D).

(ii) Students would like more emphasis on cooperating with other students (area E).

(iii) Students would like the course to be linked more closely with the theory courses (area A).

In order to achieve many of these aims there would have to be a substantial change in the style of the laboratory course.

The member of staff, on the other hand, thought that aims 1, 4, 16 and 17 should be emphasised more strongly than did the students. These were all aims which could be achieved within the framework of the existing course.
4.4.2.2.3 Differences between ideal and actual course

The differences between the member of staff and the students about the orientation that the course should take is confirmed by a comparison of the aims of the actual course and those of an ideal course for both staff and students. Graphs 4.4.3 and 4.4.4 plot the dissonance values against the mean rating for an ideal course.

The students feel that more emphasis should be placed on aims in area D (i.e. aims 24-29) and that there should be more emphasis on aims in area C to do with students experimenting themselves and designing and being in control of the way in which their experiments are carried out (i.e. aims 10, 12, 13, 14, 15, 18 and 19).

The member of staff feels that the course should continue to emphasise its present aims, but even more strongly.

4.4.3 How did the course go about achieving the aims?

4.4.3.1 The structure of the course

The course ran for eight weeks in the Spring term of 1975. Each week there was one 7 hour session lasting from 10.00 a.m. until 5.00 p.m. The students could take breaks as they felt appropriate. The course was attended by 30 students for whom there was an allocation of one member of staff and two demonstrators. The one member of staff was

---

1 Dissonance value = Mean rating for aims of ideal course minus mean rating for aims of actual course

2 Although the students found a 7 hour session in the laboratory physically very tiring they preferred it to two 3 hour sessions because they felt that they could get more done.
Staff differences between importance of aims for ideal course and actual course

Important differences

Graph 4.4.3
Students differences between importance of aims for ideal course and actual course

Graph 4.4.4

Aims of ideal course - aims of actual course
responsible for the course for the whole day whilst the two post-graduate students acting as demonstrators in the morning were replaced by another two post-graduate demonstrators in the afternoon. The students were expected to work through 6 to 8 experiments during the course.

4.4.3.1.1 Course content

The course content was selected in order to illustrate and to teach various standard practical skills and techniques. The course was fairly evenly balanced between preparative experiments, volumetric analysis and gravimetric analysis, and covered a wide range of basic practical skills and techniques.

4.4.3.1.2 Resources

The resources that each student had available to him were as follows:

(a) Written material
   (i) Printed sheets giving step-by-step instructions of the procedure for each experiment
   (ii) A copy of the book, A.I. Vogel 'A text-book of quantitative inorganic analysis'. This was supplied by the student. This book contains step-by-step instructions of specific procedures that were needed in addition to those contained in the instruction sheets and it also contains descriptions of how to carry out the techniques needed in this course.

(b) Apparatus
Each student was issued with the basic apparatus necessary for the course.
(c) People
The staff and demonstrators were usually available for consultation when necessary. The staffing ratios were:

- students : staff 30:1
- students : P.G. demonstrator 15:1
- students : staff + P.G. demonstrator 10:1

4.4.3.1.3 Activities

4.4.3.1.3.1 Student activities

The laboratory class was observed six afternoons and general notes were made of what was happening in the laboratory. In addition, at approximately half hourly intervals notes were made of staff, demonstrator activities and interactions. Table 4.4.2 shows the activities of the students.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Number of times observed</th>
<th>% of total no. of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Working at the bench</td>
<td>318</td>
<td>88</td>
</tr>
<tr>
<td>(2) Talking to other students</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>(3) Talking to staff</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>(4) Talking to P.G. demonstrators</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>

Students spent the vast majority of their time in the laboratory working individually at the bench whilst following step-by-step
instructions in the instruction sheets and in Vogel. They progressed through the experiments at their own pace. They worked through the experiments in the same order and so to start with were all doing the same experiments. Some students did two experiments at the same time in order to use their time more efficiently. In one experiment the students were able to choose a method of analysis to compare with the prescribed one, but this is the only place in the course where such a choice was given. Having made the choice the student would follow the step-by-step instructions in Vogel for the procedure.

The students made notes of results during the course of the experiment but did not write-up the practical until after the laboratory session. The form of the write-up is given in the laboratory instruction sheets: Each account should consist of 'a brief introduction followed by the experimental procedure and a brief conclusion'. The accounts of the experiments were handed in to the demonstrators at subsequent practical classes.

Most students worked from 10.00 a.m. until about 4.30 p.m. and took one to one and a half hours for a lunch break.

No record of attendance was kept by the course organiser and it was possible for students to be absent without being noticed. One student commented that some people are nearly always absent, but managed to hand in all the practicals. It was quite possible for a student to 'borrow' results from a friend and hand them in as his own.

1 Interview
The activities of the two P.G. demonstrators and the member of staff during the laboratory classes in the afternoons were noted on 18 separate occasions. They are shown in Table 4.4.3.

**TABLE 4.4.3**

<table>
<thead>
<tr>
<th>Activity</th>
<th>P.G dem.</th>
<th></th>
<th>Staff</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Marking</td>
<td>18</td>
<td>50%</td>
<td>2</td>
<td>11%</td>
</tr>
<tr>
<td>Discussing practical work with students</td>
<td>9</td>
<td>25%</td>
<td>10</td>
<td>56%</td>
</tr>
<tr>
<td>Absent(^1)</td>
<td>5</td>
<td>14%</td>
<td>5</td>
<td>28%</td>
</tr>
<tr>
<td>Talking with demonstrator or staff</td>
<td>2</td>
<td>6%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Reading</td>
<td>1</td>
<td>3%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Walking around the laboratory</td>
<td>1</td>
<td>3%</td>
<td>1</td>
<td>6%</td>
</tr>
</tbody>
</table>

\(^1\) P.G. demonstrators went for coffee in the middle of the afternoon. The member of staff had various other activities which overlapped with the practical class.

n = number of times observed performing activity
\%
= percentage of times observed performing activity

It can be seen that the largest part of a demonstrator's time was spent, sitting at a desk, in the laboratory marking. Occasionally a student would approach a demonstrator at his desk to ask a question but a demonstrator would seldom leave his desk to ask students questions.

The majority of the course organisers time in the laboratory was spent talking with students, mainly discussing practical problems and correcting incorrect techniques and procedures.
4.4.2.1.4 Interactions

The interactions between the people involved in the course were initially studied by observation. In order to determine the kinds of information being exchanged in these interactions, a number of items were included in the ad hoc questionnaire distributed after the course. The findings are shown in Table 4.4.4.

**TABLE 4.4.4 Sources of help and instruction in the laboratory**

<table>
<thead>
<tr>
<th></th>
<th>(a) Practical skills</th>
<th>(b) Procedure</th>
<th>(c) Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{x}$ $\sigma$</td>
<td>$\bar{x}$ $\sigma$</td>
<td>$\bar{x}$ $\sigma$</td>
</tr>
<tr>
<td>(1) Instruction sheets</td>
<td>3.3 1.4</td>
<td>- -</td>
<td>3.6 0.9</td>
</tr>
<tr>
<td>(2) Textbook by Vogel</td>
<td>2.6 1.3</td>
<td>- -</td>
<td>2.0 0.9</td>
</tr>
<tr>
<td>(3) Member of staff</td>
<td>3.8 0.9</td>
<td>3.3 1.0</td>
<td>4.0 1.0</td>
</tr>
<tr>
<td>(4) P.G. demonstrator</td>
<td>3.4 1.3</td>
<td>3.5 1.2</td>
<td>4.3 1.0</td>
</tr>
<tr>
<td>(5) Other students</td>
<td>2.5 1.3</td>
<td>2.6 1.0</td>
<td>3.2 1.3</td>
</tr>
</tbody>
</table>

(a) Practical skills = learning specific skills and techniques  
(b) Procedure = Explaining what procedure should be used  
(c) Understanding = Understanding the theoretical material connected with the practical experiments

Rating scale 1 = Often helped me 5 = Never helped me  
$\bar{x}$ = Mean rating  
$\sigma$ = Standard deviation

4.4.3.1.4.1 Student-student interaction

The amount of interaction between students in the course was observed to be small with an average of about 10% of the students talking amongst
themselves at any one time i.e. 2 or 3 students out of the 30 talking to one another whilst the rest worked individually.

Table 4.4.4 shows that students consulted other students more often than staff or demonstrators. They found other students most often helpful in explaining what procedures to use and for learning particular skills and techniques. They also sometimes found other students of help when trying to understand the theoretical material connected with the practical work.

4.4.3.1.4.2 Student-demonstrator interaction

The amount of student-demonstrator interaction was even less than the amount of student-student interaction and, as has already been mentioned, was usually initiated by the students.

4.4.3.1.4.3 Student-staff interaction

The amount of student-staff interaction was observed to be slightly more than the amount of demonstrator-student interaction. This was confirmed by the end of course questionnaire. The student-staff interviews were usually initiated by the member of staff.

Although students appreciated the help given by the member of staff they were critical of his absences: "He is very good at explaining what is going on as well as just showing you what to do ... but he is very often not there".
The assessment was carried out on the basis of written reports handed in to the demonstrators who did almost all the marking. The demonstrators marked according to marking schemes which were written down for each experiment. These usually allocated about 80% for the results and quality of samples and 20% for the write-up in general. These marking schemes were not strictly adhered to and students sometimes lost marks for omitting things that were considered to be important in the write up, but for which no marks were allocated.

Having marked the books the demonstrators handed them back to the students. Sometimes they discussed parts of the report with the students and sometimes they added short written comments but usually the book was handed back to the student without comment.

It was difficult for students to find out from some demonstrators what mark they had been given and some students found that if they had their books marked in the morning, they would have to wait until the afternoon before they could find a demonstrator who would tell them their mark. One student commented in an interview: 'I would have liked explanations of what was wrong with some laboratory reports; marks were not published and I found it unsatisfactory having spent so long on an experiment not to learn how well I had done'.

An overall picture is built up of the laboratory class where the students work individually, carrying out their practical exercises
by following step-by-step instructions. Occasionally a student asked a fellow student or perhaps a demonstrator for help or to discuss a practical problem. The member of staff, if he was present, would probably be discussing a practical problem with one or two students, whilst the demonstrators sat at a desk marking practical books.

4.4.3.2 How did the participants react to the course?

4.4.3.2.1 Student reactions to individual experiments

Student reactions to individual experiments were evaluated by means of feedback sheets\(^1\). Table 4.4.5 summarises the students' reactions to the experiments in terms of difficulty, interest and relevance to the lecture course.

**TABLE 4.4.5**

<table>
<thead>
<tr>
<th>Experiment number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>30</td>
<td>30</td>
<td>17</td>
<td>29</td>
<td>24</td>
<td>10</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Response</td>
<td>27</td>
<td>26</td>
<td>15</td>
<td>23</td>
<td>15</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>% response</td>
<td>90</td>
<td>83</td>
<td>88</td>
<td>79</td>
<td>58</td>
<td>50</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>(\bar{x})</td>
<td>(\sigma)</td>
<td>(\bar{x})</td>
<td>(\sigma)</td>
<td>(\bar{x})</td>
<td>(\sigma)</td>
<td>(\bar{x})</td>
<td>(\sigma)</td>
</tr>
<tr>
<td>Difficulty</td>
<td>2.6</td>
<td>0.5</td>
<td>2.7</td>
<td>0.8</td>
<td>3.6</td>
<td>0.6</td>
<td>2.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Interest</td>
<td>3.2</td>
<td>0.8</td>
<td>2.0</td>
<td>0.9</td>
<td>2.5</td>
<td>1.1</td>
<td>1.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Relevance</td>
<td>3.9</td>
<td>1.1</td>
<td>1.2</td>
<td>0.5</td>
<td>1.6</td>
<td>0.5</td>
<td>1.3</td>
<td>0.6</td>
</tr>
</tbody>
</table>

\(\bar{x}\) = Mean rating \hspace{1cm} \(\sigma\) = standard deviation

Difficulty: 1 = too easy, 5 = too difficult
Interest: 1 = boring, 5 = stimulating
Relevance: 1 = unrelated to lecture course, 5 = closely related to lecture course

For footnotes 1 and 2 see next page
(i) Difficulty

The most difficult experiments were those concerned with analysis, i.e. experiments 3, 5 and 6. This is probably because the methods of analysis were all new to the students and they were unfamiliar with the laboratory techniques and procedures used.

(ii) Interest

The students did not find the experiments particularly interesting. The course emphasised practical skills and techniques. In order to become proficient in a particular technique a student has to do a certain amount of repetitive work which tends to be boring. In an interview one student commented: 'You are just practising things that will be routine in the future and it's not very interesting.'

Significantly, the least interesting experiments, experiments 2 and 4, contained more repetitive work than other experiments.

(iii) Relevance

The course was not designed to illustrate lecture material so it is not surprising that most of the experiments were completely unrelated.

---

1 Feedback sheets gathered a lot of detailed information that would help the course organiser to make immediate improvements to the experiments. This section includes only a general summary of the summative information obtained from feedback sheets.

2 The sample size and response rate for experiments 7 and 8 are smaller because not all students did these experiments and students finished the course without returning the feedback sheets. For experiments 3 and 6 alternative assessment questionnaires were given out to half the students.
It is interesting to note that the students found the more relevant experiments (i.e. 1 and 6) also more interesting. One student commented on this in an interview: 'The preparation of a coordination complex and its analysis was quite useful because we are doing coordination chemistry in lectures.' She then went on to explain that it was difficult too see any point to the experiments except in relation to the lectures: 'Most of the course does not seem to link up with the lectures very well and there doesn't seem to be any point to it at this stage. Perhaps it will seem relevant next year. Nobody explains to you why you are doing a practical; you just get handed a sheet and try to get the best mark that you can.'

(iv) Aims

In two experiments 20 to 25% of the students thought that they had gained nothing from doing the experiment. 10% of the students said that they did not know what the aims of the experiments were and all of these thought that they had gained nothing from doing the experiment.

It therefore appears that one important factor that was leading to a feeling of frustration and lack of achievement was a lack of understanding amongst students as to the aims of the experiments. The experiments often seemed unrelated to other work and pointless.
4.4.3.2.2 How adequate were the written materials?

In the ad hoc questionnaire students were asked how often it was necessary to consult staff, demonstrators or other students about the procedure for experiments. 48% of the students (10/21) consulted other people 'occasionally, one or twice during each practical class' and 43% consulted other people 'quite often, several times during each practical class'.

Students found it difficult to understand what they were meant to be doing for certain experiments and had difficulties following instruction sheets or Vogel. One student commented in an interview: 'Sometimes it is difficult to follow Vogel. I know the basic idea of the experiment but I do not know the theory behind the details of the experiment. I am just following the instructions blindly without understanding what I am doing.'

This comment was confirmed in the responses to the questionnaire. Most students said that whilst they were doing the experiments they usually only partially understood them. After they had written them up, however, they said that their understanding was good.

Table 4.4.4 shows that the textbook by Vogel was also important for teaching specific skills and techniques and in helping students to understand the theoretical material connected with the experiments. It appears, however, that the written materials were insufficient on their own for guiding and teaching students. The written materials needed to be supported by students interacting with other people.

1 9 in feedback sheets and 4 out of 6 students interviewed.
4.4.3.2.3 What problems arose out of the roles of the staff and demonstrators in the laboratory

4.4.3.2.3.1 Demonstrators

The students were uniformly critical of the demonstrators. They found that the demonstrators were not very familiar with the experiments, and were, therefore, often unable to help them. Of the four demonstrators on the course only one was British and had in fact done the course himself five years previously and the students did find him helpful.

Students also mentioned language problems with foreign demonstrators: 'It would help if the demonstrators could explain themselves more clearly; they are mostly foreign and I can't understand them.' This problem was also recognised by the course organiser: 'I usually put the foreign demonstrators on marking books as their spoken English is not usually very good, but their written English is usually alright.'

It should be emphasised, however, that the students did not criticise the demonstrators' willingness to try to help them but only their ability to help.

The students preferred to consult other students rather than the demonstrators because of the demonstrators' lack of acquaintance with the experiments and demonstrators were usually only consulted if help could not be obtained from other students.

The demonstrators were very unhappy with their lot as semi-professional markers in this course. They were bored and frustrated and would have
welcomed an opportunity to take a more active role in the laboratory.

4.4.3.2.3.2 Staff

The main problem here was that although students found contact with the member of staff helpful, the amount of contact between most students and the member of staff was very limited.

This problem was recognised by the member of staff: 'I walk round and discuss experiments and sort out difficulties, etc. This means that it is difficult to give students much individual attention. What happens is that you often spend quite a lot of time with one person who is having particular difficulties but this means that you have to neglect the rest. This is one of the main problems of the course; that you are not able to give each student enough individual attention.'

Although there is insufficient time to help all the students adequately, this way of organising the course does enable the member of staff to concentrate his efforts where they are most needed: 'The first thing to do when you start is to pin-point those students who have really done very little work already; those students who are going to lack confidence and be very slow.'

The results from the end of course questionnaire showed that about 20-25% of the students, in contrast with the majority of the students, consulted staff and demonstrators more often than other students. None of these students, however, was a slow student and at least two of them were amongst the faster workers. It appears that more individual attention may in fact be given to the faster workers rather than the slower ones.
In interviews students compared the practical course with school practical work and most students said that this course was the first occasion on which they had had to do accurate quantitative work. The level of practical ability that students entering the course, may be assumed to have, cannot therefore be very high.

In the feedback sheets students mentioned difficulties that they had with the experiments. These fall into five categories:

(1) Specific practical skills or techniques.
e.g. 'I did not know how to use an automatic balance accurately.'

(2) General practical difficulties.
e.g. 'I could not get the precipitate to come down in the pyridine method.'
   'I could not get a clear end-point with E.D.T.A.'

(3) Difficulties following the instruction sheets and Vogel.

(4) Lack of theoretical knowledge.

(5) Difficulties with calculations and graphing errors.

The number of difficulties for each category in each of the first 6 experiments\(^1\) are shown in Table 4.4.6.

---

1 A very small number of feedback sheets were returned for experiments 7 and 8 and so they have not been included here.
TABLE 4.4.6 Difficulties in the first 6 experiments

<table>
<thead>
<tr>
<th>Difficulty</th>
<th>Expt. no.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>total</th>
<th>% of all difficulties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific practical skills or techniques</td>
<td></td>
<td>3</td>
<td>15</td>
<td>15</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>39</td>
<td>53</td>
</tr>
<tr>
<td>General practical difficulties</td>
<td></td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Difficulties following instruction sheets and Vogel</td>
<td></td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>Lack of theoretical knowledge</td>
<td></td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Difficulties with calculations and graphing errors</td>
<td></td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Total difficulties for expt.</td>
<td></td>
<td>14</td>
<td>16</td>
<td>22</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of feedback sheets returned</td>
<td></td>
<td>27</td>
<td>25</td>
<td>15</td>
<td>23</td>
<td>14</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated no. of difficulties if all feedback sheets had been returned</td>
<td></td>
<td>16</td>
<td>19</td>
<td>44</td>
<td>14</td>
<td>13</td>
<td>24</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It can be seen that the students encountered a substantial number of difficulties for which they would need help from staff or demonstrators. The number of difficulties given in the Table is probably an underestimate as the students are unlikely to have written down all the difficulties which they recognised. Also students would not necessarily recognise when they had a bad technique which needed correcting. The difficulties in the Table represent the major ones encountered and recognised by the students.

Since the course organiser was available for about half the laboratory time for helping students about three hours of his time were available during each laboratory class. If he is able to deal with one difficulty
every 10 to 15 minutes, he would be able to deal with about 12 to 18 difficulties per laboratory class. The two demonstrators together had a similar amount of time available for dealing with difficulties but students were very critical of their ability to help. Also some of the difficulties encountered took much longer than 15 minutes to sort out.

It can therefore be seen that the resources available for sorting out difficulties are severely stretched and little time is available for criticising students' techniques and methods of working in the laboratory.

4.4.3.2.5 Assessment

(i) Weighting given to different aspects of practical work.

In the assessment questionnaire students were asked to allocate marks to different aspects of the write-up according to how they thought the marks were allocated for experiments 3 and 6\(^1\). Because of the small numbers the responses for the two experiments have been lumped together in Table 4.4.7.

Table 4.4.7 compares the students' perceptions of the allocation of marks with the allocation of marks in the marking schemes.

---

\(^1\) They were also asked to allocate marks according to how they thought the marks should be allocated. The differences between the actual and ideal allocation are insignificant and only the actual allocation is discussed here.
The Table reveals a startling difference between what the students thought was being assessed and what was actually being assessed. It also reveals considerable uncertainty amongst students as to the relative importance that students think was given to different aspects of the write-up: The standard deviations were almost as large as the means for most items.

Clearly the lack of communication about the assessment of the practical work contributed to the feeling of lack of direction and pointlessness which was mentioned by some students (see section 4.4.3.2.1).

(ii) How appropriate was the form of assessment?

Two problems arose from using indirect methods of assessment, i.e. from assessing practical skills and abilities through a written report.

TABLE 4.4.7

<table>
<thead>
<tr>
<th>Allocation of marks in marking schemes (%)</th>
<th>Allocation of marks as perceived by students (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expt 3</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>(i) Accuracy of results and quality of samples</td>
<td>90</td>
</tr>
<tr>
<td>(ii) Write-up, including calculations and graphs</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>(iii) Discussion of methods used</td>
<td>0</td>
</tr>
<tr>
<td>Allocation of marks in marking schemes (%)</td>
<td>Allocation of marks as perceived by students (%)</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Exp 3</td>
</tr>
<tr>
<td>(iv) Theoretical explanation of results</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>(v) General discussion</td>
<td>0</td>
</tr>
</tbody>
</table>

\( \bar{x} = \text{Mean} \quad \sigma = \text{standard deviation} \)

(1) One student commented in an interview: 'Some people are able to do a good practical but are unable to write it up well and therefore get a bad mark. Others are bad at practical but are good at writing it up and therefore get a good mark.'

If, however, a student did get a low mark for a poor result it was difficult for him to know in what ways his technique was at fault.

(2) All the students interviewed admitted that 'fiddling' results was widespread and some actually admitted fiddling their results. Throughout the questionnaires students kept making comments about results being fiddled, even though the questionnaires did not ask about this. Some students obviously objected quite strongly to results being fiddled. Typical student comments about this phenomenon are:

'A lot of people fiddle their results. It is very frustrating when you do something wrong and have to do it all over again.'

'The practical counts 10% of the total assessment and so you've got to get as many marks as you can even if it means fiddling the results.'

'I have fiddled my results on occasions.'
'The faster workers like myself do not know what the results should be, but the slower workers check with the faster workers and pester them for the answers.'

Although the staff and demonstrators are aware that fiddling goes on, they do not seem to be aware of its pervasiveness:
'I think most of the results are genuine because there are so many bad results, but there is nothing to stop people 'cooking' their results. You have to take the attitude that if a student is capable of fiddling his results he deserves a good mark anyway.'

A system of assessment which is so widely abused must be open to doubt both as a reliable and valid method of assessing students' abilities and as a means of reinforcing the aims of the laboratory course.

(iii) How important did the students think the practical marks were?

The typical student attitude towards the total number of marks allocated to the practical course are summed up as follows:
'Not many marks are given for the laboratory course, but it makes it worth being treated seriously.'

4.4.3.2.6 Summary

The fundamental problems that have been described in section 4.4.3.2 are:
(1) The written materials have to be supplemented by individual help from demonstrators and staff. This is needed both to help students
with problems that they recognise and to correct and improve poor technique which may not be recognised by the students.

(2) Marking the reports on the experiments takes so much time that there is insufficient staff and demonstrator time to give adequate support to the written materials.

(3) Most of the demonstrators (3 out of 4) are not sufficiently conversant with the course to be of much help to the students.

(4) The assessment in its present form is abused and provides little positive reinforcement to the aims: it encourages fiddling.

4.4.4 Achievement of aims

4.4.4.1 How successful was the course in achieving its aims?

The criteria by which the achievement of the educational aims will be judged are the opinions of the organiser of this course (first year inorganic), the opinions of the organiser of the second year inorganic laboratory course, and the opinions of the students who participated in the course.

As has already been pointed out the continual assessment used in this course is indirect and could not be used as a reliable indicator as to the educational success of the course. The course organiser commented:

'I can't really judge whether the students have achieved my aims.
I can look at the marks at the end of the course and if the marks are
very low I can say that the students probably don't achieve much accuracy in any of the experiments. The best feedback is whether the second year course organiser finds they have achieved the aims.'

The second year course organiser said that when the students came into the second year laboratory course, their manual skills were very poor.

All 6 students who were interviewed said that they had learnt new practical skills and techniques and thought that their practical skills and techniques had improved in the course.

In the feedback sheets 31% of the students said that they had improved their practical skills during the experiment and 29% that they had gained greater knowledge and understanding of the various techniques and procedures included in the course.

Table 4.4.8 shows the extent to which students felt the five most important aims of the course had been achieved.

<table>
<thead>
<tr>
<th>TABLE 4.4.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 28</td>
</tr>
<tr>
<td>Rating scale: 1 = not achieved; 5 = achieved</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>(a) To teach basic practical skills (e.g. manipulative and preparative skills and techniques)</td>
</tr>
<tr>
<td>(b) To familiarise you with some important instruments and devices</td>
</tr>
<tr>
<td>(c) To train you in observation</td>
</tr>
<tr>
<td>(d) To teach a logical and methodical way of working in a chemistry laboratory</td>
</tr>
<tr>
<td>(e) To develop your ability to make deductions from experimental data and to interpret experimental data</td>
</tr>
</tbody>
</table>
The students, therefore, felt that the course had partially achieved its aims.

4.4.4.2 Were there any negative outcomes?

(a) The member of staff and students were agreed that aim 28 should be quite an important aim of the course, but unfortunately the course appeared to discourage honesty and scientific integrity.

(b) Staff and students were agreed that aim 26 should be amongst the 15 most important aims of the course (the students placed it fourth). The course, however, failed to stimulate the interest of the students (section 4.4.3.2.1).

4.4.4.3 Summary

The course went some way to achieving its aims, but could definitely not be said to have been successful. In addition, it had some undesirable side-effects with respect to students' attitudes (aims 26 and 28).

4.4.5 Conclusions and Recommendations

Various problems have been revealed by this evaluation, some of which could be solved within the framework of the existing course and others which could only be solved by a complete restructuring of the course.

First problems which could be solved within the framework of the existing course are outlined and possible solutions are considered.
More radical solutions to some of these problems are considered in section 4.4.5.3.

Secondly, problems which could not be solved within the existing course structure are outlined and possible solutions considered.

4.4.5.1 Problems which could be solved within the framework of the existing course

The course has been shown to be achieving its aims only to a limited extent (see section 4.4.4). Several factors seem to be limiting the success of the course.

4.4.5.1.1 Organisational problems

(1) The instruction sheets and Vogel have to be supplemented by help from staff and demonstrators. For some experiments the amount of help needed could be reduced by rewriting the instruction sheets, but in a course where students are learning practical skills and techniques, help from staff and demonstrators is essential.

(2) Demonstrators spend the majority of their time marking. This means that the demonstrators have little time available to help the students and that the demonstrators are bored.

Demonstrators are not sufficiently conversant with the practical details of the course to be of much help to the students. The demonstrators seem to be trapped in a vicious circle: They are unfamiliar with the course and therefore isolated from it by being designated markers and consequently cannot become familiar with it.
(3) Students are aware that results are important in the assessment and consequently 'fiddle' their results: The assessment thereby ceases to assess practical ability.

(4) Students do not understand the experiments very well when they are performing them, but only gain an understanding of them whilst writing them up: In the practical class they are merely following step-by-step instructions. The students would clearly gain more from the experiments if they understood what they were doing.

4.4.5.1.2 Problems with individual experiments

(1) The course as a whole is seen as uninteresting and this is particularly so for some experiments.

(2) Most of the experiments are not related to the lecture courses. The experiments which were related to the lecture courses, however, were of more interest to the students.

(3) In two experiments 20 to 25% of the students thought that they had gained nothing from doing the experiments. In addition, many students could often see no point or purpose in some of the experiments: they seemed to have no intrinsic value and could not be related to any other work that the students were doing in chemistry.
4.4.5.2  Some solutions within the framework of the existing course

4.4.5.2.1  Experimental script

The most common ways of improving or altering practical courses are:
(a) to modify experiments or experimental scripts or
(b) to replace unsuitable experiments with new experiments.

These approaches could be used to overcome some of the problems indicated in section 4.4.5.1.1 subsection 1 and 4 and section 4.4.5.1.2.

The experimental sheets could be modified in the following ways:

(1) Students should be issued with the instruction sheets for the experiment at least a week in advance of the practical class. The instruction sheets should indicate what theoretical material a student must know in order to perform the experiment with understanding. Before being allowed to do the experiment the student could take a short test. If he failed this test he could be required to go away and do some more studying before being allowed to attempt a test for a second time.

(2) For each experiment the purpose of the experiment should be clearly stated and if the emphasis is on experimental accuracy the acceptable limits of accuracy should be stated so that a student is able to judge whether he has achieved the aim of the experiment.

(3) Scripts could be modified in order to reduce the number of difficulties encountered by the students. Other measures would, however, also be needed in order to deal with the difficulties
(4) Attempts should be made to modify the experiments in order to make
them more interesting and in order to emphasise their relevance to
other parts of the course. The use of feedback sheets could be
built into the course.

4.4.5.2.2 Assessment

A complete rethink of the assessment scheme is required:

(a) The time that students spend writing reports should be reduced
in order to bring the amount of effort put into report writing in
line with the importance accorded to report writing in the aims of
the course.

(b) The time needed to assess students must be reduced.

(c) The assessment must be made less susceptible to 'fiddling'.
Possible solutions include:
1. Short reports perhaps only including results and conclusions,
perhaps in conjunction with the use of
2. Oral assessment.
3. Some experiments could be completely written up in the laboratory.
4. Some of the marking could be done outside laboratory hours.

4.4.5.2.3 Role of demonstrator

A change in the role of demonstrator from one of an assessor to one
where he is more involved in helping the students with practical difficulties is probably the change which would have the greatest effect on the course. As well as putting the demonstrators in a position to help students more, it would give the demonstrators more satisfaction in their job as demonstrators.

In order to facilitate this change in role some form of demonstrator training would be necessary. The demonstrators' new role should be clearly defined to him.

4.4.5.2.4 Additional resources

In order to assist in the teaching of practical skills additional resources could be made available. These include programmed texts, audio-tapes, tape-slides and video-tapes. The most popular of these for teaching practical skills in chemistry are video-tapes. (172).

The main advantages of video-tapes in this course would be:
(1) They would save staff and demonstrator time making the staff and demonstrators more available to criticise students' techniques and to discuss problems with them.

(2) Students would be able to see well organised, clearly presented demonstrations when they needed them and as often as they needed them.

(3) They would also be an advantage in the training of demonstrators in that they would clearly define to the demonstrators how the students were expected to perform the various skills and techniques.
4.4.5.3 Problems which cannot be solved within the framework of the existing course

(1)(a) The students want a course in which they have more independence from the staff and more control over their own experiments; a course which is more open and more challenging.

(b) The students would like more emphasis on learning and cooperating with other students.

(2) There is a tendency for experiments which are primarily designed to teach practical skills and techniques to be unsatisfying and boring. The experiments are inevitably repetitive and can often appear to the students to be pointless and irrelevant.

(3) There was a tendency in this course for the better students to get more help from the staff and demonstrators. Two possible explanations for this are firstly, the better students worked faster than the rest of the students and were therefore unable to consult their fellow students about problems. Secondly, students are unwilling to reveal their ignorance to staff or demonstrators, whereas they are more willing to do this with other students. A system in which most of the help given to students is given 'on demand' will, therefore, inevitably lead to more help being given to better students. The course needs restructuring so that the weaker students are located and given extra help.

4.4.5.4 Some solutions

(1) Pass-fail tests of competence.
In this course, a course designed to teach practical skills and techniques, one fundamental problem in the assessment is that it is assessing the student as he learns. It does not assess what he has learnt at the end of the experiment but his abilities whilst learning. An alternative method of structuring a course and the method of assessment, which avoids this problem, is suggested by M.J. Frazer (54). He suggests that in skills courses when a student has had sufficient practice in a particular skill or technique he should take a practical test, designed to measure adequate competence, for which he is given a pass or a fail grade. If he passes the test then he proceeds to the next experiment. If he fails, he would have to do some remedial work before retaking the test. He also suggests that no course marks should be given for such a course, thus emphasising the fact that the course is a learning activity in the same way as lectures and tutorials.

Such a system has the following advantages:

(a) It could be used to reduce fiddling and encourage a more healthy attitude towards learning in the laboratory.

(b) It would cope with different levels of student ability. Good students, in the practical sense, would pass rapidly through the course, whereas poor students would be rapidly identified and could be given extra help.

(c) Hopefully students would get some satisfaction in seeing their skills improving and would feel that their time was being spent profitably.
A unit laboratory could be used to cope with a reorientation of aims into the attitudinal area, area D (see section 4.4.2) whilst maintaining a strong emphasis on practical skills. The essential features of a unit laboratory are that it is a short course of about 3-6 weeks in length, concentrating on a limited content area or a 'topic'. It is organised by one member of staff in his own style and in a way which gives coherence of design and organisation and integrates theory and practical. A design and organisation that has been used successfully is to organise the unit into three stages:

(i) Learn basic practical skills.

(ii) Practice basic practical skills in a closed, i.e. prestructured, experiment.

(iii) Use basic practical skills in a more open investigation.

Such a system would give relevance and immediacy to learning practical skills and at the same time put more emphasis on the additional aims that the students feel should be important.
4.5 An evaluation of a chemistry laboratory course for first year chemical engineers (1975) (Course IV).

<table>
<thead>
<tr>
<th>Index</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
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<td>273</td>
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<tr>
<td>4.5.2 Aims</td>
<td>275</td>
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<td>4.5.2.2 Aims for an ideal course</td>
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<td>4.5.3 How did the course go about achieving the aims?</td>
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<tr>
<td>4.5.3.1 How was the course structured?</td>
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<td>4.5.3.2 How did the participants react to the course?</td>
<td>285</td>
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<td>4.5.4 Outcomes</td>
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</tr>
<tr>
<td>4.5.5 Conclusions and recommendations</td>
<td>302</td>
</tr>
</tbody>
</table>
This evaluation reports on the 1975 chemistry laboratory course for chemical engineers.

The 1974 course is described in Section 4.3 but since then the course had been developed further with the aid of the 1974 evaluation report. In the 1975 course the open experiment was extended so that it constituted the major part of the course and the students worked in groups for most of the course. The course also made more extensive use of videotapes for teaching practical skills.

The course was thus peculiar in combining open practical work, group work and a relatively high amount of individualised learning using videotapes. The evaluator was, therefore, presented with an opportunity of studying the further development of a highly innovative course.

### 4.5.1 Methods of evaluation

Details of the methods of evaluation used are given below:

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of students attending the course</td>
<td>32</td>
</tr>
<tr>
<td>Total number of staff attending the course</td>
<td>1 or 2</td>
</tr>
<tr>
<td>Total number of postgraduate demonstrators</td>
<td>3</td>
</tr>
<tr>
<td>attending the course</td>
<td></td>
</tr>
<tr>
<td>Data source</td>
<td>Time of use</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>(1) Documentary evidence</td>
<td></td>
</tr>
<tr>
<td>(a) Instruction sheets &amp;</td>
<td>Prior to and</td>
</tr>
<tr>
<td>hand-outs given to students</td>
<td>during course</td>
</tr>
<tr>
<td>(b) Student practical</td>
<td>After the course</td>
</tr>
<tr>
<td>books</td>
<td></td>
</tr>
<tr>
<td>(2) Observation</td>
<td></td>
</tr>
<tr>
<td>Participant observation</td>
<td>Throughout the course</td>
</tr>
<tr>
<td>as demonstrator</td>
<td></td>
</tr>
<tr>
<td>(3) Interviews (Type 1)</td>
<td></td>
</tr>
<tr>
<td>(a) Staff - Many informal</td>
<td>Before, during and</td>
</tr>
<tr>
<td>discussions took place with</td>
<td>after the course</td>
</tr>
<tr>
<td>staff. Notes were made on</td>
<td></td>
</tr>
<tr>
<td>these soon afterwards</td>
<td></td>
</tr>
<tr>
<td>(b) P.G. demonstrators -</td>
<td>During the course</td>
</tr>
<tr>
<td>occasional informal</td>
<td></td>
</tr>
<tr>
<td>discussions took place in</td>
<td></td>
</tr>
<tr>
<td>the laboratory. Notes were</td>
<td></td>
</tr>
<tr>
<td>made as above</td>
<td></td>
</tr>
<tr>
<td>(c) Students (5)</td>
<td>After 2 or 3 weeks</td>
</tr>
<tr>
<td>9 (37% sample)</td>
<td>8th week of course</td>
</tr>
<tr>
<td>(4) Questionnaires</td>
<td></td>
</tr>
<tr>
<td>To students</td>
<td></td>
</tr>
<tr>
<td>(a) aims questionnaire</td>
<td>End of course</td>
</tr>
<tr>
<td>(b) feedback sheets</td>
<td>After each experiment</td>
</tr>
<tr>
<td>(c) videotape questionnaire</td>
<td>after viewing each</td>
</tr>
<tr>
<td></td>
<td>videotape</td>
</tr>
<tr>
<td>To staff</td>
<td></td>
</tr>
<tr>
<td>aims questionnaire</td>
<td>2 2 100</td>
</tr>
</tbody>
</table>

* See Section 4.1.2
4.5.2. Aims

4.5.2.1 Aims of the actual course

Information about the aims of the course was obtained from the aims questionnaires, from feedback sheets and from the student interviews and discussions with staff. The aims questionnaire shows that the agreement between staff and students about the aims of the course is strong (see Graph 4.5.1). A wide variety of aims was emphasised in this course:

Aims in area A : 34, 2
area B : 6, 7
area C : 35, 10, 19
area D : 24, 25
area E : 33, 31

The 9 student interviews revealed a similar distribution of aims. The aims that were mentioned together with the number of students who mentioned each aim are given in Table 4.5.1.

<table>
<thead>
<tr>
<th>Aim</th>
<th>No. of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) To gain experience in experimentation; to find out how to go about solving problems in the laboratory.</td>
<td>5</td>
</tr>
<tr>
<td>(2) To become aware of the apparatus that is available to a chemist.</td>
<td>4</td>
</tr>
<tr>
<td>(3) To learn basic laboratory techniques and how to use various chemical instruments.</td>
<td>3</td>
</tr>
<tr>
<td>(4) To gain knowledge of chemistry.</td>
<td>2</td>
</tr>
<tr>
<td>(5) To illustrate lecture material.</td>
<td>2</td>
</tr>
<tr>
<td>(6) To develop the ability to work in a team.</td>
<td>1</td>
</tr>
</tbody>
</table>

1. Two additional aims were included in the aims questionnaire. These resulted from the course being a service course: Aim 34: To illustrate the relevance of chemistry to chemical engineers. Aim 35: To familiarise the student with laboratory scale experiments within the content of the research and development requirements of chemical engineers.
Aims of actual course

Graph 4.5.1

STAFF (mean rating)

STUDENTS (mean rating)
In the feedback sheets students were asked, 'What did you think was the purpose of the experiment?'. The aims derived from the feedback sheets have been weighted according to the length of time it took to complete each experiment and are shown in Table 4.5.2. The distribution of aims is similar to the distributions obtained from the two earlier sources mentioned.

**TABLE 4.5.2**

<table>
<thead>
<tr>
<th>Aim/Purpose</th>
<th>Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) To carry out an experiment at laboratory scale to discover some of the problems that would be faced on an industrial scale i.e. experimental conditions, problems involved in purification, processing etc.</td>
<td>84</td>
</tr>
<tr>
<td>(2) To gain chemical knowledge; to illustrate lecture material.</td>
<td>28</td>
</tr>
<tr>
<td>(3) To learn laboratory skills, techniques and instrumentation.</td>
<td>24</td>
</tr>
<tr>
<td>(4) To illustrate the relevance of chemistry for chemical engineers; to illustrate the industrial applications of chemistry.</td>
<td>17</td>
</tr>
<tr>
<td>(5) To develop students ability to work in a team.</td>
<td>7</td>
</tr>
</tbody>
</table>

The main emphasis of the course is therefore on the problem-solving aspects of area C with strong emphasis also being placed on a variety of aims in area A, B, D and E.

**4.5.2.2 Aims for an ideal course**

Once again the aims questionnaire shows strong agreement between staff and students (see Graph 4.5.2). They are agreed that the main aims of the actual course are the right ones, i.e. the same as for an ideal course.

A comparison of the mean ratings for the actual course and for an ideal
Aims of an ideal course

Graph 4.5.2.

STAFF (mean rating)

STUDENTS (mean rating)
course reveals that both staff and students felt that some aims in area C should be emphasised more strongly i.e. aims to do with experimental design (aims 12 and 14), training students in keeping a day-to-day laboratory notebook (aim 18) and aims to do with communicating and processing results (aims 21 and 23).

In addition staff felt that report writing and extracting information from the literature were under-emphasised in this course. The students, however, felt that these were already quite important aims, presumably because they had to spend quite a lot of time on them.

4.5.3 How did the course go about achieving the aims?

Having established what the aims of the course were, it is now important to compare what actually happened in the course with the aims of the course. How did the course go about achieving its aims? Was the enactment of the course congruent with the aims?

4.5.3.1 How was the course structured?

The course ran for 10 weeks in the spring term of 1975. Each week there was one 3 hour session lasting from 10.00 am until 1.00 pm. The course was attended by 32 students, the course organiser, two postgraduate demonstrators, the evaluator who was also a postgraduate demonstrator and usually, but voluntarily, the second member of staff who had been involved in re-organising the course. Of the students, one third were British and the other two thirds were foreign.

The students were expected to work through one open experiment in groups and were expected to take about 7 weeks to complete it. The rest of the
course consisted of two experiments which were more traditional, one of which lasted two weeks and the other one week.

4.5.3.1.1 Course content

The possible choice of content that is suitable for achieving the primary aims of the course is wide. Two factors constrain the choice of content; firstly the secondary aims i.e. to teach basic practical skills, to become familiar with the important instruments and to illustrate the lecture material, and secondly the previous experience of the students.

The major part of this course was the open, group experiment which was designed to achieve the primary aims but which was structured in such a way that students would learn many basic practical skills and become familiar with important instruments, some of which had been mentioned in the lectures. The major link-up with the lectures was through the more traditional experiments which were designed to illustrate specific topics in the lecture course i.e. carbonyl compounds and radioactivity. The evaluator discussed the problem of what lecture content should be illustrated in the laboratory with the staff. He was unable to discover why it was felt necessary to illustrate these particular topics in the laboratory class but the staff were adamant that it was important that some parts of the lecture course should be illustrated in the laboratory, so that the students are able to experience, in a concrete situation, chemistry that they have previously only met as abstract concepts, and thereby gain another dimension in their understanding of chemistry.

In the experimental feedback sheets 6 students mentioned that the carbonyl and/or the radioactivity experiments were 'well-known' from
A-level. It is perhaps significant that the 6 students mentioned here were all British and therefore represented 54% of the British contingent of the course. A further 3 foreign students commented in interviews that some of the work had been covered previously at school.

4.5.3.1.2 Resources

The resources that each student had available to him were as follows:

(a) Written materials

(1) A general introductory sheet, giving the aims, the approximate time to complete each experiment and the requirements in terms of what practical work each student was expected to do, was issued in the first week of the course. The aims part of this introductory sheet was based on the evaluation of the 1974 course, but since then there had been a reorientation of the course and in the 1975 course more emphasis was put on aims to do with personal interactions. This discrepancy between the stated aims and the actual aims underlines the difficulty of making explicit aims which are implicit in the course structure.

(2) Experimental sheets

The students were given a sheet for each experiment. The instructions for the open experiment, the acetanilide experiment (issued in the first week) were designed to orient the student towards the problem being studied, but included no instructions about how to proceed with the experiment. The sheets for the carbonyl experiment left some of the decisions, about how to proceed with the experiment, to the students.
(b) Apparatus

Each student was issued with a set containing the basic apparatus necessary for the course.

(c) Audio-visual material

Six demonstrations of practical techniques and the use of certain instruments were available on video-cassettes. The students were able to view these, when they required them, in a laboratory adjacent to the one in which they were working. More details of the video-tapes are included in Chapter 5.

(d) People

Other members of a student's group, demonstrators and staff were available for consultation when necessary.

4.5.3.1.3 Activities

4.5.3.1.3.1 Student Activities

The course started with a film and a short talk to explain the purpose of the course to the students. Various printed sheets were distributed, the students formed themselves into groups of 4 or 5 and finally a short lecture outlining the initial strategy for approaching the acetanilide experiment was given. In the second week of the course the students started their experimental work with the preparation of acetanilide and most students continued to work on this experiment until the fifth or sixth week of the course, after which most of the students' efforts went into the carbonyl and radioactivity experiments whilst at the same time they completed small parts of the acetanilide experiment.
The main activities of a student during a typical laboratory session would be that on arrival in the laboratory he would first spend about 10 minutes discussing with his group what each member of the group was going to do, after which practical work would begin, punctuated by frequent discussions about the practical work throughout the practical sessions.

Two changes in student activities were noted as the course progressed. Firstly, it was noticeable that in the second and third week of the laboratory course all five staff/demonstrators were fully occupied, but from the fourth week onward the demands on staff/demonstrator time dropped off suddenly. The students became much more reliant on one another as the groups began to operate more as units, and at the same time, they became more confident.

Secondly, students had to learn a number of techniques at the beginning of the course and therefore had to view certain video-tapes. Some students watched the video-tapes in the second week of the course and in the third week of the course the TV monitor was in continuous use, but after this the use of the video-tapes fell off until after the sixth week the video-tapes were used by only one or two students each session.

4.5.3.1.3.2 Staff and demonstrator activities

For most of the course staff/demonstrators had to perform two roles: firstly, they had to adopt a consultative role, discussing the problems of designing the experiment with the students, and secondly, they had to criticise practical techniques.
The two members of staff and the demonstrator/evaluator had no difficulty in adopting the consultative role because they had all been involved in the planning of the course and knew exactly what was expected of the students. The other two post-graduate demonstrators, however, did not know what to do; they had received no prior instruction in what they should do in the laboratory course. They quickly picked up that they were expected to criticise the students' experimental techniques but did not help the students plan their experiments.

When the students started to do the more traditional experiments later in the course there appeared to be a slight change in the role of the staff/demonstrators. There was less staff/demonstrator involvement required (which must also have contributed to the fall off in demand for staff/demonstrator time) and their role seemed to have changed to one where they were consulted in order to explain why certain chemical reactions had occurred and to say what 'should' have happened.

4.5.3.1.4 Interactions

This course could be said to have been characterised by the large amount of interaction both amongst students and between students and staff/demonstrators. The atmosphere in the laboratory was very informal and students did not hesitate to consult staff and demonstrators if they wished. Conversely staff and demonstrators often asked students how they were getting on and to explain what they were doing.
The students had to write reports on their experiments to be handed in during the summer term. These reports were marked by the staff and were not handed back to the students until the following academic year.

Towards the end of the course a practical report from the previous year's practical group was circulated to give the students an idea of what was expected of them.

4.5.3.2 How did the participants react to the course?

This section first compares student reactions to the 1974 and 1975 courses and then examines student comments on the 1975 course. The following topics are then discussed: student reactions to the openness of the course, the adequacy of the resources, working in groups, the role of staff and demonstrators and finally report writing and assessment.

4.5.3.2.1 Comparisons between the 1975 and 1974 courses (i.e. courses IV & II)

Similar feedback sheets were used in both courses allowing for some crude comparisons to be made between the two courses. Table 4.5.3 shows the mean ratings with respect to difficulty, interest and relevance for each experiment in the two courses.

In the 1974 course there were six experiments. Of these all but
TABLE 4.5.3

<table>
<thead>
<tr>
<th>Title of Experiment</th>
<th>Carbonyl</th>
<th>Radioactivity</th>
<th>Acetilnilde</th>
<th>Water Treatment</th>
<th>Co-ord Compds</th>
<th>Ethyl Acetate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
<td>19 32</td>
<td>19 25</td>
<td>19 28</td>
<td>19</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>Number of Responses</td>
<td>19 23</td>
<td>16 17</td>
<td>10 17</td>
<td>10</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>% Response Rate</td>
<td>100 72</td>
<td>84 68</td>
<td>53 61</td>
<td>53</td>
<td>63</td>
<td>74</td>
</tr>
<tr>
<td>Difficulty</td>
<td>2.3 0.6 2.3 0.3</td>
<td>2.0 0.1 2.2 0.7</td>
<td>3.2 0.4 2.7 0.7</td>
<td>3.2 1.0</td>
<td>2.9 0.5</td>
<td>2.9 0.9</td>
</tr>
<tr>
<td>Interest</td>
<td>2.1 1.0 2.7 0.9</td>
<td>3.1 1.2 3.5 0.9</td>
<td>3.7 1.1 3.5 0.8</td>
<td>3.5 1.2</td>
<td>2.9 0.7</td>
<td>3.4 0.8</td>
</tr>
<tr>
<td>Relevance</td>
<td>3.1 1.0 4.0 0.7</td>
<td>3.6 1.0 3.0 1.4</td>
<td>3.8 1.1 3.7 0.9</td>
<td>3.7 1.3</td>
<td>4.0 0.6</td>
<td>3.0 1.8</td>
</tr>
<tr>
<td>Approx No. of Weeks to complete expt.</td>
<td>2 2</td>
<td>1 1</td>
<td>3 7</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
the acetanilide experiment were traditional in format and included step-by-step instructions. The acetanilide experiment was an open experiment which required the students to tackle a problem concerned with the initial stages in developing a pilot plant. In the 1974 course all the experiments were performed individually except for the radioactivity experiment which was performed in pairs and the acetanilide experiment which was performed in groups. The 1975 course consisted of three experiments, the carbonyl, the radioactivity and the acetanilide experiments. The radioactivity experiment remained essentially unchanged except for some clarification of the script. The carbonyl experiment included the same chemical reactions as previously but was presented in a more problem solving, discovery oriented approach. The acetanilide experiment was expanded to take about twice as long as in 1974. It included elements of the ethyl acetate experiment and an attempt was made to integrate the water treatment experiment into it.

The students found the 1975 carbonyl experiment both more interesting (significant at the 0.05 level) and more relevant (significant at the 0.01 level) than the 1974 experiment but it was still considered rather easy.

The radioactivity experiment proved to be more interesting (not significant at the 0.10 level) but less relevant (not significant at the 0.10 level). This was because radioactivity had not yet been covered in the lecture course when the students did the 1975 experiment, whereas it had when most of the students did the 1974 experiment.

There was very little change in the ratings for the acetanilide
experiment. The students appeared to find it somewhat easier in 1975 (significant at the 0.05 level) presumably because they had more time to adapt to the 'openness' of the experiment and because they got more help from other students.

4.5.3.2.2 General reactions to the experiments

In interviews 6 out of 9 students interviewed said that they found the course interesting. The most interesting experiment was the acetanilide experiment, the open experiment. One experiment, the carbonyl experiment was rather uninteresting (Table 4.5.3).

In the feedback sheets students said that they encountered a number of difficulties carrying out techniques with which they were unfamiliar in the acetanilide experiment (5 out of 17 students) and that they were unsure how to handle some of the chemicals in the carbonyl experiment (5 out of 23 students). Overall, however, the students thought that the acetanilide experiment was of about the right difficulty and the other two experiments rather easy (Table 4.5.3).

In spite of the fact that students did not find the course difficult they thought that the course made them use their initiative.

The students also thought that the laboratory course was relevant to the lecture course, with the exception of the radioactivity experiment (Table 4.5.3).

In interviews 6 out of 9 students said that they thought the
practical course was closely related to the lectures:

'The practical course integrates all the parts of the course. It combines what we do in the lectures with what we do in practicals.'

One problem was that a number of students had done the work in the carbonyl experiment and the radioactivity experiment prior to the course. In the carbonyl experiment 8 out of 17 students returning feedback sheets said that they had gained little or nothing from the experiment and of these 5 had done the work before. For the radioactivity experiment 5 out of 17 students said that they gained little or nothing, of whom 4 had done the work before. These students clearly felt that they were wasting their time repeating work done previously.

4.5.3.2.3 How well did the students cope with the openness of the course?

The majority of the students interviewed (7 students: 78%) commented favourably on the problem solving or open aspect of the course and many of them were enthusiastic. Students (5 students) appreciated the freedom that this approach gave them in planning their work and the fact that they had to use their initiative:

"I have never done experiments without instruction sheets before and I find it more interesting doing it this way. It makes you make decisions about the practical."

"It's better this way. Being able to work out for yourself
what you are going to do makes a welcome change from having to do exactly what you are told to do."

Initially, however, students (4 students) found the freedom confusing:

"It's rather confusing at the moment. I don't really know what we are trying to do. It seems rather vague." (Comment made after 2 weeks of the practical course.)

Another problem that the students had in adjusting to the openness of the course was judging at what pace they should work. They were observed to rush through the experimental work and not plan what they were doing. They were reluctant to watch the video-tapes initially because they felt that they had not got sufficient time to spare. This meant, however, that they wasted time in the end because they found themselves unable to perform techniques properly. By means of some slight coercion by staff they were quite easily persuaded to watch the video-tapes during the third week.

After the third week the course settled down to a steady pace, the confusion diminished and students stopped raising these issues as problems in interviews.

4.5.3.2.4 Were the resources adequate? 1

The resources available to the students were on the whole very adequate. As has been mentioned previously the students appreciated the freedom offered by strictly limiting the amount of step-by-step

1. Information from observation, informal discussion with staff and demonstrators, video-tape questionnaires and interviews
instruction sheets, but to start with found problems coping with
the open format. The deliberately scanty written instructions had
to be backed-up initially by a great deal of discussion with staff
and demonstrators about how to proceed through the course and
video-tapes to teach some of the laboratory skills and techniques.
During the second and third weeks of the course all the resources
were being fully utilised: the unusually large number of staff and
demonstrators (i.e. 5 staff/demonstrators for 32 students) was
fully occupied and the video-monitor was in constant use. In fact,
in the third week of the course a second video-monitor would have
been desirable.

During weeks 4 to 7 of the course the demands on the resources
dropped. The video tapes were only used occasionally and
3 staff or demonstrators would have been sufficient to discuss the
various problems that arose with the students.

During weeks 8 to 10 of the course the demands on the resources
dropped further. The video-tapes were rarely used and two staff or
demonstrators would have been sufficient.

The reactions of staff, demonstrators and students to the use
of video tapes in the course were very favourable, their main
advantages being, firstly that they saved staff and demonstrator
time thus making the staff and demonstrators more available for
discussion with students, and secondly, that they showed a clear
well-planned demonstration which was accessible to the students at
any time. A more detailed evaluation of the use of video-tapes in
this and other courses is included in Chapter 5.
The problems that arose in the course were as follows:

(1) Students were initially unwilling to watch the video-tapes (see Section 4.5.3.2.4). Perhaps it would be worthwhile to include notes in the written material for each experiment indicating what relevant video-tapes are available.

A second problem with video-tapes was that staff were unwilling to let 1st year chemical engineers use the spectrometers when their only instruction had been in the form of video-tapes. They felt that the students needed supervising.

(2) By the time the students had reached the 5th or 6th week of the course they had accumulated, as groups, quite a sizeable amount of data and some groups were having trouble collating it.

(3) By the 6th or 7th week of the course students wished to start the section of the acetanilide experiment concerned with the purity of water but instruction sheets were not ready. Eventually students were referred to a standard textbook. This does not seem to have been a disadvantage and on the contrary one student commented that he liked this experiment more than the others because he had to do it all by himself. Students, however, did not see the water treatment experiments as being integrated with the acetanilide experiment and the vast majority of them talked about it as a separate experiment and wrote it up separately.
What were the students' reactions to working in groups?

Two students from each group were asked if they would be prepared to be interviewed, one after the course had been running for 2 or 3 weeks and the other after the course had been running about 8 weeks. Interviews were arranged with 14 students in all but 5 of these failed to materialise. The distribution of the 9 remaining interviews is indicated in Table 4.5.4.

### TABLE 4.5.4

<table>
<thead>
<tr>
<th>Letter assigned to group</th>
<th>Size of Group</th>
<th>Number of students interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
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<tr>
<td>C</td>
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</tr>
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<td>D</td>
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</tr>
<tr>
<td>E</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>F</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>G</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

(1) Advantages

All the students interviewed mentioned two main advantages of working in groups. Firstly, they had to discuss problems with one another, to explain different parts of the experiment to one another and to reach joint decisions. They found that by working in groups they were able to help one another cope with the open situation:

"You can discuss things ... You don't feel you are disturbing someone if you are working in a group whereas you might if
The second main advantage was that students were able rapidly to accumulate data and were able to compare and discuss results.

(2) Problems

Four students thought that their groups were too big, one each from groups B, C, D and E. The two students from the groups of 5 (i.e. B and C) and one from a group of 4 (i.e. D) said that their groups had essentially split into two groups because they found it too difficult to organise and keep track of what everyone was doing and to carry on discussions with such large numbers in a group. Group F also encountered difficulties organising itself.

A further problem that was mentioned by 2 students was that they did not trust the results of other group members.

Out of the 9 students interviewed, 3 said that they would have preferred to work alone but 2 of these were from group E, which was unfortunate in consisting of 4 foreign students whose English was not very good.

One problem that was not anticipated was that after completing the acetanilide experiment the students continued to work as a group on the carbonyl and radioactivity experiments although these were designed to be performed individually and in pairs, respectively. This worked quite well for the carbonyl experiment where in most groups all
the students participated in the experiment and discussed and compared results. In the radioactivity experiment however there was no scope for more than 2 people to participate and in most groups only 2 members of the group performed the experiment and then passed the results on to the rest of the group.

4.5.3.2.6 Staff and demonstrators

The students were unanimous in saying that they found the staff and demonstrators helpful. They found them useful when they had problems which they wanted to discuss and did not find them too intrusive.

Members of one group commented that a demonstrator had told them to do something that was wrong near the beginning of the course but they appeared to have regained their confidence in the demonstrator later in the course, when the demonstrator was better acquainted with the course. This problem obviously arose because the demonstrator was inadequately briefed before the course. This issue is discussed further in Section 4.5.4.

4.5.3.2.7 Were there any problems with report writing and the assessment?

The students kept notes of the practical results during the course but were unable to write-up the practicals until towards the end of the course because most of the course consisted of one experiment, and students did not wish to start writing it up before they had finished it. Only two students mentioned report writing in the interviews and both of these said that they were unsure how they
should write-up their experiments, but both these comments were made before an example practical report from the previous group of students was circulated.

4.5.4 Outcomes

This section is concerned with the educational outcomes of the course. How successful was the course in achieving its aims?

The criteria by which the achievement of the educational aims will be judged are given below with the data sources for each criterion.

TABLE 4.5.5

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Staff opinions</td>
<td>(a) Informal discussion with staff</td>
</tr>
<tr>
<td>(2) Student opinions</td>
<td>(a) Interviews</td>
</tr>
<tr>
<td>(b) Feedback sheets for each experiment</td>
<td></td>
</tr>
<tr>
<td>(c) Video-tape questionnaire</td>
<td></td>
</tr>
<tr>
<td>(3) Factual information</td>
<td>(a) Observation</td>
</tr>
<tr>
<td></td>
<td>(b) Student practical note-books</td>
</tr>
</tbody>
</table>

4.5.4.1 Aims in area E

Data source 2a, 3a

Aim 33: To develop students' skill in working and cooperating with others in a team. (Primary Aim.)

Initially the students were observed to be having problems organising themselves as groups (Section 4.5.3.1.3.1) but after the
course had been running for about 3 weeks they began to work better in groups and become more reliant on one another than on staff or demonstrators. Students did, however, still mention substantial problems with working in groups (Section 4.5.3.2.4.2). This may be because the students had not developed the ability to work in teams to a sufficient extent or it may have been, as the students suggested, due to the fact that the groups were too large for this type of experiment.

Nevertheless there is no doubt that the students learnt a lot about working in groups and that most groups worked as quite efficient units most of the time.

Another aim in area E is one of the secondary aims:

Aim 32 : To provide closer contacts between students and academic staff.

There was observed to be a great deal of interaction between students and academic staff (Section 4.5.3.1.4). Informal conversations between staff and students over coffee or at the bar were not uncommon. Whether the structure of the course produced the closer contact between the students and staff or whether it was due to the enthusiasm of the staff is debatable. The course was certainly structured in such a way that the staff and students had to discuss practical problems, strategies for problem solving etc., but it is my opinion that the unusually informal and relaxed nature of the relationships between the staff and students was due largely to the enthusiasm of the staff.
4.5.4.2 Aims in areas A and C

Data sources 1a, 2a, 2b, 3a, 3b.

Aim 35: To familiarise the students with laboratory scale experiments within the context of the research and development requirements of chemical engineers (Area C).

Aim 34: To illustrate the relevance of chemistry to chemical engineers (Area A).

Aim 10: To simulate conditions in research and development laboratories (Area C).

Aim 19: To develop students' ability to make deductions from experimental data and to interpret experimental data (Area C).

Aim 2: To illustrate material taught in lectures and tutorials (Area A).

These are all aims concerned with students organising the experiments themselves and with relating chemistry to chemical engineering.

When students were asked in the feedback sheets what they gained from doing the experiment the most predominant reply was practice in problem solving or knowledge of the problems involved in designing a pilot plant (Table 4.5.6).
Seven out of the nine students interviewed commented favourably on the problem solving aspect of the course (Section 4.5.3.2.3) and also found it relevant to them as chemical engineers (Table 4.5.3). Two students, however, said that they did not know enough about
chemical engineering to be able to judge whether it was relevant.

The seven students found the acetanilide experiment particularly relevant because it taught them how to go about solving a research and development problem and it illustrated the first stage in the planning of a pilot plant:

"It (the course) is good for us as chemical engineers. It gives us some basic ideas about reactions and laboratory equipment. It seems relevant to chemical engineering. We actually try out the experiment ourselves; we try different conditions, make our own samples, test them etc."

"It teaches you how to approach the problem; to read up the relevant matter, how to put the apparatus together, what apparatus to use, what reactions take place."

"It shows the stages by which a chemical manufacturing process is derived from original ideas, by trying it out in the laboratory, then in a pilot plant and finally modifying it for a commercial process."

Students had difficulties collating their results and drawing conclusions from them (Section 4.5.3.2.5). Examination of student reports revealed a wide range of ability in making deductions from experimental data and interpreting experimental data. The area indicated by aim 19 is therefore one in which more help is needed for the students.
4.5.4.3 Aims in area B

Data sources 1a, 2b, 2c, 3a.

Aim 16: To teach basic practical skills (e.g. manipulative and preparative skills and techniques).

Aim 17: To familiarise the students with some important instruments and devices.

A number of skills and techniques were identified, when designing the course, to be taught by video-tapes. Student responses to questions on a questionnaire about the use of video-tapes indicated that the students thought the video-tapes were successful in teaching them the different skills.

Reference to the comments made on the feedback sheets (Table 4.5.3) also indicates that the students thought that they had learnt a lot about specific laboratory techniques.

Observation of the students performing the techniques after they had seen the video-tapes revealed that they were competent in the particular techniques. This was confirmed in discussion with the staff; They were satisfied with the level of competence reached by the students in these skills and techniques.

The course can therefore be considered to have successfully achieved aims 6 and 7 at least in the areas where skills and techniques were taught by video-tapes.
4.5.4.4 Aim in area D

Data source 2a

Aim 25: To encourage initiative and resourcefulness in the students.

The majority of the students interviewed mentioned the fact that they had to use their initiative (Section 4.5.3.2.3). The course can therefore be considered to have successfully achieved this aim.

4.5.4.5 Summary

As far as can be judged, using the mainly subjective sources of data available, the course was successful in achieving all its primary aims and all its secondary aims with the exception of aim 19, for which only partial success was achieved.

4.5.5 Conclusions and recommendations

This evaluation has revealed no problems which cannot be solved within the framework of this course. The problems discussed below only require modifications to the course for their solution and do not require fundamental changes in the course structure.

Organisational problems and possible solutions will first be discussed and then problems concerned with individual experiments.
4.5.5.1 Organisational problems and possible solutions

4.5.5.1.1 Effective deployment of staff and demonstrators

The central organisational problem in this course is how to meet the requirements of the students for help from and discussion with the staff.

The initial demands for staff and demonstrator time were high but dropped off as the course proceeded (Section 4.5.3.2.4). The demands on the staff and demonstrator time were partially mitigated by the use of video-tapes for teaching basic practical techniques but nevertheless the demands remained very high. Although the staff and demonstrators attending this course were able to cope with the heavy initial demands on their time, they were assisted by two facts:

(1) The normal number of staff/demonstrators attending a laboratory class of this size is 3, not 5 as was the case in this course.

(2) Of the 5 staff/demonstrators attending this course, 3 were well acquainted with it and how it was proposed to organise it. This again is not normal. Usually only the one member of staff who is organising the course is well acquainted with it. It would be common for at least one of his two postgraduate demonstrators to be inexperienced since this was a first year course, and certainly neither of them would be well acquainted with the course since there is no briefing or training for demonstrators prior to the course.
This course therefore had a much better chance of succeeding than a course with a more normal allocation of staff and demonstrators.

There are two possible solutions to this problem:

(a) A flexible staff/demonstrator allocation would be helpful with 5 staff/demonstrators for the first three weeks of the course, 3 staff/demonstrators for the next four weeks and 2 staff/demonstrators for the final three weeks. This kind of flexible allocation of staff/demonstrators would mean that over the whole of the ten week course the staffing allocation would be very similar to that in a normal situation.

(b) It is imperative that as the number of staff and demonstrators, who have been directly concerned with organising the course, drops, the new demonstrators drafted onto the course be trained or at least well briefed about the course. They must be well acquainted with the aims of the course, the organisation of the course and with their role with respect to the students; how they should go about discussing problems with the students and the extent to which they are expected to criticise students' techniques.

4.5.5.1.2 Report writing and collating results

The students were found to be having difficulties collating the results of the open experiment by the time they reached the fifth or sixth week of the course (Sections 4.5.3.2.5 and 4.5.4.2). In the majority of the courses surveyed in Section 2.2.3.2 some sort of formal discussion with each group plus a member of staff or
demonstrator was held at this stage. In this course the students could be asked to present for discussion in a seminar, a summary of their results, what conclusions they had drawn and what further information they needed. Such a seminar would also have given the staff/demonstrators an opportunity to give some guidance about report writing (see Section 4.5.3.2.6).

4.5.5.1.3 Problems with groups

(a) Size of groups
Students felt that groups with five students in them were too large (Section 4.5.3.2.5). Perhaps groups of three or four students would have been better. It must be remembered, however, that one of the aims of the course was 'to develop students' skill in working and co-operating with others in a team'. It is to be expected that in achieving this aim the students will encounter problems. Another solution to changing the size of the groups is to consider new methods of trying to make the groups more cohesive.

(b) Problems of experiment design
Students did all the experiments in the course as group experiments although two of them had not been designed to be done in this way (see Section 4.5.3.2.5). If all the experiments are going to be done as group experiments, then those that are not designed as group experiments need to be revised so that they are of more benefit to students working in groups.

4.5.5.1.4 Preknowledge

As noted in Section 4.5.3.1.1 parts of the course overlapped with
A-level but on the other hand some students thought that they did not know enough about some experiments before they did them (i.e. 4 students for the acetanilide experiment and 5 students for the carbonyl experiment).

The content of the course must therefore be re-examined to find out whether the aims of the course can be achieved whilst at the same time eliminating overlap with A-level. In addition study guides could be produced to help students who were unfamiliar with the work.

4.5.5.1.5 Assessment

In its present form the assessment did not produce any positive reinforcement of the educational aims of the course.

In order to assess the aims of the course a wider range of assessment techniques must be used.

4.5.5.2 Problems with individual experiments

4.5.5.2.1 Lack of cohesion of acetanilide experiment

Two facets of the acetanilide experiment were not sufficiently integrated with the experiment. These are the video-tapes (Sections 4.5.3.2.3 and 4.5.3.2.4) and the treatment of water experiment (feedback sheets). These two problems could be solved by altering the written material given to the students i.e. by indicating the relevance of the video-tapes and by describing explicitly how the water treatment experiment is relevant and what part the results
4.5.5.2.2 Students who thought that they gained nothing from certain experiments

Apart from the problems mentioned in Sections 4.5.5.1.3 and 4.5.5.1.4 a central problem with the carbonyl and radioactivity experiments is to make the students feel that they have gained something from doing these experiments.

Perhaps the fault lies in the content (Sections 4.5.3.2.2) or perhaps in the rather traditional design of the experiments.

4.5.5.3 Summary

Most of the problems described above are minor and are of the type that one would expect with a new course. One central problem, however, stands out: This is the problem of staffing a course when the student:staff ratio is very low. If postgraduate demonstrators are used the demands on staff time drop but the demonstrators must be trained.
4.6 An evaluation of a second year physical chemistry laboratory course (Course V)

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Introduction

Courses I to IV described in the earlier part of this chapter were all at the same university. In order to gain an appreciation of how institutional factors can affect chemistry laboratory courses it was decided to study two courses at different institutions. The first of these is described in this section.

The course was selected on the basis of the questionnaire responses in Chapter 3. The course was run at a polytechnic which was reasonably accessible to the evaluator. The course was also claimed to be closely integrated with the theory course and it was thought valuable to find out how this integration was achieved. It soon became apparent that the course was not fully integrated but it did contain two aspects which had as yet not been studied, i.e. the use of pairs and the use of computers, and for this reason it was decided that this would be a worthwhile course to study.

4.6.1 Methods of evaluation

Initially the evaluation was to be based on questionnaires, interviews and observation, with about equal emphasis on each. The response rates for the questionnaires were, however, very low and the evaluation strategy had to be modified in order to obtain the required information by other means. More emphasis was, therefore, placed on interviews than had originally been planned, and by the end of the course 17 out of the 25 students (68%) attending the course had been interviewed.
The sources of data for the evaluation, the times when the particular sources were used and the stages in the evaluation to which they are mainly related are outlined below. All relevant questionnaires and interview schedules are included in Appendix A 4.6.

Data sources

Total number of students attending course = 25
Total number of staff regularly attending course = 4
Total number of demonstrators attending course = 1
Total number of technicians attending course = 2

<table>
<thead>
<tr>
<th>Data source</th>
<th>Time of use</th>
<th>Response</th>
<th>Stage of evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Documentary evidence</td>
<td>prior to and during course</td>
<td>-</td>
<td>(i)</td>
</tr>
<tr>
<td>Instruction sheets given to students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Observation</td>
<td>throughout c.</td>
<td>-</td>
<td>(i)(ii)</td>
</tr>
<tr>
<td>Observation as a researcher</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Interviews</td>
<td>prior to the course</td>
<td>-</td>
<td>(i)(ii)</td>
</tr>
<tr>
<td>(a) staff</td>
<td>throughout course</td>
<td>all</td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>type 1 interview - 1 member of staff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>type 2 and informal discussion - 4 members of staff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) students</td>
<td>throughout course</td>
<td></td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>17 students (68%)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>mainly type 1. More details below.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) Questionnaire</td>
<td>No. given</td>
<td>No. returned</td>
<td>% response</td>
</tr>
<tr>
<td>students</td>
<td>week 7</td>
<td>25</td>
<td>8 32%</td>
</tr>
<tr>
<td>(a) aims questionnaire</td>
<td>after each experiment</td>
<td>494</td>
<td>61 12.4</td>
</tr>
<tr>
<td>(b) ad hoc questionnaire</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(c) feedback sheets</td>
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<td></td>
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<tr>
<td>staff aims questionnaire</td>
<td>week 7</td>
<td>3</td>
<td>1 33%</td>
</tr>
</tbody>
</table>

1 See section 4.1.2
In order to guard against possible bias in the interview and questionnaire data the respondents have been analysed as follows:

The evaluator assigned the students to 5 groups according to practical ability, on the basis of his contact with the students. These groups were discussed with the course organiser as a result of which the 3 middle groups were condensed into a single 'average' group and 2 students were reallocated to different groups. Table 4.6.1 compares the ability groups for the whole class with those attained in the questionnaires and interviews:

**TABLE 4.6.1**

<table>
<thead>
<tr>
<th></th>
<th>All class</th>
<th>Questionnaire</th>
<th>Interview 1</th>
<th>Interview 2</th>
<th>Int.1+2¹</th>
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<tbody>
<tr>
<td>Weak</td>
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<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
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<td>Good</td>
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<td>2</td>
<td>2</td>
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</tbody>
</table>

It can be seen that the interviews were relatively unbiased according to practical ability whereas the students returning the questionnaires were an above average sample. Throughout this report the source of data has been quoted so that it is possible to check the data for bias.

¹ Two interview schedules were used for students in this course. 'Interview 1' refers to the first interview schedule used for the first 3 weeks of the course and 'interview 2' refers to a revised interview schedule used for the rest of the course.
4.6.2 Aims

Students' opinions of the aims of the course were obtained from aims questionnaires for which there was a 32% response rate. In addition 8 (32%) of the students were asked in interviews what they thought the aims of the course were, making a total of 14 (56%) of the students who provided information about aims (2 students were in both groups).

The course organiser also completed an aims questionnaire and a further member of staff was interviewed about the aims.

The evaluator was also present at an introductory lecture given by the course organiser which implicitly outlined some of the aims, although these were not stated explicitly.

4.6.2.1 Aims of the present course

Graph 4.6.1 is a plot of the mean ratings for the aims of the present course given by the 8 students who returned the questionnaire against the corresponding rating given by the course organiser.

It is clear that the course organiser is trying to achieve a wide variety of aims.

Both the course organiser and the students felt that aim 2 (area A) was important.

Aim 2: 'To illustrate material taught in lectures and tutorials.'

This emphasis was confirmed in interviews with two members of staff.
Aims of the present course

Graph 4.6.1.

Staff

Students

x2
x21
x8
x19, 33
x22
x30
x11, 13
x16, 24, 31
x20
x24
x1, 27
x18
x4, 29
x28
x32
x14
x5
x10, 12
x23
and by 6 of the 8 students who were asked in interviews what they thought were the main aims of the course (see Table 4.6.2). A typical student comment was that the aim was 'to see the reaction happening in front of you; to see things that have only been dealt with in theory before'.

The course organiser also emphasised the relationship between the practical course and the theory courses in an introductory lecture for the practical course.

**TABLE 4.6.2** Aims of the course derived from 8 student interviews

<table>
<thead>
<tr>
<th>Aim</th>
<th>no. of students stating the aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) To illustrate the theoretical material taught in lectures (aim 2)</td>
<td>6</td>
</tr>
<tr>
<td>(2) To learn basic manipulative skills and techniques (aim 6)</td>
<td>2</td>
</tr>
<tr>
<td>(3) To learn how to use certain instruments (aim 7)</td>
<td>1</td>
</tr>
<tr>
<td>(4) To learn how to organise oneself in the laboratory (aim 17)</td>
<td>1</td>
</tr>
<tr>
<td>(5) Do not know</td>
<td>1</td>
</tr>
</tbody>
</table>

The course organiser and the students also agreed that aims 19, 22, 30 and 33 were important.

Aim 19: 'To develop students' ability to make deductions from experimental data and to interpret experimental data (area C)'.

Aim 22: 'To train students in writing reports on experiments (area C)'.

Aim 30: 'To train students in extracting information from the literature (including training in the use of the library) (area C)'.

Aim 33: 'To develop students' skill in working and cooperating with others in a team (area E)'.

Of these the course organiser, in the introductory lecture, emphasised that it was important to examine results to see where errors might have occurred and encouraged students to read the section of the laboratory manual dealing with the treatment of errors.

The main emphasis of the course, however, was in area A in illustrating material taught in the lectures.

4.6.2.2 Aims over which there was disagreement

The aims over which there is some disagreement are indicated in Graph 4.6.2. In Graph 4.6.2
(a) only the aims where disagreement between the course organiser and the students ≥ 1.0 on the rating scale have been plotted.
(b) X indicates that the course organiser thought the aim was more important than did the students, and Θ indicates that the students thought the aims was more important than did the course organiser.

The most important differences are in the top right hand corner of the graph. These differences are discussed in section 4.6.3.1 in the light of what actually happened in the course.

4.6.2.3 Aims of an ideal course

Graph 4.6.3 is a plot of the mean ratings of the aims of an ideal course by students against the corresponding ratings given by the course
Aims of Actual Course - Differences between Staff & Students

Graph 4.6.2

Mean rating given by staff (X) or students (O)

Difference between staff & student ratings

0.0

0.5

1.0

1.5

2.0

2.5

0.0

0.5

1.0

1.5

2.0

2.5

3.0

3.5

4.0

4.5

5.0
Aims of an Ideal Course

Graph 4.6.3

- X22
- X26
- X8, 17, 19, 25
- X21
- X27
- X10, 33
- X11, 13, 15, 16, 24, 29, 30, 31, 32
- X18
- X28
- X14, 23
- X4, 10
- X12
- X1, 5

No staff
It can be seen that both the course organiser and the students were very undiscriminating in the aims that they would like emphasising and that they would like the course to emphasise aims in all five areas A, B, C, D and E.

4.6.3 How did the course go about achieving the aims?

Having established what the aims of the course were, it is now important to compare what actually happened in the course with the aims of the course. How did the course go about achieving its aims? Was the enactment of the course congruent with the aims?

4.6.3.1 How was the course structured?

In this section the evaluation will be focused on the following areas:

1. Length of course: How was the time allocated to the course used?

2. Course content: Was the course content suitable for achieving the aims of the course?

3. Resources: What resources were available to the students?

4. Activities: What did the students, staff, demonstrators and technicians actually do in the laboratory? How did they interact with one another?

5. Assessment: How was the assessment carried out?

4.6.3.1.1 Length of course

The course was scheduled to run for 10 weeks in the Spring term of 1976, but in fact after the eighth week of the course no students
attended the laboratory.

Table 4.6.3 shows the mean student attendance in the Physical Chemistry laboratory each week.

TABLE 4.6.3 Student attendance based on observations made throughout the day, each week

<table>
<thead>
<tr>
<th>Week of course</th>
<th>Mean student attendance in Phys.Chem.Lab.</th>
<th>no. of observations made</th>
<th>Mean student attendance corrected to include students not in Phys. Chem. Lab.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.0</td>
<td>9</td>
<td>22.5</td>
</tr>
<tr>
<td>2</td>
<td>18.7</td>
<td>6</td>
<td>23.2</td>
</tr>
<tr>
<td>3</td>
<td>17.0</td>
<td>3</td>
<td>21.3</td>
</tr>
<tr>
<td>4</td>
<td>13.7</td>
<td>7</td>
<td>17.1</td>
</tr>
<tr>
<td>5</td>
<td>14.3</td>
<td>7</td>
<td>17.9</td>
</tr>
<tr>
<td>6</td>
<td>12.1</td>
<td>8</td>
<td>15.1</td>
</tr>
<tr>
<td>7</td>
<td>8.5</td>
<td>4</td>
<td>10.6</td>
</tr>
<tr>
<td>8</td>
<td>3.9</td>
<td>7</td>
<td>4.9</td>
</tr>
<tr>
<td>9</td>
<td>0.0</td>
<td>1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Each week there were two laboratory sessions both lasting from 10.00 a.m. to 5.00 p.m. with an hour lunch break, although the laboratory was supervised during the lunch break to enable students to continue working if they wished.

4.6.3.1.2 Course content

The course was made up of 44 experiments. The experiments were divided into four branches of Physical Chemistry as follows:
<table>
<thead>
<tr>
<th>Branch of Phys. Chem.</th>
<th>No. of experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermochemistry</td>
<td>11</td>
</tr>
<tr>
<td>Kinetics</td>
<td>10</td>
</tr>
<tr>
<td>Electrochemistry</td>
<td>12</td>
</tr>
<tr>
<td>Spectroscopy</td>
<td>7</td>
</tr>
</tbody>
</table>

There were also three experiments on surface chemistry and one on X-ray crystallography.

All the staff who gave lectures related to the laboratory course were involved in the course (see section 4.6.3.1.3d).

The students were expected to complete 20 experiments of which the grades for the best 15 would form the final course mark.

The students had a guided choice of which experiments to do: the course organiser advised students to do certain experiments in each branch of Physical Chemistry after which students were free to pursue their own interests within the framework of the experiments available. Eleven of the experiments were studied by 80% or more of the students whilst eight experiments were studied by none. At the beginning of the course students selected partners and worked with the same partner throughout the course as a pair. Each of the students studied a different set of experiments in a different order from the other students: The amount of integration between the lecture courses and laboratory courses was therefore limited. Some students would do a particular experiment before it had been studied in the lectures whilst others would do it afterwards.
4.6.3.1.3 Resources

The resources available to each student were:

(a) Written material

A laboratory manual, containing step-by-step instructions for almost all the experiments together with some theoretical background to each experiment.

(b) Apparatus

One set of apparatus for each experiment was available in a variety of locations so that students only had the opportunity to do an experiment if no other students were doing it.

(c) Calchem

Two Computer Asserted Learning in CHEMistry (Calchem) programmes were available for the students to study. Both went over the theoretical background to certain experiments with the students and one guided students in the design of an experiment. The students did the programmes in pairs.

The programmes were based on programmed learning principles and used branching to programmes. The questions were typed out and students typed in their responses.

The one programme that allowed students to design their own experiment was the only opportunity in the course for students to design their own experiment, which accounts for the discrepancy between the opinions of the course organiser and the students about aims 10, 12 and 15 (see section 4.6.2.2).
(d) People
The mean observed attendance and staffing ratios over the 8 weeks for which the course effectively ran are shown in Table 4.6.4 below.

TABLE 4.6.4

<table>
<thead>
<tr>
<th>(i) Attendance:</th>
<th>(ii) Mean of numbers present throughout course in Phys. Chem. Lab.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>15.2</td>
</tr>
<tr>
<td>Staff</td>
<td>1.5</td>
</tr>
<tr>
<td>Demonstrators</td>
<td>1.2</td>
</tr>
<tr>
<td>Technicians</td>
<td>1.5</td>
</tr>
</tbody>
</table>

(ii) Staffing ratios:
- Students : Staff = 10 : 1
- Students : Demonstrators = 13 : 1
- Students : Staff + Demonstrators = 6 : 1
- Students : Technicians = 10 : 1

These ratios, however, varied over the duration of the course because of the fall in students' attendance (see Table 4.6.3), whilst the numbers of staff, demonstrators and technicians present were maintained.

The student : staff ratio also varied during each day because the number of students present throughout the day remained fairly constant, whereas staff attendance dropped off (see Table 4.6.5). This was because the course organiser who attended the laboratory course between
10.00 a.m. and 3.00 p.m. encouraged other members of staff to be present in the morning, and particularly during the first hour each day. In all 4 members of staff attended the Physical Chemistry Laboratory, the course organiser more frequently than the others.

TABLE 4.6.5  Variation of staff attendance with time of day

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean no. of staff present</th>
<th>No. of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00 - 11.00</td>
<td>1.8</td>
<td>15</td>
</tr>
<tr>
<td>11.00 - 12.00</td>
<td>1.4</td>
<td>17</td>
</tr>
<tr>
<td>12.00 - 1.00</td>
<td>1.4</td>
<td>12</td>
</tr>
<tr>
<td>1.00 - 2.00</td>
<td>1.4</td>
<td>5</td>
</tr>
<tr>
<td>2.00 - 3.00</td>
<td>1.0</td>
<td>8</td>
</tr>
<tr>
<td>3.00 - 5.00</td>
<td>0.8</td>
<td>5</td>
</tr>
</tbody>
</table>

In addition to the experiments which were carried out in the Physical Chemistry Laboratory, the spectroscopy experiments and X-ray crystallography experiment were carried out in separate laboratories and were supervised by 3 members of staff whose offices were adjacent to the spectroscopy and crystallography laboratories. Students were observed to spend about one fifth of their time in these laboratories performing experiments.
4.6.3.1.4 Activities

4.6.3.1.4.1 Student activities

The course began on a Monday with an introductory lecture which all the students attended. This was given by the course organiser and described the relationship between the laboratory course and the theoretical chemistry covered in lecture courses. It was also used to explain the requirements of the course.

On the following Friday work in the laboratory began. The students were observed on 54 occasions over the eight weeks for which the course ran. They usually worked from about 10.00 a.m. until sometime after 4.00 p.m. with a break of about half an hour for lunch. Their activities are shown in Table 4.6.6.

TABLE 4.6.6 Student activities

<table>
<thead>
<tr>
<th></th>
<th>Wks 1-4</th>
<th>Wks 5-8</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>(1) Working at bench</td>
<td>254</td>
<td>52.8</td>
<td>118</td>
</tr>
<tr>
<td>(2) Talking with other student in pair</td>
<td>117</td>
<td>24.4</td>
<td>49</td>
</tr>
<tr>
<td>(3) Talking to staff</td>
<td>47</td>
<td>9.8</td>
<td>12</td>
</tr>
<tr>
<td>(4) Talking to demonstrator</td>
<td>36</td>
<td>7.5</td>
<td>7</td>
</tr>
<tr>
<td>(5) Talking to technician</td>
<td>2</td>
<td>0.04</td>
<td>11</td>
</tr>
<tr>
<td>(6) Talking to student in different pair</td>
<td>4</td>
<td>0.1</td>
<td>13</td>
</tr>
<tr>
<td>(7) Write-up</td>
<td>2</td>
<td>0.04</td>
<td>2</td>
</tr>
<tr>
<td>(8) Informal chat with other students</td>
<td>24</td>
<td>4.9</td>
<td>0</td>
</tr>
</tbody>
</table>

For footnote see next page
It can be seen that the major part of a student's time is spent at the bench either performing the experiment (53%) or talking to his partner about the experiment (24%)\(^2\). It is interesting to note that the total amount of time that students spent talking to other people besides their partner changed little between the first and second half of the course, but that the students talked less to staff and demonstrators in the second half of the course and more to the technicians and to students from other pairs.

4.6.3.1.4.2 Staff activities

Table 4.6.7 shows what staff actually did in the laboratory.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Wks 1-4</th>
<th>Wks 5-8</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Talking to students</td>
<td>32</td>
<td>11</td>
<td>43</td>
</tr>
<tr>
<td>(2) Talking to staff</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>(3) Talking to demonstrators</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(4) Marking</td>
<td>2</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>(5) Allocating experiments</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>(6) Other, e.g. reading</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(7) Nothing; walking around the lab.; sitting at desk</td>
<td>6</td>
<td>1</td>
<td>7</td>
</tr>
</tbody>
</table>

1  The evaluator was only able to be present on one occasion after 4.00 p.m.

2  It was not possible to determine whether all the talking was about practical work, but it is my impression that it usually was.
For the first half of the course the major part of the time was spent talking to students but as the course proceeded they spent considerably less time talking to the students. Part of this drop can be attributed to a fall in student attendance from a mean 21.0 in the first half of the course to 12.1 in the second half of the course, but not all. As noted in section 4.6.3.1.4) the students appeared to consult other people for help in the second half of the course.

The staff used about half the time released by talking to the students less, for marking and the other half was spent talking to colleagues.

4.6.3.1.4.3 Demonstrator activities

A similar trend was noted with the demonstrators (Table 4.6.8), but

TABLE 4.6.8 Demonstrator activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Wks 1-4 n (%)</th>
<th>Wks 5-8 n (%)</th>
<th>All n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Talking to students</td>
<td>29 (76)</td>
<td>7 (33)</td>
<td>36 (55)</td>
</tr>
<tr>
<td>(2) Helping students to find apparatus</td>
<td>1 (3)</td>
<td>1 (4)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>(3) Talking to staff</td>
<td>0 (0)</td>
<td>2 (8)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>(4) Talking to demonstrators</td>
<td>0 (0)</td>
<td>4 (16)</td>
<td>4 (6)</td>
</tr>
<tr>
<td>(5) Talking to technicians</td>
<td>1 (3)</td>
<td>2 (8)</td>
<td>3 (5)</td>
</tr>
<tr>
<td>(6) Marking</td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>(7) Other, e.g. reading</td>
<td>2 (6)</td>
<td>3 (12)</td>
<td>5 (8)</td>
</tr>
<tr>
<td>(8) Nothing; walking round; sitting at desk</td>
<td>4 (13)</td>
<td>6 (24)</td>
<td>10 (16)</td>
</tr>
</tbody>
</table>
because the staff did most of the marking, the demonstrators spent most of their free time in the second half of the course either doing activities unrelated to helping the students (items 3, 4, 5, 7) or doing nothing (item 8).

4.6.3.1.4.4 Activities of technicians

The important role of the technicians was not realised until the course had been running for a few weeks and consequently fewer observations were made of their activities (Table 4.6.9).

Table 4.6.9 Activities of technicians

<table>
<thead>
<tr>
<th></th>
<th>Wks 1-4</th>
<th>Wks 5-8</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. of observations made of technicians</td>
<td>13 + 14 = 27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of times observed = 22</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| (1) Showing students where apparatus is | 3 23 | 0 0 | 3 11 |
| (2) Helping students to operate apparatus | 1 8 | 7 50 | 8 30 |
| (3) Social chat with students | 0 0 | 2 14 | 2 7 |
| (4) Talking to demonstrators | 1 8 | 3 21 | 4 15 |
| (5) Other in lab., e.g. looking after apparatus | 4 31 | 2 14 | 6 22 |
| (6) Nothing; sitting at desk | 4 31 | 0 0 | 4 15 |

It can be seen that in the second half of the course the technicians played an important role in the practical course by helping students to operate the apparatus and instruments.
4.6.3.1.5 Assessment

The students were expected to write full reports for each of the 20 experiments that they were expected to complete, but the mark given for the course was based on the best 15 experiments.

Students were told that they could have only 2 experiments not written-up at any one time but no attempt was made to enforce this regulation.

The staff did nearly all the marking, some of it whilst they were in the laboratory and some of it after the course had finished, because many students did not write-up some of their experiments until after the course had finished.

The reports were all assessed subjectively.

Oral reports by students were not used, although staff did occasionally have discussions with students about their reports. The rarity of oral communication about results accounts for the gross descrepency between the students' and the course organiser's perception of the importance of aim 23 in the course.

4.6.3.2. How did the participants react to this particular course structure?

This section is concerned with the reactions of the participants to the structure of the course and to any problems that arose. The questions that this section focusses on are:
What were the reasons for the students finishing the practical course early? What effect did this have upon the course?

What were the reactions to the course content?

How adequate were the available resources?

What were the students' reactions to the assessment scheme?

4.6.3.2.1 Reasons for, and effects of finishing the course early

4.6.3.2.1.1 Reasons for rushing

When the course started it was noted that students worked industriously in the laboratory. The high level of activity continued and some students were found to be completing the laboratory at the rate of 2 experiments per day. Consequently as mentioned in section 4.6.3.1.1 most students completed the laboratory course in 6 or 7 weeks instead of in 10. The numbers of students completing different numbers of experiments is shown in Table 4.6.10

<table>
<thead>
<tr>
<th>No. of experiments completed</th>
<th>No. of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>23</td>
<td>2</td>
</tr>
</tbody>
</table>

1 Only 1 student worked alone
The cause of the students rushing through the practical course was undoubtedly the overall degree course structure, together with a practical course which allowed students to work at their own pace. The degree course was divided into units. In order to obtain a degree the students had to pass 9 units. There were 3 units each year and the Physical Chemistry Laboratory course was part of the second year. Physical Chemistry unit, which also comprised 5 lecture courses. Each unit lasted one term at the end of which there were exams to assess the lecture courses. The practical course was assessed on the basis of written reports of the experiments submitted throughout the term.

The academic staff involved in the practical course were critical of the unit structure of the degree. Two of them said that they objected to the fact that the Chemistry degree course was divided into concentrated 'packages' and that students had little time to assimilate and reflect upon the subject matter before they were examined on it. They felt that the students rushed through the practical course in order to leave themselves more time to revise for the exams. One of them pointed out that each experiment counted for only 1% whilst the exams counted for 85%, so it was in the students' interest to sacrifice their practical work in favour of the exams.

Seven out of the eight students responding to question 7 in the questionnaire said that the fact that there were exams at the end of the unit made them rush through the practical work so that they had more time for revision later in the term. Three students made similar comments in interviews. A typical student comment was:

'I like to get all the practical done as soon as possible leaving as much time as possible for revision, preparing for the exams. When you
Another two students, however, said that the exams had no effect on the way in which they worked in the laboratory. One of them said that he just did each experiment as well as he could and, significantly, he and his partner were amongst the few students still present in the laboratory during week 8 and they completed 23 experiments (more than any other pair) instead of the 20 recommended. The other student continued working steadily in the laboratory until week 7 after which she and her partner stopped having completed 18 experiments.

4.6.3.2.1.2 Effects of rushing

(1) Understanding

One effect that might have been expected is that students' understanding might suffer if they rushed. This did not happen. When asked in interviews how well they understood the experiments whilst they were in the laboratory, four students (25%) said that they nearly always understood them, nine students (56%) said that they usually understood them and three students (19%) said that they understood some of them. The reasons were as follows:

(a) When asked whether they prepared for the practical work by reading each experiment in the laboratory manual before they came into the laboratory 10 students (71%) said that they always did and four students (29%) said that they usually did. Eight students said that in addition they also sometimes read textbooks before coming into the laboratory. Early in the course four students mentioned that they
were sometimes unable to study in advance because they did not know in advance which experiment they would be doing. This ceased to be a problem as the course proceeded, presumably because students made sure that they knew in advance which experiment they would be studying.

The motivation for studying in advance was as follows:
(1) Twelve students (86%) said that it helped them to plan and to organise themselves in the laboratory;
(2) Nine students (64%) also said that it helped them to understand the experiments. This in turn helped them to execute them more efficiently.
(3) The course organiser encouraged the students to study beforehand.

Reading beforehand, thus saved time for the students as well as helping them to understand the experiments.

(b) A second reason for the students understanding the experiments as they did them, was that they had studied the related theoretical material previously in lectures. Nine students said in interviews that the theoretical material for some of the experiments had been covered in earlier years and similarly in the questionnaire students said that about a third of the theoretical material had been covered in previous years. This was particularly true in the first 3 weeks of the course when the six students interviewed at this stage were unanimous in saying that so far the laboratory course had been little related to the present year's lectures, but was related to work previously covered. As the course proceeded it became more related to the current lecture courses. Two students said that nearly all
the experiments were related, two said that most were and six said that some or a few were.

(c) The fact that students worked in pairs helped them to understand the experiments. This is discussed fully in section 4.6.3.2.3.4.

The factors affecting whether students understood the experiments are summarised in Figure 4.6.1.

FIGURE 4.6.1

Factors which inhibited the students' understanding of experiments whilst they did them were:

(1) Not having covered the material in lectures (3 students)
(2) Rushing; not having time to read the theory (2 students)
(3) Not reading the experimental theory and instructions beforehand (1 student)
It seems that in order to work efficiently in the laboratory the students were prepared to read about the experiments before they came into the laboratory and thus gained quite a good understanding of the experiments before they started. Rushing seems to have prompted the students to make more efforts to understand the experiments.

(2) Write-up

Another effect of rushing was on the write-up.
The course organiser estimated that it took about 2 hours to write-up each experiment. Since the students did on average 3 experiments per week this meant a total of 6 hours writing-up per week. Students usually wrote up the experiments a week or two weeks after they had completed the practical work, i.e. they were constantly 3 to 6 experiments behind with their write-ups. Fourteen students (78%) thought that the gap between doing the experiment in the laboratory and writing it up did not matter. Four students, however, thought that there was a tendency to forget the experiments.

The fact that students rushed does seem to have delayed the writing-up of experiments but this did not seem to matter for most students.

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1 Estimates made by four students in interviews agree with this figure
2 Information from 8 questionnaires and interviews of a further 6 students
3 12 out of 15 students consulted in interviews and 7 out of the 8 students who returned the questionnaire; 5 students were represented in both questionnaires and interviews.
4.6.3.2.2. Reactions to the course content

4.6.3.2.2.1 Relevance

Each pair of students did a different set of experiments in a different order from any other pair (section 4.6.3.1.2). Overall students thought that about one third of the experiments were related to previous years' work and that only some of the experiments were related to the current lecture courses (section 4.6.3.2.1). Obviously a student's perception of the relevance of a particular experiment to the lecture courses would depend on when he did it. The evidence from feedback sheets indicates that the students' perceptions of the relevance of the experiments did, in fact, vary considerably.

It was pointed out in section 4.6.3.1.2 that the students had a guided choice of experiments. This did in fact mean that there was some sort of progression in the course. The course organiser started the students off with easier experiments related to the theory covered in previous years (section 4.6.3.2.1.2) and later the students began to tackle experiments related to the current lecture courses.

In discussions the course organiser said that he expected students to concentrate on those areas that interested them most. In actual fact 16 students (64\%)\(^2\) did not concentrate on a particular area and seemed to view the practical course as a broadly based course illustrating all the Physical Chemistry lecture courses. This was

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1 The 12.4\% response rate for feedback sheets precludes this evidence from being viewed as very forceful.

2 These students all did between 3 and 5 or 4 and 6 experiments in each of the main branches of Physical Chemistry.
emphasised by two students (free response section of questionnaire) who said that there was not sufficient time to do all the experiments although they were all useful for the Physical Chemistry unit. This difference between the opinions of the course organiser and the students explains the large discrepancy noted in section 4.6.2.2 about the importance of aim 5 in the course:

Aims 5: 'To study a small area of chemistry in depth'.

The fact that integration between the laboratory course and the lectures was limited was seen as a problem by one of the members of staff, but an inevitable one where for many experiments only one set of apparatus is available.

Fifteen students (7 in questionnaires, question 8, and 8 in interviews) said that they preferred to have the lectures before the related experiments rather than afterwards, whilst three students thought that it did not matter.

Ten students (7 in questionnaires, question 9; 3 in interviews) were agreed that the main advantage of having the lectures first was that when they did the experiment they could understand it; they would know what they were doing and why.

They saw two problems if they did an experiment before they had covered the related theory in lectures:

(1) They would not have enough theoretical background to be able to understand the experiments (10 students: 5 in questionnaires, question 11; 5 in interviews). This problem was usually overcome, however, by the students studying by themselves before they came
Sometimes students were unable to cope with having to study the theoretical material by themselves because of lack of time or because the theory was too advanced for them to cope with yet. One student's comment was:

'I would rather wait until after I had done the lectures before doing an experiment. In one experiment we did it without knowing what it was about ... I've written it up but I copied directly what was in the textbook ... but I didn't know what it was all about.'

(2) The second problem was that the experiment took longer; the theory had to be mastered first (2 students: 1 in questionnaire, question 11; 1 in interview); the experiment took longer to perform in the laboratory (1 student: questionnaire, question 11) and the write-up took longer and was more difficult (1 student: interview).

One advantage of the students doing different experiments at the same time was observed. If an experiment was particularly troublesome or difficult only one pair of students would be doing it and so it was possible for more help to be given to them: In a laboratory course where the experiments were sequential, however, all the students would encounter the same problems at the same time.

4.6.3.2.2.2 Interest

The feedback sheets suggest that the students usually found the experiments quite interesting.
4.6.3.2.2.3 Difficulty

The feedback sheets also suggest that on the whole the students found the experiments either of about the right level of difficulty or slightly too easy.

In the feedback sheets students made comments which indicate where the difficulties lay. These are shown in Table 4.6.11 below.

<table>
<thead>
<tr>
<th>Problem</th>
<th>No. of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Difficulties handling the experiment</td>
<td>12</td>
</tr>
<tr>
<td>(2) Insufficient theoretical knowledge</td>
<td>5</td>
</tr>
<tr>
<td>(3) Difficulties with write-up and calculations</td>
<td>5</td>
</tr>
<tr>
<td>(4) Correct equipment not available</td>
<td>3</td>
</tr>
<tr>
<td>(5) Experiments badly designed</td>
<td>3</td>
</tr>
<tr>
<td>(6) Faults with apparatus</td>
<td>2</td>
</tr>
<tr>
<td>(7) Difficulties due to overcrowding</td>
<td>2</td>
</tr>
<tr>
<td>(8) Instruction sheets confusing</td>
<td>1</td>
</tr>
</tbody>
</table>

It is interesting to note that the main problems were with the manipulation of unfamiliar equipment (item 1) rather than with having insufficient theoretical background (items 2 and 3), indicating that students did in fact manage to cope reasonably well with the lack of integration between the theory and the practical.
4.6.3.2.3 Resources - How adequate were the resources?

4.6.3.2.3.1 Written materials

The students seemed satisfied with the laboratory manual (Table 4.6.11). Initially, there were a few complaints about mistakes in the manual but this soon became common knowledge and therefore less important. The manual, however, often needed to be supplemented by help on an individual basis when students were learning how to operate instruments with which they were unfamiliar (Table 4.6.11, item (1); Table 4.6.8, item (2); 4 students in interviews). One of the members of staff commented that the first year Physical Chemistry Laboratory course was inadequate in this respect; in that it did not give the students a very good grounding in practical skills and techniques.

Item (5) on Table 4.6.11 is interesting in that once again it emphasises the fact that the experiments are structured in such a way that aims 10, 12 and 15 are difficult to achieve (see sections 4.6.2.2 and 4.6.3.1.3d.)

4.6.3.2.3.2 Apparatus

There was usually only one set of apparatus available for each experiment, which severely limited the integration between the practical and lecture courses (see section 4.6.3.2.2). Possible ways of overcoming this are discussed in section 4.6.5.2.

Students also found difficulties with the apparatus that was available (Table 4.6.11, items (4), (5) and (6); also observation).
One student said that it was very frustrating if you had prepared for an experiment and then found that you were unable to do it because the apparatus was faulty. Faults with apparatus, however, were not a major problem and technicians were always at hand to give assistance.

4.6.3.2.3.3. Calchem

The class records for the usage of the two calchem programmes are incomplete: 16 students did at least one of the programmes, 4 students did neither and for the remaining 5 students there are no records.

The Calchem programmes were not assessed but students were strongly encouraged to do at least one of the programmes. The students worked in pairs at the terminal.

Calchem was discussed with 3 members of staff involved in the practical class. They were all very enthusiastic. They saw the main advantages as being:

(1) The teaching programme had been very carefully prepared and so students got the benefit of a well prepared scheme, which was therefore better than the equivalent scheme done by a member of staff.

(2) Students were not afraid of revealing their ignorance to a computer whereas they were with a member of staff. The programmes were designed so that they gave encouraging responses to the students' answers. One member of staff also mentioned that the computer will wait for the answer whereas a member of staff might not.
(3) The students enjoy the programmes.

One member of staff thought that a limitation was that weaker students had difficulties with the computer programmes. This was, however, followed up with 3 of 4 students who the member of staff indicated as being weak and, if anything, their reactions were more enthusiastic than the other students'.

Information was obtained from 10 students (8 in interviews, 6 in questionnaires: 4 overlapped) about their attitudes to Calchem. All these students were enthusiastic about Calchem, although before they had done a programme some of them were rather apprehensive. The four students who are known not to have done a Calchem programme, deliberately avoided doing one because of their apprehensiveness.

In interviews students said that there were a number of advantages to the Calchem programmes and these are shown below. Some of these views are supported by questionnaire evidence as indicated.

(1) Students liked working in pairs at the terminal (7 out of 8 students: 5 in interviews, 3 in questionnaires). They tended to have discussions when they were not certain of the answers to questions. A typical student comment is:

'What usually happens in our pair is that one of us puts forward a theory to answer the question: if the other agrees we put it down; if he disagrees we talk it over and then we put it down.'

Three students said that they thought the Calchem programmes made you think.
Eight students (4 in interviews; 5 in questionnaires) said that with the computer they were not afraid of getting the wrong answer, whereas with a member of staff they tended to be more on their guard.

Six students (2 in interviews and 4 out of the 5 students responding in the questionnaire) said that they thought it was useful having immediate feedback about whether they had got the answer right or wrong, often together with an explanation. One student said that he found the computer's responses to his answers encouraging: This was one of the features noticed when watching students working at the terminal; that they seemed very encouraged by the responses to their answers.

Some problems were mentioned by a few students:

1. In interviews, two students, neither of them weaker students, said that it can be frustrating if a topic with which one is not familiar is introduced.

2. Four out of the six students responding to the Calchem questions in the questionnaire thought that the programmes were rather too long.

3. Five students (one in interview; 4 out of 6 in the questionnaire) thought that the fact that the computer sometimes did not understand their answers, was a problem.

4. One negative aspect of the interest shown by staff and students in Calchem was that one pair of students said that they were distracted whilst doing the programme by people coming to see how the Calchem
In summary, it seems that the format of the Calchem programmes, working at the terminals in pairs and the absence of a member of staff all encouraged discussion, thought and consequent learning. The problems were mainly concerned with the fact that the computer was only able to adapt to a limited extent to individual learning needs.

4.6.3.2.3.4 People

Students got help from a variety of people in the laboratory (Table 4.6.6). These can be categorised as follows:

(1) Partner in pair
(2) Staff (academic)
(3) Demonstrators
(4) Technicians
(5) Students from a different pair

(1) Partner in pair
At the beginning of the course students chose a partner with whom they worked for the rest of the course. Inevitably, some students were disappointed because they could not work with a student of their own choosing.

Students spent about one quarter of their time in the laboratory talking to their partner (Table 4.6.6) and as will be seen got a considerable amount of help in this way.
Students were asked in interviews (15 students) and in questionnaires (8 students = 32% response rate) various questions about working in pairs.

In the following discussion students who would have preferred to work alone will be referred to as 'A' students and students who preferred to work in pairs as 'P' students.

The students' reactions to working in pairs are shown in Table 4.6.12. They are as follows:

(1) There were approximately the same number of 'A' students (9) as 'P' students (10).

(2) All 'A' students and nearly all 'P' students found that (i) discussion with their partners gave a greater understanding of the experiment than if they had worked alone (item c) and (ii) discussion with their partner was helpful when working out results and calculations (item h).

(3) There were some distinct differences between 'A' and 'P' students: 'P' students thought that they learnt more (item e), made fewer mistakes (item b), worked well as a team (item f) and worked faster (item d) when they worked in pairs, whereas 'A' students usually did not work well in a team, thought that they learnt more when working alone and some thought that they worked faster alone.

There seem to have been 2 factors influencing whether students preferred to work in pairs, compatibility and personal learning strategies.
(a) I prefer working alone to working in pairs.

(b) I make more mistakes when doing an experiment if working in pairs than if working alone.

(c) Discussion with my partner gives me greater understanding of the experiment than if I had worked alone.

(d) I work faster when working alone than when I work in a pair.

(e) I learn more when I work alone than when I work in a pair.

(f) My partner and I work well as a team.

(g) I like having my partner for company during the practical classes.

(h) Discussion with my partner is helpful when working out results and calculations.

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Preferred working in pairs</td>
<td>Q I I T</td>
<td>Q I I T</td>
<td>Q I I T</td>
<td>Q I I T</td>
<td>Q I I T</td>
<td>Q I I T</td>
</tr>
<tr>
<td>(b) I prefer working alone to working in pairs</td>
<td>0 0 0</td>
<td>1 0 1</td>
<td>4 2 6</td>
<td>1 0 1</td>
<td>1 1 1</td>
<td>1 0 1</td>
</tr>
<tr>
<td>(c) Make more mistakes when doing an experiment if working in pairs than if working alone</td>
<td>5 3 8</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>1 4 4</td>
<td>1 1 1</td>
<td>1 1 2</td>
</tr>
<tr>
<td>(d) Discuss with my partner gives me greater understanding of the experiment than if I had worked alone</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>5 3 8</td>
<td>3 2 5</td>
<td>0 0 0</td>
<td>0 3 3</td>
</tr>
<tr>
<td>(e) Work faster when working alone than when I work in a pair</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>5 1 5</td>
<td>2 1 2</td>
<td>1 1 1</td>
<td>0 0 0</td>
</tr>
<tr>
<td>(f) I learn more when I work alone than when I work in a pair</td>
<td>5 1 5</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>1 0 1</td>
<td>1 1 1</td>
<td>4 1 5</td>
</tr>
<tr>
<td>(g) My partner and I work well as a team</td>
<td>5 0 5</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>2 0 2</td>
<td>1 0 1</td>
<td>0 1 1</td>
</tr>
<tr>
<td>(h) Discussion with my partner is helpful when working out results and calculations</td>
<td>4 2 6</td>
<td>1 0 1</td>
<td>0 0 0</td>
<td>2 1 3</td>
<td>1 0 1</td>
<td>0 0 0</td>
</tr>
</tbody>
</table>

Q = Information from questionnaires
I = Information from interview
T = Total no. of students expressing opinion
In the 19 students in Table 4.6.1.2 there were 7 complete pairs. All the students in three of the pairs were 'A' students, all the students in three of the pairs were 'P' students whilst only one pair was made up of an 'A' and a 'P' student. This suggests that one of the factors influencing the success of a pair was compatibility. This was born out by the following facts:

(1) At least 3 of the 'A' students were amongst those who had not been able to have a partner of their own choice.

(2) 'A' students from two of the above pairs were interviewed. In one pair one of the students did all the work and in the other one of the students commented:

'My partner is absolutely useless. Allshe does is mess up the experiment. I have to watch her all the time to see that she doesn't mess it up and so I get her to do the washing-up!'

A similar comment was made by an 'A' student from another pair.

Another pair of 'A' students presented a different picture. They got on well together and gave responses in the 'agree' and 'neutral' categories for items d, f and g in Table 4.6.12 but they both felt that they learnt better when working alone (item e).

The overall picture presented is therefore that all the students benefitted in some ways from working in pairs but that some either had difficulties in cooperating with their partner or simply preferred to work alone. In a course which emphasises illustrating the lectures, understanding the experiment is important (items c and h).
and it therefore appears that the large majority of students gain more from working in pairs than alone.

(2) Academic staff, demonstrators, technicians and students from another pair

(a) Attitudes

This section examines how the attitudes of some of the participants in the course affected the relationships between the different groups of people. Attitudes towards technicians and student attitudes to students from other pairs were not investigated and are therefore not included below.

The staff on the whole were quite enthusiastic. In the first week of the course one of the demonstrators commented that this course contrasted greatly with a previous course on which he had demonstrated in that a lot of staff attended voluntarily, whereas in the previous course even the member of staff, who was meant to be present, was not always there. The course organiser thought that it was important to be able to deal with students on an individual basis and encouraged other staff to be present at certain times (section 4.6.3.1.3). Similarly, it was observed that the demonstrators were enthusiastic and willing to help the students.

Two members of staff on a number of occasions mentioned to the evaluator that they thought the academic standard of the students was low. Certain members of staff also tended to become rather impatient with the weaker students. For example, one member of staff said that he did not bother with weaker students because they were going to fail anyway.
This attitude communicated itself to the students. Some students found staff members very helpful and interested in their work, whilst others found certain members of staff not so helpful. For example, five students were asked in interviews whether the staff ever came up to them whilst they were working at the bench or whether they, the students, had to go to ask the staff for help. Two students who were both above average ability\(^1\) said that the staff often came up to them to see how they were getting on, whereas three other students who were all average or below average ability found that they always had to go to the member of staff for help.

In addition to this many students felt inhibited in talking to the staff because of fear of revealing things that they did not know. This has already been mentioned in section 4.6.3.2.3.3 in connection with the Calchem programmes. In addition to those comments, four students\(^2\) made comments, such as:

'I think lecturers expect too much of you. If you haven't done it before they expect you to know it anyway.'

'You are always on your guard as to what you say, even if the lecturer says that it doesn't matter what you say to him.'

Situations were also observed where students seemed to be afraid of

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1 Students were divided into 5 categories, according to practical ability, by the evaluator on the basis of his observations and interactions with the students. These were shown to the course organiser for comment and a few minor alterations made. These categories have been used in this analysis as a crude measure of practical ability.

2 i.e. a total of 10 students out of the 19 students from whom information has been obtained made such comments.
consulting the staff. For example, one student did not understand her results for an experiment and consulted the evaluator for help. When encouraged to consult a member of staff she was very reluctant.

This is also born out by the discrepancy between the students' and the course organiser's opinions of the importance of aim 23. Aim 23: 'To develop students' ability to communicate results orally.'

There was clearly not as much consultation between students and staff as the course organiser would have wished.

Some students were also reluctant to consult demonstrators (conversation with a demonstrator), but this was a lot less common.

The students tended to view the staff and demonstrators in rather different ways:

(a) Three students said that they preferred to consult lecturers to demonstrators. They seemed to view the lecturers more as experts: 'First of all you can consult Dr. X. because he has written it all out, so if anything is wrong, he'll know about it.'

(b) The demonstrators, however, were seen as being more like students and were more in touch with the students. Typical comments of four students who preferred to consult demonstrators to staff were:

'The demonstrators are more like students and I feel more at ease with them.'

'I don't find the lecturers as helpful as the demonstrators. They talk to you and you don't understand what they are saying, whereas demonstrators
will say, "Oh yes, this is what he (the lecturer) means", and you go over to him for a translation.'

The demonstrators were seen less as experts and in fact only learnt about some of the experiments as the course proceeded.

(b) Strategies

Students adopted different strategies in order to obtain the kind of help that they needed. The kinds of help that students might need in a course of this type can be divided into four areas:

(1) Understanding
(2) Problems following the laboratory manual
(3) Learning how to use specialised apparatus and instruments
(4) Problems encountered in carrying out the experiment; the experiment 'going wrong'.

For the most part the students gained their understanding of the experiments by reading outside the laboratory, from lectures and by discussing the experiments with their partners. If they could not understand the experiment after using these resources, which was not often, they consulted academic staff (interviews of 6 students).

In the first half of the course the students tended to consult staff and demonstrators for (2), (3) and (4), but in the second half of the course students consulted them less and consulted technicians and students from other pairs more (section 4.6.3.1.4.1, Table 4.6.6). Presumably as the students and technicians gained more experience

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1 (a) Both technicians were newly appointed this academic year; (b) a smaller choice of experiments would have meant that students would have been able to help one another more.
with the laboratory course students preferred to consult them because they were not inhibited by being afraid of revealing things that they did not know.

(c) Deployment of staff, demonstrators and technicians

The change in the people that students consulted, together with the fall in students' attendance in the latter part of the course meant that the staff and demonstrators had considerable amounts of time 'free', i.e. not being used to help students or to administer the laboratory course, in the second half of the course (Table 4.6.7, items 2, 3, 6, 7 and Table 4.6.8, items 3, 4, 5, 7, 8). The amounts of 'free' time during the course for staff, demonstrators and technicians are shown below:

| TABLE 4.6.13 Amount of 'free' time as a percentage of total time spent in the laboratory |
|---------------------------------|----------------|----------------|----------------|
|                                 | Weeks 1-4 | Weeks 5-8 | Change |
| Staff                           | 14        | 44        | +30     |
| Demonstrators                  | 25        | 64        | +39     |
| Technicians                    | 31        | 35        | +4      |

We see here another hidden consequence of the students rushing in the laboratory. Staff and demonstrators were unable to use free time marking because students had not yet written their reports on many experiments. Nevertheless, it appears that appreciable savings in staffing could be made in the latter part of this course. It must, however, be born in mind that the staff, demonstrators and technicians must have some free time in the laboratory to prevent queues of
students forming.

The staff and demonstrator activities at different times of the day have been analysed for weeks 5 to 8. There were too few observations to determine when would be the best times to reduce the number of staff and demonstrators. It is clear, however, that the numbers of staff should not be reduced between 10.00 a.m. and 11.00 a.m.

4.6.3.2.4 Reactions to the laboratory assessment

The issues examined in this section are the students' opinions of the value of the write-ups or reports on experiments, their opinions as to the bad features of the reports and the amount and type of feedback about their progress in the course.

The information in this section was gathered by interviews and questionnaires.

(1) The value of the write-up.

(a) 15 Students were asked what they gained from doing the write-up for each experiment. 13 Students (7 in interviews, 7 in questionnaires) thought that the write-up helped them to understand the experiment and its purpose and 5 of them said that they had to study textbooks in order to write a reasonable report.

(b) 8 Students (2 in questionnaires, 8 in interviews) thought that the write-up helped them to remember the experiment and the theory

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1 The questionnaire was based on responses in interviews. The interview schedule was modified to follow-up particular areas of interest. This means that in some areas the attitudes of many students have been gathered, whilst in others only a few students commented.
involved in the experiment.
(c) 6 Students (interviews) saw the write-up as linking the lectures and practical work; as reinforcing the material covered in lectures.

(2) Criticisms of the write-ups

The students were asked whether they thought the time spent on the write-ups was time well spent: 8 students (5 in questionnaire, 3 in interviews) thought it was not, whilst 3 (questionnaire) thought it was. Six students (4 in questionnaire, 2 in interviews) thought that there was a lot of needless repetition of the laboratory manual in the write-up. They could see little point in writing the procedural details and the theory which was in the manual. They suggested that a calculation of the results and a discussion would form an adequate write-up. One student (interview), however, disagreed and thought that the present kind of write-up should be preserved.

(3) Feedback

Six students (questionnaire) thought that they were not given enough information about how well they were getting on: 'You just get a signature at the end.'

These comments are born out by the discrepancy between the students' and the course organiser's view of the importance of aim 23 (section 4.6.2.2 and section 4.6.3.2.2.3.

Aim 23: 'To develop students' ability to communicate results orally!'. Two students, however, said that the lecturers sometimes wrote comments
in their books to tell them where they had gone wrong and one of them said that he had had useful discussions with a member of staff as a result of these comments. One such discussion was in fact observed, but this kind of discussion did not occur frequently.

Students suggested the kinds of information that they would find useful:
(a) 5 students (questionnaire) said that they would have liked to have been given a mark for each experiment.

(b) 2 students (questionnaire) said that they would have liked more criticism of their practical technique in the laboratory.

(c) 1 student (interview) said that he would have liked more comments about what was wrong in the report.

In conclusion, it seems that there are three possible reasons for including a formal report on experiments in the course. The first is to assess the students; to judge the extent to which individual students were achieving the aims of the course. This could not be examined because a considerable amount of work in redefining the aims in behavioural terms would have been necessary first. Secondly, the write-up can be included to assist the students in learning from the experiments. This has been important in this course. Thirdly, the write-up can be included in order to provide a channel for feedback to the students. Clearly, it has not been used for this.

It is my impression from observing students and talking to them, that the fact that students were unable to see whether they were
improving as they progressed through the course, contributed to an attitude in many students whereby they viewed the experiments as exercises that had to be done or got out of the way rather than as learning experiences. Unfortunately, there was insufficient time to follow up this hypothesis

4.6.4 Outcomes

This section examines how successful the course was in achieving its aims. The aims of the course are outlined in section 4.6.2.

Ten students were asked in interviews what they had gained from doing the course. Their replies can be grouped in 3 categories:

(1) Seven students said that the practical course reinforced the theory; to quote one student: 'It grinds the knowledge into you!'

(2) Four students said that the lecture course enabled them to see things in reality that they had only learnt in theory before; to actually experience the problems involved in carrying out an experiment and being able to apply the theory that they had learnt in a practical situation.

(3) Four students said that they had learnt various manipulative skills and how to use certain instruments.

Items (1) and (2) are clearly related to the aim that was agreed to be the most important:

Aim 2: 'To illustrate theoretical material taught in lectures and tutorials'. 
It has been pointed out, however, in sections 4.6.3.2.1.2 and 4.6.3.2.2 that the amount of integration between the practical course and the lecture courses is limited by constraints of apparatus and space.

Other aims which were thought to be important are aims 19, 22, 30 and 33.

Aim 19: 'To develop students' ability to make deductions from experimental data and to interpret experimental data'.

The amount of information gathered about this aim is limited. The students were required to draw conclusions from their data for each experiment in their reports but no information was collected about how successful they were. Five students, however, commented that they had difficulties with the write-up and calculations (section 4.6.3.2.2).

Aim 22: 'To train students in writing reports on experiments'.

Again, the amount of information gathered about the aim was limited. Students were required to write a report about each experiment, but detailed instructions were given in the laboratory manual about how to proceed with the experiment. Consequently, the descriptive part and to some extent the theory involved in the experiments were already written for the students. As was pointed out in section 4.6.3.2.4 six students thought that repeating what the manual said, in their reports, was a waste of time.

The amount of feedback on student reports was small, which must have limited how much the students learnt in this course about report writing.

Aim 30: 'To train students in extracting information from the lecture (including training in the use of the library)'.

One of the results of the integration of the theory and practical being limited was that students had to study on their own to understand the experiments (see section 4.6.3.2.1.2). Eight students (57% of the students interviewed about this aspect) said that in addition to studying the laboratory manual before coming into the laboratory they sometimes studied textbooks and five students (interviews) said that they studied textbooks when writing the report. Clearly, this course demanded that for some experiments the students should study alone and make use of textbooks.

Aim 33: 'To develop students' skill in working and cooperating with others in a team'.

Section 4.6.3.2.3.3 examines how well students managed to cooperate with their partners. In most pairs students worked and cooperated well together.

Summary

As far as can be judged, from the sometimes limited information available, the course was reasonably successful in its major aims. The biggest reservation is with respect to the most important aim, aim 2, because of the limited integration between the lectures and the practical course.

4.6.5 Conclusions and recommendations

4.6.5.1 Conclusions

This course was not unusual in that it failed to achieve good integration between the laboratory and lecture courses. Lee (94) and Black and
Whitworth (12) criticise traditional courses for being insufficiently integrated with theory courses. Black and Whitworth also criticise 'circus' laboratories for the lack of coherent development in the sequence of experiments performed by students.

In this course the institutional policy of organising unit or modular degree courses had a profound effect. The main effect was that students rushed the laboratory course in order to have more time at the end of the course to revise for the examinations. It appears, however, that on the whole this had a positive effect on students' learning in that they were prepared to spend time studying before doing an experiment, thereby overcoming some of the problems caused by lack of integration. In addition, some sort of coherent development was achieved by guiding the students' choice of experiments. Nevertheless integration with the theory courses was limited.

Two other factors which enhanced the students' understanding of the experiments were the use of Calchem programmes and working in pairs. The Calchem programmes encouraged thought, discussion and consequent learning and students found it helpful to work in pairs at the terminals. Students, with a small number of exceptions, also found working in pairs throughout the course to be valuable.

The students found that doing a write-up for each experiment helped them to understand the experiment and some said that it helped them to remember the experiment and some said that it helped to link the lectures and practical work. The data indicate that students would like to see the length of the write-up reduced by excluding material already stated in the laboratory manual.
Students got little feedback through their written reports about how well they were getting on in the course. The data indicate that they would have liked more feedback.

One problem with the course was that help from staff and demonstrators tended to go to those students who were least reluctant to consult them. They were usually the students who were in least need of help.

4.6.5.2 Recommendations

The main problem with this course was the difficulty of achieving good integration between theory and practical courses.

In section 3.3.3.2 two alternatives for achieving greater integration are proposed. They are, radically retimetabling the course or using a wide variety of teaching and learning techniques, particularly individualised learning.

Barrett and Blake (6), King and Parlett (86) and Black and Whitworth (12) all describe courses in which integration is achieved by concentrating the courses into a shorter time scale. In course V this would mean dividing the course into the four branches of physical chemistry, thermodynamics, kinetics, electrochemistry and spectroscopy, and doing concentrated courses lasting 2 or 3 weeks to include all the theory and practical work which is now spread over 10 weeks. Although this would allow greater integration of theory and practical work within each topic it would split the degree course into even smaller units; a trend which is deplored by the staff on this course (section 4.6.2.2.1.1). It would also fail to overcome
the problem of having limited sets of specialised equipment.

A second approach is to introduce more individualised learning techniques such as audio-visual materials and computers, so that students are more able to integrate the theory and practical work for themselves. Coyle and Servant (36) have used films to replace experiments and to emphasise 'scientific method' and 'critical understanding' in practical work. In addition to the use of computers in the tutorial mode described in this course, computer simulations have been used to replace laboratory experiments (4,5,38,110,154). These can be used to direct the emphasis of the course away from teaching manipulative skill towards manipulation of data and they allow students to vary experimental parameters beyond the physical time limits of the laboratory. Such audio-visual or computer experiments do not have to be performed in the laboratory, thus saving laboratory space and do not have to be done during laboratory hours, thereby allowing more integration of laboratory and lecture courses.

An example of a fully integrated laboratory/lecture course based on the use of individual learning techniques is the audio-tutorial approach (40,58,134; see also section 2.2.4.1.1). This has not yet been reported in chemistry laboratory courses, although a course which has achieved integration by using a wide variety of teaching methods is described in section 3.3.3.2 2.

In summary, it appears that there are 3 alternatives available to produce greater integration of theory and practical work:

(i) The laboratory and lecture courses could be radically retimetabled
into shorter self-contained units. This would appear to be undesirable because staff felt that the course was already too fragmented.

(ii) The traditional format of the laboratory and lecture courses could be abandoned and individual learning techniques could be used to achieve integration. This would, however, involve a vast amount of staff time in redesigning the courses and would necessitate buying and setting up the necessary hardware and software.

(iii) More individualised learning could be introduced into the existing course. This is probably the most realistic of the 3 alternatives as it involves no sudden investment in time or money. More individualised learning techniques could be slowly introduced and staff would have time to evaluate their effectiveness and to find the best ways of using them.
4.7 An evaluation of a part I chemistry laboratory course (course VI)

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Introduction

This part I laboratory course was chosen as a suitable course to study on the basis of the data obtained from the nationwide survey of laboratory courses described in Chapter 3.

The course was unusual in that it had been designed to integrate as far as possible the main branches of chemistry. Staff felt that there was a trend in chemistry away from traditional branches of chemistry (i.e. physical, organic and inorganic) towards much more interdisciplinary work and that the laboratory course should reflect this.

The course was also unusual in that during the 4 terms for which it ran, it was broken down into eleven 3 week units. The laboratory course as a whole was designed and coordinated by a team of 4 members of staff, but within the scheme agreed by them each unit was organised by one member of staff in a way that he felt was appropriate.

The evaluation described in this report was, therefore, designed to study the effect of this method of organising a laboratory course on the way that students learnt in the course and in addition to study any institutional factors that may be affecting the way that students learnt. The evaluation therefore studies the perceived aims of the course, how the course is structured to achieve these aims and to discover the main factors which were contributing to, or limiting, the achievement of the aims.

1 Data from staff interview
The course lasted for 4 terms, which meant that it was possible for the evaluator to study some issues, which emerged in the course of the evaluation, in depth. It also meant that it was possible to carry out the evaluation simultaneously with 2 groups of students, the first year students in term 1 and the second year students in term 4.

4.7.1 Methods of evaluation

The sources of data for the evaluation, the times when the particular sources were used and the stages of the evaluation to which they are mainly related are outlined below. All relevant questionnaires and interview schedules are included in Appendix A 4.7.

The course was attended by 43 chemistry I students and 40 chemistry II students. Four members of staff had been involved in planning the course. Of these 3 attended different units of the course and they were aided by other members of staff and demonstrators. Different units were staffed by different members of staff and demonstrators.

In this course members of staff were referred to as senior demonstrators and P.G. demonstrators were referred to as junior demonstrators. This nomenclature is used throughout this report.

The lower response rates for the chemistry II students is a reflection of the fact that the chemistry II students finished the course 6 weeks after the evaluation started and therefore it was not possible for the evaluator to get to know many of the students. Chemistry II students also had to prepare for their part I examinations at the end of the autumn term and had less time to spare.
<table>
<thead>
<tr>
<th>Data source</th>
<th>Time of use</th>
<th>Response</th>
<th>Stage of evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Documentary evidence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Instruction sheets given to students</td>
<td>prior to and during course</td>
<td>-</td>
<td>(i)</td>
</tr>
<tr>
<td>(b) Minutes of meetings of course organisers convened to design the course</td>
<td></td>
<td></td>
<td>(i)</td>
</tr>
<tr>
<td>(c) Practical grades of Chem II students</td>
<td>after course</td>
<td>-</td>
<td>(iii)</td>
</tr>
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<td>(2) Observation; as researcher</td>
<td>throughout</td>
<td>-</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>(a) Senior demonstrators</td>
<td>prior to course</td>
<td>-</td>
<td>(i)(ii)</td>
</tr>
<tr>
<td>(i) Type 1 interviews-3 of the 4 course organisers (the 4th was on sabbatical leave in Canada)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ii) Type 2 interviews-notes were made of occasional conversations with senior demonstrators</td>
<td>throughout course</td>
<td>-</td>
<td>(i)(ii)</td>
</tr>
<tr>
<td>(b) Junior demonstrators</td>
<td>throughout course</td>
<td>-</td>
<td>(i)(ii)</td>
</tr>
<tr>
<td>Type 2 interviews-as in (a)(ii)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Students</td>
<td></td>
<td></td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>(i) Type 1</td>
<td></td>
<td></td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>Chem I</td>
<td>5 students</td>
<td>unit 3</td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>16 students</td>
<td>unit 4</td>
<td>(i)(ii)(iii)</td>
<td></td>
</tr>
<tr>
<td>Chem II</td>
<td>9 students</td>
<td>unit 10</td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>(ii) Type 2</td>
<td></td>
<td></td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>Chem I</td>
<td>3 students</td>
<td>unit 2</td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>Chem II</td>
<td>9 students</td>
<td>unit 11</td>
<td>(i)(ii)(iii)</td>
</tr>
<tr>
<td>(4) Questionnaires</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Staff</td>
<td>end of spring term 1976</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Aims questionnaire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Students</td>
<td></td>
<td></td>
<td>(i)</td>
</tr>
<tr>
<td>Chem I</td>
<td></td>
<td></td>
<td>(i)</td>
</tr>
<tr>
<td>(i) aims questionnaire</td>
<td>end spring 76</td>
<td>43</td>
<td>31</td>
</tr>
<tr>
<td>(ii) ad hoc questionnaire 1</td>
<td>end autumn 75</td>
<td>43</td>
<td>31</td>
</tr>
<tr>
<td>(iii) ad hoc questionnaire 2</td>
<td>end spring 76</td>
<td>43</td>
<td>31</td>
</tr>
<tr>
<td>Chem II</td>
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<td>(i)</td>
</tr>
<tr>
<td>(i) aims questionnaire</td>
<td>end autumn 75</td>
<td>40</td>
<td>19</td>
</tr>
<tr>
<td>(ii) ad hoc questionnaire</td>
<td>end autumn 75</td>
<td>40</td>
<td>19</td>
</tr>
<tr>
<td>Feedback sheets were used for units 1,2,3,10 and 11</td>
<td>after each experiment</td>
<td>Response rates are given in appropriate sections</td>
<td></td>
</tr>
</tbody>
</table>

1 See section 4.1.2

2 There were 3 units held each term. Unit 3 was therefore held towards the end of the autumn term 1975. Units 10/11 were studied at the same time as units 1 and 2 respectively.
4.7.2 Aims

4.7.2.1 Aims of the present course

4.7.2.1.1 General comments on the aims of the course

The aims of the course gradually changed in emphasis as the course proceeded. The documentation for the course describes its overall structure:

'The course is integrated across the traditional areas of inorganic, organic and biochemistry, but is subdivided into 3 week units each with a recognisable theme. The early units are concerned primarily with the acquisition of techniques, this emphasis changing later in the course to the investigation of particular chemical systems. Throughout there is an attempt to relate laboratory material to lecture courses currently in progress.'

The interviews with members of staff confirmed the overall orientation of the course and it became clear that there were distinct differences in the aims of individual units. These are discussed in sections 4.7.4.1, 4.7.4.2 and 4.7.4.3.

4.7.2.1.2 Agreed aims of the present course

The data from the questionnaires confirms the overall picture described above and supplies more detailed information.

The mean ratings and standard deviations for each of the 33 aims in
the aims questionnaire have been calculated for the Chemistry I and Chemistry II students and staff.

There is substantial agreement between the Chemistry I and Chemistry II students about what the aims of the course were: There were only 4 aims for which there were statistically significant differences and these are discussed in section 4.7.2.1.3.

There are also areas of agreement between the students and the staff although in other areas staff and students' perceptions of the aims of the course differed.

Graph 4.7.1 is a plot of the mean ratings for the aims of the present course given by the Chemistry II students against the corresponding ratings given by the members of staff. The more important aims are those with the higher ratings. The aims which the staff and students were agreed were most important lie in the right hand corner of the graph and are:

Aim 6: 'To teach basic practical skills and techniques (e.g. manipulative and preparative skills and techniques) (Area B)'.

Aim 7: 'To familiarise students with some important instruments and devices (Area B)'.

Aim 8: 'To train students in observation (Area B)'.

Other aims which staff and students agreed were quite important were aims 11, 16, 17 and 18 (Area C).

4.7.2.1.3 Aims over which there was disagreement

(1) There are 3 aims which staff thought were very important but which
Graph 4.7.1

Aims of present course vs Chem. II. v Staff
students thought were important but emphasised less. They are:

Aim 2: 'To illustrate material taught in lectures and tutorials.'

Aim 9: 'To make students aware of specific hazards in experimental chemistry and to teach them to take the necessary safety precautions.'

Aim 21: 'To develop students' ability in estimating the size and significance of errors.'

(2) Aims which students thought were quite important but staff did not were aims 4 and 19.

(3) The four aims for which the Chemistry I and Chemistry II students disagreed as to their importance are as follows: Chemistry I students thought 2 aims were more important:

Aim 1: 'To teach theoretical material not included in lectures and tutorials' (significant at the 0.05 level).

Aim 21: 'To develop students' ability to estimate the size and significance of errors' (significant at the 0.01 level).

Chemistry II students thought 2 aims were more important:

Aim 12: 'To train students in experimental design' (significant at 0.05 level).

Aim 18: 'To train students in keeping a day-to-day laboratory notebook' (significant at the 0.01 level).

4.7.2.1.4 Summary of aims of the present course

(1) The main emphasis of the course lies in area B (section 4.7.2.1.2).

(2) Some emphasis is also placed on aims in area C (section 4.7.2.1.2).

(3) There is some disagreement about how important aim 2 (area A) is in the present course. Staff feel it is a very important aim whereas students see it as only quite important (section 4.7.2.1.3). Aim 1 seems to be emphasised more earlier in the course indicating that as
the course proceeds less material is included in the laboratory course that is not covered in the lecture courses.

(4) Staff and Chemistry I students (i.e. students half way through the course) are agreed that aim 21 is a very important aim. Chemistry II students (at the end of the course) felt that it was less important indicating that the statistical treatment of errors which is emphasised strongly in the early parts of the course (e.g. unit 2) is not followed up and reinforced in the later parts of the course (see section 4.7.4.2.6 for a more detailed discussion of this aspect.)

(5) It is perhaps disturbing that students do not see aim 9 being as strongly emphasised as the staff.

(6) The discrepancy over aim 19 is surprising. Perhaps students find this aspect of their work more tasking than the staff expect.

(7) Although staff do not feel aim 4 is an important aim they do try to relate the experiments to something outside the experiment wherever possible, to the lecture courses and to social issues¹ (e.g. one experiment measures the alcohol level in a blood sample). Thus, although aim 4 may not be as important as an aim aspects of the course are related to it.

4.7.2.2 Aims for an ideal course

4.7.2.2.1 Agreed aims for an ideal course

Once again the Chemistry I and Chemistry II students were in good

¹ Data from staff interview
agreement.

Graph 4.7.2 is a plot of the mean ratings for the aims of an ideal course given by the Chemistry II students against the corresponding ratings given by the staff.

It can be seen that the most important aim in an ideal course would be aims 2 (area A), 6 and 7 (area B), all with mean ratings ≥ 4.0. Other important aims would be 8, 9, 19, 28 and 29 with aims 16, 17 and 21 also being quite important.

It can be seen that the staff and students are agreed that aims in area B should be emphasised strongly, as indeed they are at present, that aim 2 (area A) should ideally be emphasised more strongly than at present and that it would be desirable to put more emphasis on two of the attitudinal aims in area D, aims 28 and 29.

4.7.2.2.2 Aims over which there is disagreement for an ideal course

It is clear from the wide scatter on Graph 4.7.2 that there are a number of aims which students felt should be more important in an ideal course, than did staff. In order to assess whether there were any educationally significant differences between the perceptions of aims for an ideal course and those for the present course, the following procedure has been adopted:

1 There are only 2 aims for which there is a statistically significant difference at the 0.05 level. Since there are 33 aims this would be expected as a random fluctuation.
Aims of an ideal course  Chem. II. v Staff

Graph 4.7.2

Staff

Chem. II.
(i) A dissonance value has been calculated for each aim. The dissonance value is defined as the mean rating for an ideal course minus the mean rating for the present course.

(ii) t-Tests have been carried out to determine whether each dissonance value is statistically significant at the 0.05 level. All the statistically significant dissonance values are positive.

(iii) Scatter graphs have been plotted of the mean rating for an ideal course against the dissonance (Graphs 4.7.3 and 4.7.4) for all the aims where the dissonance value is statistically significant.

For the data from the staff aims questionnaires only one dissonance value is statistically significant (within the 0.05 level) because of the small numbers. Aims with dissonance values ≥0.75 have therefore been arbitrarily chosen for inclusion in Graph 4.7.5.

(iv) The aims for which there is an educationally significant dissonance lie in the top right hand corner of the graphs and have been arbitrarily defined on each graph according to the scatter as:

Graph 4.7.3, Chemistry I - rating > 3.3, dissonance > 1.1
Graph 4.7.4, Chemistry II - rating > 3.5, dissonance > 1.1
Graph 4.7.5, Staff - rating > 3.5, dissonance > 1.1

The differences which are educationally significant are shown below.
<table>
<thead>
<tr>
<th></th>
<th>Area A</th>
<th>Area C</th>
<th>Area D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry I</td>
<td>2, 4</td>
<td>12, 13, 14, 15, -, 30</td>
<td>24, 25, 26, 28, 29</td>
</tr>
<tr>
<td>Chemistry II</td>
<td>- -</td>
<td>- - - - -</td>
<td>24, 25, 26, 28, 29</td>
</tr>
<tr>
<td>Staff</td>
<td>- -</td>
<td>- - - - - 19</td>
<td>- - 28, 29</td>
</tr>
</tbody>
</table>

Comments:

(1) It is notable that the dissonance values for the staff are on the whole smaller than those for the students. This is to be expected as the course had only been running for 1.5 years when the staff filled in the questionnaire and will obviously have designed the course to be as close to their ideal as possible.

(2) Students would like to see a lot more emphasis placed on the aims in area D, and to some extent area C, which can be achieved by more open and problem-solving experiments; experiments in which students have control over the planning of the experiments and how they carry out the experiments.

(3) During the interviews one member of staff was asked why there was not more open and problem solving work in the course: An attempt had been made in previous years to introduce more open work into the Part I laboratory course. A series of mini projects had been used and at one time about half the course had consisted of open work. This had, however, been largely abandoned for a number of reasons:

(a) Students found it extremely difficult to cope with. They needed
a lot more guidance than had been anticipated and often tended to waste
time following 'blind alleys'.

(b) Students also kept on coming up with ideas which might be feasible
but for which the apparatus was not available.

(c) Students became frustrated with the open experiments and asked to
change back to a more traditional approach.

(d) The demonstrating was more difficult.

The results from the aims questionnaire show that the main emphasis of
the course should remain on teaching basic skills and techniques and on
illustrating the lectures, but that students would like some more
openness in the course. It appears that a compromise between the
mainly traditional experiments now in use and the open experiments
tried out previously is necessary.

4.7.3 Overall structure of the part I laboratory course

7.7.3.1 Length of the course

The laboratory course lasted for 4 terms. In each term there were 3
units, each 3 weeks long, with the exception of term 4 which consisted
of only 2 three week units. Each week the students were meant to spend
about 11 hours in the laboratory out of the 17 hours for which it
was open.
4.7.3.2 Course content

The organisation of the content of the course is described below in Table 4.7.3

TABLE 4.7.3 Part I laboratory course

<table>
<thead>
<tr>
<th>Term</th>
<th>Unit</th>
<th>Week</th>
<th>Subject matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1-3</td>
<td>Apparatus, purification and separation techniques</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4-6</td>
<td>Chromatography</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Quantitative measurements and their significance</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>7-9</td>
<td>Equilibria</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>1-3</td>
<td>Introduction to analysis</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4-6</td>
<td>Methods of synthesis</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>7-9</td>
<td>Dynamics</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>1-3</td>
<td>Analytical procedures</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>4-6</td>
<td>Synthetic methods</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>7-9</td>
<td>Electrochemistry</td>
</tr>
<tr>
<td>4</td>
<td>10/11</td>
<td>1-3</td>
<td>Chemical systems</td>
</tr>
<tr>
<td></td>
<td>10/11</td>
<td>4-6</td>
<td>Chemical systems</td>
</tr>
</tbody>
</table>

4.7.3.3 Resources

The resources available to each student varied from unit to unit. However, throughout the course instruction sheets were used: There was an instruction sheet for each experiment which usually contained
the theoretical background to the experiment and detailed step-by-step instructions about how to perform the experiment.

The students were not required to write a complete report for each experiment, but to write down results, calculations and conclusions in spaces left in the instruction sheets and to answer questions included in the instruction sheets.

'Workshops'\(^1\) were also used throughout the course. These were usually a combination of a demonstration and a short talk lasting perhaps half an hour in all, given usually at the beginning of a unit or the beginning of a week by a demonstrator\(^2\) to a group of about 10 students.

4.7.3.4 Assessment

The assessment schemes used varied from unit to unit and from experiment to experiment. Each experiment, however, was assessed using up to 3 methods:

(i) Marking the students' results, conclusions, discussion and answers to questions in the instruction sheets.

(ii) Assessment of a student's understanding of an experiment in a viva, in which students answered questions and discussed the experiment for

---

1 Students were expected to attend all workshops.

2 There were 2 kinds of demonstrators: senior demonstrators who were members of academic staff and junior demonstrators who were usually post-graduate students.
about 5 to 10 minutes with a demonstrator.

(iii) Observation of students at work in the laboratory.
The latter method was rarely used.

For most experiments the assessment was made on the basis of:

(i) The quality of the reporting of results, conclusions, etc.,
(ii) The accuracy of results (and perhaps laboratory technique),
(iii) Calculations and conclusions and
(iv) Understanding as displayed by answers to questions on the instruction sheets and in the viva.

In general marks obtained for the experiments counted towards the total part 1 grade allotted to students, but in order to allow first year students time to adjust to their new situation and to become familiar with the requirements for laboratory work, marks for term 1 work were not included in the final part 1 grade.

4.7.3.5 General reactions of second year students to the course

Nine second year students were asked in interviews about their reactions to the part I laboratory course.

(1) Interest

The reactions of the students were on the whole favourable. Of the 9 students interviewed the reactions of 8 of them were favourable: 3 of them said that it was a good course and 6 of them said that it was interesting. Only 1 student did not like the course and did not find it very interesting.
(2) Importance
The students commented on the importance of the laboratory work in relation to the rest of the course. Most of them (4) saw the tutorials as being the most important part of the chemistry course, with laboratory work taking a secondary place, whilst two of them saw the tutorials, laboratory classes and lectures as being complimentary and of equal importance.

(3) Relevance
The amount of relationship that the students saw between the practical work and the lectures varied. Most students (6) saw the practical work as being loosely related to the lecture course and saw it becoming more related to the lecture course as it proceeded (4 students). Students (3) also commented that the physical chemistry units (units 3, 6 and 9) were quite closely related to the lecture course. Only one student thought that the practical course should be more closely related to the lecture course.

(4) Integration
Six students commented on the integrated nature of the course. They were unanimous that it was a good idea to have an integrated course. Although students still talk of physical units, organic units, etc. they were unanimous in saying that the integration of the course where the sub-disciplines of chemistry overlap is a good feature of the course. A typical comment is:
'It's better having the course integrated. We learn to apply techniques where appropriate not just in organic, inorganic or physical.'

1 Numbers in brackets are the number of students expressing the opinion.
4.7.4 Units 1, 2 and 3

A detailed study was made of units 1, 2, 3, 10 and 11 during the autumn term of 1975. Units 10 and 11 were taken by second year students who were the first group of students to take the whole part I laboratory course. At the same time units 1, 2 and 3 were taken by first year students.

4.7.4.1 Unit 1

4.7.4.1.1 Aims of unit 1

The vast majority of students (>80%) thought that the aims of this unit were to give them knowledge and experience of specific laboratory techniques. They also saw the experiments as being mainly unrelated to the lecture courses (see Table 4.7.6); i.e. not designed to achieve aim 2.

4.7.4.1.2 Content of unit 1

There were in all 6 experiments concerned with purification and separation techniques entitled:

1.1 Simple properties of some organic solvents
1.2 Recrystallisation
1.3 Fractional distillation
1.4 Steam distillation
1.5 Vacuum distillation
1.6 Sublimation

1 Information from feedback sheets (question 6). See Appendix A 4.7 for feedback sheets
4.7.4.1.3 Resources

(a) Written materials - see section 4.7.3.3

(b) Apparatus. Each student had his own set of apparatus for this unit and students were therefore able to work through the experiments in the same order.

(c) Workshops. There were 5 workshop/demonstrations.

(d) People. During unit 1 there were usually one senior demonstrator and two junior demonstrators present, at any one time, who students could consult when they wished.

44 Students attended unit 1. Although students were expected to attend the laboratory for only 11 out of the 17 hours for which it was open, students often spent more time than this in the laboratory as shown by the data from the Chemistry I questionnaire I in Table 4.7.4.

TABLE 4.7.4

<table>
<thead>
<tr>
<th>(a) Total time spent per week in the laboratory doing practical work (hrs) (This includes (b))</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>13.0</td>
<td>11.7</td>
<td>10.8</td>
</tr>
<tr>
<td>S.D.</td>
<td>1.8</td>
<td>2.0</td>
<td>2.3</td>
</tr>
<tr>
<td>(b) Time spent per week in the lab. writing up experiments (hours)</td>
<td>1.8</td>
<td>4.2</td>
<td>2.7</td>
</tr>
<tr>
<td>S.D.</td>
<td>1.4</td>
<td>2.8</td>
<td>1.4</td>
</tr>
<tr>
<td>(c) Time spent per week out of the lab. writing up experiments (hours)</td>
<td>0.6</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>S.D.</td>
<td>1.7</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>(d) Total (hours)</td>
<td>13.6</td>
<td>13.2</td>
<td>12.3</td>
</tr>
<tr>
<td>S.D.</td>
<td>3.5</td>
<td>3.2</td>
<td>3.5</td>
</tr>
</tbody>
</table>

1 Standard deviation
The staffing ratios calculated on the basis of the amount of time that students said they spent in the laboratory for unit 1 are therefore as shown in Table 4.7.5.

TABLE 4.7.5

<table>
<thead>
<tr>
<th>Students : Senior demonstrator</th>
<th>34:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students : Junior demonstrator</td>
<td>17:1</td>
</tr>
<tr>
<td>Students: Sen.+Jun. demonstrator</td>
<td>11:1</td>
</tr>
</tbody>
</table>

4.7.4.1.4 Activities

(1) The part I laboratory course started with an introductory lecture given by one of the members of staff who organised the laboratory course. The organisation of the laboratory course was described to students. They were also told that they were only expected to attend the laboratory for 11 out of the 17 hours for which it was open and that they would have to find a balance between the amount of time that they spent on the laboratory and theory courses: It might pay them to settle for a lower grade in the practical in order to spend more time on the theory course or vice versa.

(2) The introductory lecture was followed by 3 workshops: the students were divided into 3 groups which attended in rotation workshops on safety, use of quickfit apparatus and heating devices. These workshops consisted of an approximately 15 minutes talk/demonstration given by a demonstrator in the laboratory. Students watched and occasionally, usually at the end of a workshop, asked questions.
There was a further workshop after experiment 1.4 at the beginning of the 3rd week of unit 1 on vacuum techniques. During the last week of unit 1 a demonstration of freeze-drying was given.

(3) During the rest of unit 1 students worked individually at the bench consulting demonstrators or other students when they wished.

The demonstrator time was divided between helping the students at the bench and marking their results and conclusions.

4.7.4.1.5 Outcomes

The vast majority (≥70% for each experiment) of the students thought that the aims for each experiment had been achieved for them and that they had gained knowledge and experience of using specific laboratory techniques.

In an interview one member of staff said that the course is bound to succeed in its aims to some extent in that when students carry out techniques which are new to them they are bound to gain experience and knowledge of the techniques. Another member of staff said that as well as gaining experience of techniques students were obliged to compare different techniques so that they would be able to select the most appropriate technique in future experiments.

4.7.4.1.6 Students' reactions specifically related to unit 1

Table 4.7.6 shows the mean and standard deviation for the ratings given

1 Information from question 7, feedback sheets. Feedback sheets are included in Appendix A.
by students on the feedback sheets for difficulty, interest and relevance.

**TABLE 4.7.6**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>1.1</th>
<th>1.2</th>
<th>1.3</th>
<th>1.4</th>
<th>1.5</th>
<th>1.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Response</td>
<td>41</td>
<td>36</td>
<td>27</td>
<td>22</td>
<td>29</td>
<td>23</td>
</tr>
<tr>
<td>% response</td>
<td>93</td>
<td>82</td>
<td>61</td>
<td>50</td>
<td>66</td>
<td>52</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>(\bar{x})</th>
<th>S.D</th>
<th>(\bar{x})</th>
<th>S.D</th>
<th>(\bar{x})</th>
<th>S.D</th>
<th>(\bar{x})</th>
<th>S.D</th>
<th>(\bar{x})</th>
<th>S.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty</td>
<td>2.2</td>
<td>0.6</td>
<td>3.4</td>
<td>0.7</td>
<td>3.0</td>
<td>0.6</td>
<td>2.9</td>
<td>0.5</td>
<td>3.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Interest</td>
<td>2.6</td>
<td>0.7</td>
<td>3.4</td>
<td>1.0</td>
<td>3.0</td>
<td>0.8</td>
<td>3.0</td>
<td>0.8</td>
<td>3.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Relevance</td>
<td>2.1</td>
<td>1.4</td>
<td>2.0</td>
<td>1.2</td>
<td>1.5</td>
<td>0.7</td>
<td>1.3</td>
<td>0.6</td>
<td>1.9</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Rating scales

- **Difficulty**: 1 = too easy; 5 = too difficult
- **Interest**: 1 = boring; 5 = stimulating
- **Relevance**: 1 = not related to lectures; 5 = closely related to lectures

\(\bar{x}\) = Mean

S.D. = Standard deviation

It can be seen that students thought the experiments were at about the right level of difficulty except for experiments 1.1 and 1.6 which were too easy; these experiments were also the least interesting. On the whole the students thought the experiments were quite interesting. The experiments were not related to the lecture courses.

---

1 Questions 1, 2 and 3
Table 4.7.7 shows where the students found most difficulties with the experiments.

**TABLE 4.7.7**

<table>
<thead>
<tr>
<th>Difficulties</th>
<th>Experiment</th>
<th>1.1</th>
<th>1.2</th>
<th>1.3</th>
<th>1.4</th>
<th>1.5</th>
<th>1.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Insufficient chemical knowledge</td>
<td>n</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n %</td>
<td>7%</td>
<td>17%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>26%</td>
<td>16%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Insufficient previous experience</td>
<td>n</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of basic apparatus or techniques</td>
<td>n %</td>
<td>10%</td>
<td>20%</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>45%</td>
<td>25%</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Difficulties carrying out experiments</td>
<td>n</td>
<td></td>
<td>26</td>
<td>51</td>
<td>16</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n %</td>
<td></td>
<td>26%</td>
<td>51%</td>
<td>16%</td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td></td>
<td>72%</td>
<td>41%</td>
<td>11%</td>
<td>23%</td>
<td>6%</td>
</tr>
<tr>
<td>(d) Difficulties answering questions</td>
<td>n</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>on instruction sheets</td>
<td>n %</td>
<td>1%</td>
<td>2%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>1%</td>
<td>2%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e) Apparatus not working properly</td>
<td>n</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>n %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9%</td>
<td>31%</td>
</tr>
<tr>
<td>(f) Problems with techniques</td>
<td>n</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>described by demonstrators</td>
<td>n %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

n = Number of students with particular kind of difficulty

% = Percentage of students with particular kind of difficulty

The main difficulties were connected with the fact that students were using techniques which were new to them (see (c)). Typical of this type of difficulty are the following:

(i) In experiment 1.2 many students found it difficult to judge how much solvent should be added for the recrystallisation.

(ii) In experiment 1.3 many students found it difficult to decide when to collect the different fractions.

It would seem that such difficulties are an inevitable part of the learning experience, of becoming familiar with different techniques.
A second type of difficulty which is prelevent in experiments 1.2 and 1.3 is that students were assumed to possess certain very basic skills, but did not. For example in experiment 1.2 some students did not know how to use sintered glass crubicles, or Buchner funnels and one student did not even know how to use a water bath and another did not know how to set up a reflux condenser.

Perhaps it would be worth considering the use of pairs in these 2 experiments so that students could draw upon one another's past experience.

It would appear from item (f) that some students are reluctant to consult demonstrators even though the instruction sheets on certain occasions specifically recommend them to consult demonstrators.

In experiment 1.5 there were problems with the apparatus not working properly, in particular in obtaining a good vacuum and in obtaining a rotary evaporator that was working properly.

Table 4.7.8 shows that on the whole students understood the experiments in unit 1 quite well, whilst they were doing them in the laboratory.

TABLE 4.7.8

<table>
<thead>
<tr>
<th>Unit</th>
<th>Understanding of theoretical material connected with experiments when doing them in the laboratory</th>
<th>Understanding of theoretical material connected with experiments after finishing write-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D</td>
</tr>
<tr>
<td>1</td>
<td>3.9</td>
<td>0.7</td>
</tr>
<tr>
<td>2 (Chromat)</td>
<td>3.5</td>
<td>0.8</td>
</tr>
<tr>
<td>2 (Statistics)</td>
<td>1.8</td>
<td>0.9</td>
</tr>
<tr>
<td>3</td>
<td>3.2</td>
<td>1.1</td>
</tr>
</tbody>
</table>

1 Data from questions 8 and 9, Chem I Questionnaire I
4.7.4.2 Unit 2

4.7.4.2.1 Aims of unit 2

Unit 2 consisted of two themes which ran concurrently, i.e. chromatography and the statistical treatment of errors. These two themes had different aims and so will be discussed separately.

(1) Chromatography
The vast majority of students (≥ 80%) thought that the aim of this part of unit 2 was for them to learn or gain experience of chromatographic techniques. This was in agreement with the aims of the organiser of unit 2.

(2) Statistical treatment of errors
The aims of the organiser of unit 2 were to familiarise the students 'with the notion that when one makes a measurement there is an error' and familiarising them with the scale of the error and how to deal with it.

The majority of the students thought that the experiments were designed to give them experience and knowledge of the statistical treatment of errors and knowledge and experience of the accuracy of specific pieces of chemical equipment. A sizeable minority of students, however, did not correctly perceive the aims of the experiments and either thought an experiment was designed to give them experience of the use

1 Feedback sheets, question 6
2 Information from interview
of specific laboratory apparatus (Table 4.7.9, item (c)) or did not know what the aim of the experiment was (Table 4.7.9, item (e)).
This confusion about the aims of experiments seems to stem from a complete lack of understanding of the experiments (see section 4.7.4.2.6).

**TABLE 4.7.9 Aims of statistical experiments in unit 2**

<table>
<thead>
<tr>
<th>Experiments</th>
<th>(a) n</th>
<th>(b) n</th>
<th>(c) n</th>
<th>(d) n</th>
<th>(e) n</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 QM1</td>
<td>17</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>2 QM2/M4</td>
<td>-</td>
<td>15</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2 QM2/M5</td>
<td>-</td>
<td>12</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>2 QM3</td>
<td>15</td>
<td>-</td>
<td>1</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

(a) Experience and knowledge of the statistical treatment of errors.
(b) Experience and knowledge of the accuracy of specific pieces of chemical equipment
(c) Experience in the use of laboratory apparatus
(d) No response
(e) Do not know

n = number of students
% = percentage of students

**4.7.4.2.2 Contents of unit 2**

The unit consisted of two separate subjects which were studied together in order to make economic use of time and apparatus. There were 6 chromatography experiments:
Thin layer chromatography
Column chromatography
Paper chromatography
Paper electrophoresis
Ion exchange chromatography
Gas chromatography

The statistics or 'quantitative measures' section of unit was divided into 3 parts each containing related exercises.

Mean and standard deviation
Systematic errors; accuracy and precision
Linear regression

4.7.4.2.3 Resources

(a) Written materials - see section 4.7.3.3
(b) Apparatus
The apparatus for unit 2 was limited. Students were therefore divided into 4 groups. Each group studied a different topic at a specific time according to a timetable. About 3 hours was allowed for each experiment. Each week 1 or 2 of the 3 hour session were timetabled to be free.

(c) Workshops
At the beginning of each week there was a workshop to explain the experiments that each group would be doing during the week and to describe the apparatus.

(d) People
On the first morning of the week 2 senior demonstrators and 2 junior
Demonstrators attended the laboratory course in order to run the workshops. One the afternoon of the first day 1 senior and 1 junior demonstrator were present and for the remaining 2 days of the unit 1 senior demonstrator full time and 1 junior demonstrator, half-time were present.

The overall staffing ratios for unit 2 can be calculated using estimates of the number of hours that the students spent in the laboratory per week. The student estimate of 11.7 hours per week spent in the laboratory (Table 4.7.4) is in close agreement with an estimate based on the observed student attendance on 28 separate occasion on 4 days; this estimate is approximately 12 hours. The overall staffing ratios are:

<table>
<thead>
<tr>
<th>Students : Senior demonstrator</th>
<th>26 : 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students : Junior demonstrator</td>
<td>37 : 1</td>
</tr>
<tr>
<td>Students : Sen &amp; Jun demonstrator</td>
<td>16 : 1</td>
</tr>
</tbody>
</table>

These ratios of course varied considerably throughout the unit as indicated above.

4.7.4.2.4 Activities

(1) Apart from the time spent in workshops students' activities are listed in Table 4.7.11. 26 Observations were made of what students were doing at specific times on 4 separate days during unit 2.
It can be seen that the vast majority of a student's time was spent working at the bench either doing an experiment or working out the results. One sixth of this time was spent working out the results using the calculators provided.

It is significant that for the majority of the time that students spent talking to other people, they were discussing the statistics exercises and that on the four occasions that students were observed talking socially to one another, they were doing the chromatography experiments. The students found the chromatography exercises relatively easy which meant that demonstrators were able to devote almost all their time talking to students about the statistics.

(2) Apart from the time spent in workshops the demonstrator activities are listed below in Table 4.7.12.
TABLE 4.7.12

<table>
<thead>
<tr>
<th>Activity (observed on 26 occasions)</th>
<th>No.of demonstrators performing activity</th>
<th>% performing activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sen.</td>
<td>jun.</td>
</tr>
<tr>
<td>(a) Talking to students</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>(b) Talking to senior demonstrators</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>(c) Talking to junior demonstrators</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(d) Other</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>(e) Nothing; walking round the lab</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

All the demonstrators appeared to be very helpful to the students. There are, however, two factors which could explain why the junior demonstrators spent less of their time talking to students than the senior demonstrators:

(i) Senior demonstrators tended to be much more outward going: they were observed in a number of occasions to go up to students to find out how they were getting on. Junior demonstrators on the other hand tended to wait for students to consult them.

(ii) Junior demonstrators were not so well acquainted with the exercises as the senior demonstrators\(^1\). One senior demonstrator commented that the junior demonstrators tend not to know what the unit is about until it is finished. They often know little more about it than the students and therefore have to work through the problem with the students.

---

\(^1\) Information from interviews and discussions with 4 senior demonstrators
(1) Chromatography
The majority of students (>65% for each experiment) thought that the
aims for each experiment had been achieved for them, with the
exception of experiment 2C5, and that they had gained knowledge and
experience of using specific laboratory techniques\(^1\) (cf. section
4.7.4.1.5). For experiment 2C5 seven students (41%) thought that
the above aim had been achieved, whereas four students (23%) said that
they had gained little or nothing. Six students (35%) did not answer
the question on the feedback sheets. An explanation for the low
achievement of the aims in experiment 2C5 may be that some students\(^2\)
thought that they had already learnt about the skills and techniques
needed in experiment 2C2 (see also section 4.7.4.2.6).

(2) Statistical treatment of errors
The confusion about the aims of the quantitative measures experiments
is reflected in what the students felt that they had gained from the
experiment\(^1\), as is shown in Table 4.7.1 3.

TABLE 4.7.1 3 Outcomes

<table>
<thead>
<tr>
<th>Expts</th>
<th>(a)</th>
<th></th>
<th>(b)</th>
<th></th>
<th>(c)</th>
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<th>(d)</th>
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<th>(e)</th>
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<td>13</td>
<td>52</td>
<td>3</td>
<td>12</td>
</tr>
</tbody>
</table>

1. Information from question 7, feedback sheets
2. 3 students: 2 of whom gained little or nothing and 1 who did not
answer question 7 in the feedback sheets.
(a) Experience and knowledge of the statistical treatment of errors
(b) Knowledge and experience of the accuracy of specific pieces of chemical equipment
(c) Experience in the use of laboratory apparatus
(d) No response $n = \text{Number of students}$
(e) Nothing; little $\% = \text{Percentage of students}$

In all of the experiments a sizeable minority of students said that they had gained little or nothing from the experiment.

4.7.4.2 Student reactions specifically related to unit 2

Table 4.7.1 4 shows the mean and standard deviation for the ratings given by the students on the feedback sheets for difficulty, interest and relevance.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>2C1</th>
<th>2C2</th>
<th>2C3</th>
<th>2C4</th>
<th>2C5</th>
<th>2C6</th>
<th>2QM1</th>
<th>2QM2</th>
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<th>SD</th>
<th>$\bar{x}$</th>
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<th>SD</th>
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<tr>
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<td>0.4</td>
<td>1.3</td>
<td>0.6</td>
<td></td>
<td></td>
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</tbody>
</table>

Rating scales as before - see Table 4.7.6

1 Questions 1, 2 and 3
It can be seen that:

(i) all the experiments were at about the right levels of difficulty with the exceptions of 2QM1 and 2QM3 which were rather difficult, and 2QM2/M5 which was rather easy;

(ii) the chromatography experiments were quite interesting with the exception of 2C5, presumably because of its similarity to 2C2. The quantitative measures exercises tended to be rather uninteresting;

(iii) none of the experiments were related to the lecture courses. Table 4.7.15 shows where the students found most difficulties with the experiments.

The chromatography experiments ran quite smoothly. A large number of students had difficulties with experiments 2QM1 and 2QM3. Some of them felt that they had insufficient mathematical background (Table 4.7.15 (a)) and many students had difficulties in understanding the concepts (Table 4.7.15 (h)) and with the mathematics needed to work out the calculations (Table 4.7.15 (i)). A few students did not know how to operate the calculators (Table 4.7.15 (b)).

The fact that most students had a poor understanding of the quantitative-measures experiments is confirmed by the data from the Chemistry I, questionnaire I in Table 4.7.7, page 388 and from student interviews. Of the 19 students who commented on 2QM1, 2 and 3, only one felt that

---

1 In experiments 2C2 and 2C5 students had difficulties in seeing the colour changes of the solutions eluting through the columns. They also had difficulties in packing columns in spite of the fact that this had been demonstrated in the workshops (see (f) on Table 4.7.15).
<table>
<thead>
<tr>
<th>Table 4.7.15</th>
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<tbody>
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<td>2OM3</td>
<td>-</td>
</tr>
<tr>
<td><strong>Difficulties</strong></td>
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</tr>
<tr>
<td>(a) Insufficient pre-knowledge</td>
<td></td>
</tr>
<tr>
<td>(b) Insufficient previous experience of basic apparatus and techniques</td>
<td></td>
</tr>
<tr>
<td>(c) Difficulties carrying out the experiments</td>
<td></td>
</tr>
<tr>
<td>(d) Difficulties answering questions on the instruction sheets</td>
<td></td>
</tr>
<tr>
<td>(e) Apparatus not working properly</td>
<td></td>
</tr>
<tr>
<td>(f) Could not perform skills which should have been demonstrated in workshops, workshops poor</td>
<td></td>
</tr>
<tr>
<td>(g) Experiment too long</td>
<td></td>
</tr>
<tr>
<td>(h) Difficulties understanding the experiment</td>
<td></td>
</tr>
<tr>
<td>(i) Difficulties with maths needed to do the calculations</td>
<td></td>
</tr>
</tbody>
</table>

\( n = \) Number of students with particular kind of difficulty
\( \% = \) Percentage of students with particular kind of difficulty
he understood the work at the time, three said that they gained an understanding of it on applying the statistics to later work but all the rest did not understand it. Students tended to work through the statistical calculations in this unit without understanding what they were doing or why. A typical comment was: 'You are presented with a load of formulae and are meant to sort out your answers.'

The complete lack of understanding of the statistics had a demoralising effect on the students. Six second year students were interviewed about unit 2 and it transpired that they had rarely had to use the statistics from unit 2 in later work\(^1\). This is confirmed by the disagreement between Chemistry I and Chemistry II students about the importance of aim 21 (see section 4.7.2.1.3). Two of the students said that they simply guessed the errors from the accuracy of the apparatus.

Several factors tended to alleviate the problems with the quantitative measures part of unit 2:

(1) The fact that the quantitative measures exercises ran concurrently with the chromatography experiments meant that the demonstrators were able to spend most of their time helping the students with the quantitative measures exercises.

(2) Senior demonstrators sometimes attended the laboratory for longer hours than those scheduled\(^2\).

---

1 Although one of them said that he could see the relevance now.

2 Observation
(3) Students were encouraged to and did\textsuperscript{1} use periods which were time-tabled as being free to discuss problems with demonstrators.

These factors, however, were insufficient to compensate for the difficulties which students encountered.

In summary, the main problems with unit 2 (quantitative measures) were that:

(1) The unit was overloaded. Too many new concepts were introduced in a short time space in the quantitative measures section and the wide range of chromatographic techniques being introduced to the students meant that a large staffing allocation had to be given to running workshops leaving fewer demonstrators to discuss students' problems on an individual basis (cf. the staffing ratios in Tables 4.7.5 and 4.7.10).

(2) The concepts taught in unit 2 were not used sufficiently often in the rest of the part I course in order to reinforce them and to demonstrate their relevance to chemistry.

It would appear that a radical restructuring of the statistical part of this unit is needed. Four students suggested that a better way of teaching this topic would be through a lecture course.

\textsuperscript{1} Observation
4.7.4.3 Unit 3

4.7.4.3.1 Aims of unit 3

The organiser of unit 3 said that the aims of unit 3 were 'to give the students a back up to the lecture course'; to give them practical experience in actually using the concepts that have been introduced in the lecture course. Its aims were also to teach them about the instrumentation needed in the experiments, to compare the accuracy of instruments and to teach the type of instrument that is appropriate for particular types of experiments. Unit 3 also tried to reinforce the statistical work of unit 2 by including its application in two experiments.

The students were in substantial agreement with the organiser of unit 3 (see Table 4.7.1.6) about the aims.

TABLE 4.7.1.6 Aims of experiments in unit 3

<table>
<thead>
<tr>
<th>Experiments</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
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<td>n</td>
<td>%</td>
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<td>3.2</td>
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<td>26</td>
<td>5</td>
<td>22</td>
<td>5</td>
<td>22</td>
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</tbody>
</table>

1 Interview
2 Information from feedback sheets, question 6
(a) To illustrate material taught in the lectures (e.g. to illustrate how various thermodynamic functions can be determined experimentally)

(b) To learn how to use or to gain experience of specific skills or techniques

(c) To gain experience in data handling; tabulations, calculations, etc.

(d) To learn theoretical material (e.g. to learn about the ionisation of amino acids and to introduce the idea of $pK$)

(e) No response

(f) Do not know

It can be seen that the emphasis in unit 3 has shifted much more to area A with the aims in area B being emphasised less. The overall balance of the aims of the first three units is therefore similar to that described in section 4.7.2.1.4.

4.7.4.3.2 Content of unit 3

The content of unit 3 was designed to relate to the Physical Chemistry lecture course and was concerned with thermodynamics and equilibria. Of the first 3 units, this unit is the one which is the most closely related to a specific branch of chemistry, although, of course, the physical measurements are done on organic and inorganic systems.

This unit came last in the first term in order that sufficient material would have been covered in the lectures before students did the experiments.

There were six experiments:

3.1 Ammonium carbamate equilibrium

3.2 Stability constant of iron (III) thiocyanate

3.3 Calorimetry and heat of solution
3.4 Freezing point depression
3.5 Ethanol liquid-vapour equilibrium
3.6 Ionisation of amino acid

In the first year that the course ran students were expected to do all six experiments, but this was reduced to five in the second year so as not to overload the students.

In the first week of the unit the students were divided into 2 groups which did experiments 3.1 and 3.2 in rotation. For the remainder of the unit students did three of the remaining experiments in any order.

4.7.4.3.3 Resources and activities

(a) Written materials - see section 4.7.3.3
(b) Apparatus
The availability of apparatus was limited, which meant that students worked in pairs doing the experiments in the order described at the end of section 4.7.4.3.2 and that students were usually restricted to spending no more than one day in each experiment. The organiser of unit 3 commented that the lack of availability of apparatus caused problems for the demonstrators and laboratory technicians when it broke down. He felt that he had to be 'on call' for the first half of his unit and that the laboratory technicians had to be very familiar with the equipment.

(c) Workshops
Students attended workshops at the beginning of each week in which the

1 Interview
apparatus to be used in the course was described and the results obtained by the class on the previous weeks' experiments received.

(d) People

Senior and junior demonstrators were available for the students to consult as in the previous units. The laboratory was observed on the first day of week 3 of unit 3 and at this stage about half the students had already completed the unit and so student demands on demonstrator time were small.

Students were also able to get help from their partner (see section 4.7.4.4.2.2) and on the 8 occasions when they were observed, no students consulted students in other pairs.

This was the only unit in term 1 in which a viva was held (see section 4.7.3.4). In this viva the emphasis was on finding out how well the unit had run and how students had coped with it. The viva counted for 5% of the marks for unit 3, but the marks for unit 3 were not included in the final part I grades (see section 4.7.3.4).

.4.7.4.3.4 Outcomes

Table 4.7.17 shows what students felt they had gained from doing the experiments.

Comparison with Table 4.7.16 shows that most of the students who felt that the experiments were designed to teach them specific laboratory skills and techniques thought that the course had been successful but fewer students thought that they illustrated the
TABLE 4.7.1 7

<table>
<thead>
<tr>
<th>Experiments</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
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<td>-</td>
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</tbody>
</table>

(a) Practical insight into theoretical material; familiarisation with practical methods related to the theoretical material
(b) Experience in the use of laboratory apparatus and techniques
(c) Chemical knowledge
(d) Practice in calculations, tabulations and analyses
(e) Reinforcement of statistical analysis procedures
(f) No response
(g) Nothing; little

lectures sufficiently well (c.f. comments on aim 2 in sections 4.7.2.1.4 and 4.7.2.2.2). This is clearly connected with the fact that students did not think the experiments in this unit were closely related to the lecture course (see section 4.7.4.3.5). Indeed in experiment 3.6 six students had learnt chemistry which was new to them (Table 4.7.1 7 (c)) (see also section 4.7.2.1.3 aim 1).

4.7.4.3.5 Comments related specifically to unit 3

Table 4.7.1 8 shows the means and standard deviations for the ratings
given by students on the feedback sheets for difficulty, interest and relevance\(^1\).

**TABLE 4.7.18**

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<th>(\bar{x})</th>
<th>S.D</th>
<th>(\bar{x})</th>
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<td>1.7</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>0.9</td>
<td>3.3</td>
<td>0.9</td>
<td>3.3</td>
<td>0.9</td>
<td>2.6</td>
<td>0.9</td>
<td>3.2</td>
<td>0.9</td>
<td>3.1</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>3.1</td>
<td>1.4</td>
<td>2.0</td>
<td>1.1</td>
<td>1.9</td>
<td>0.8</td>
<td>2.2</td>
<td>1.1</td>
<td>2.9</td>
<td>1.4</td>
<td>1.7</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

(see Table 4.7.6. for explanation of rating scales)

The students thought the experiments were at about the right level of difficulty, were mainly quite interesting and were not closely related to the lecture course.

The main difficulties that students had are listed in Table 4.7.19.

**TABLE 4.7.19**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>3.1</th>
<th>3.2</th>
<th>3.3</th>
<th>3.4</th>
<th>3.5</th>
<th>3.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>(a)</td>
<td>7</td>
<td>27</td>
<td>3</td>
<td>11</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>(b)</td>
<td>9</td>
<td>35</td>
<td>3</td>
<td>11</td>
<td>6</td>
<td>46</td>
</tr>
<tr>
<td>(c)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>38</td>
</tr>
</tbody>
</table>

For footnotes see next page
(a) Difficulties carrying out the experiment
(b) Difficulties getting the apparatus to work properly; faulty apparatus
(c) Experimental scripts difficult to understand

In some experiments students had difficulty in getting the apparatus to work properly. For example:

(i) In experiment 3.5 at the higher temperature it was difficult to obtain an equilibrium and consequently difficult to balance the isotenoscope.

(ii) In experiment 3.1 students had difficulties in obtaining a good vacuum.

(iii) In experiment 3.3 students had a variety of problems in getting the electric circuit to function correctly and this was not assisted by the fact that some of them could not understand the experimental script (c) and others had difficulties in setting up the circuit in the first place (a). Two students said that they had insufficient knowledge of electric circuits to be able to benefit fully from this experiment.

In addition to their difficulties with the apparatus some students had difficulties in carrying out experiments with which they were unfamiliar (a). Students had difficulties with experiment 3.4, particularly in obtaining accurate readings for the melting points (10 students; 40%). These difficulties could account for the low achievement of the aims of the experiment noted in Table 4.7.17.

1 Questions 1, 2 and 3
2 The figure of 33 for the sample size assumes that experiments 3.3 to 3.6 were equally popular with the students.
4.7.4.4 A comparison of units 1, 2, and 3

The fact that students studied 3 units per term enabled a useful comparison of the units to be carried out.

4.7.4.4.1 General comparisons

Chemistry I students in their first questionnaire\(^1\) were asked which unit or part of a unit had been most worthwhile and which had been least worthwhile and why\(^2\). The responses are summarised in Table 4.7.20 below.

**TABLE 4.7.20**

<table>
<thead>
<tr>
<th>Number of students</th>
<th>Most worthwhile</th>
<th>Least worthwhile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Unit 1</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>Unit 2 (QM)</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>58</td>
</tr>
<tr>
<td>Unit 2 (C)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Unit 3</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>56</td>
<td>10</td>
</tr>
</tbody>
</table>

(1) Reasons for being most worthwhile:

Unit 1 (a) It taught us a lot of basic experimental techniques that you have to know to carry out other experiments (10 students; 32%)

---

1 Chem I Questionnaire 1 is in Appendix A 4.7
2 Questions 4 and 5
3 Some students gave more than one unit in response to the question
Unit 2 (QM)(a) It led to an understanding of errors in practical work and how to deal with them (6 students; 19%)

Unit 3 (a) It was related to the lecture course; one was able to apply the thermodynamics learnt in the lecture course (8 students; 26%)
(b) The experiments were interesting; new apparatus, methods and techniques (7 students; 23%)
(c) It was more satisfying because the results were more tangible and left one with a greater sense of achievement; real experiments (4 students; 13%)
(d) Reinforced the statistics learnt in unit 2 (2 students; 6%)

(2) Reasons for being least worthwhile:

Unit 2 (QM) (a) Difficult to understand; confusing (12 students; 39%)
(b) Boring (6 students; 19%)
(c) Experiments took too long (3 students; 10%)
(d) Too much time spent waiting for calculators (2 students; 6%)

Unit 3 (a) Faulty apparatus for some experiments meant that it was difficult to get results (2 students; 6%)

There appear to be three main factors that contribute to students feeling that practical work is worthwhile:
(i) Relevance-relevance to future work (unit 1, unit 2 (QM)) and relevance to the lecture courses (unit 3).
(ii) Interest\(^1\) - whether the students find it intrinsically interesting

---

\(^1\) The ratings for interest for unit 3 are not significantly higher, however, than unit 1 and unit 2(c). See Tables 4.7.5, 4.7.14 and 4.7.18.
(iii) Sense of achievement (unit 3).

There also appear to be three main factors that contribute to students feeling that practical work is not worthwhile:

(i) Lack of understanding (unit 2(QM)).
(ii) Lack of interest (unit 2(QM)).
(iii) Organisational problems (unit 2(QM)(c)(d); unit 3(a)).

It is interesting to note that 81% of the students reacted either favourably or unfavourably to unit 2(QM). The seven students who reacted favourably to unit 2(QM), understood this part of the unit better than the other students when they had completed it. This confirms the conclusions drawn in section 4.7.4.2.6.

4.7.4.4.2 Comparison of the organisation of units 1,2,3

4.7.4.4.2.1 Timetabling

Students were asked whether they preferred to have the experiments in a unit timetabled so that they did them at a fixed time (e.g. unit 2) or to be able to do them at a time that they decided (e.g. units 1 and 3). 24 Students (78%) preferred to be able to choose when they did the experiments, two (6%) preferred them to be timetabled and five (16%) did not mind.

---

1 c.f. the rating of 3.3 (S.D. = 0.3) for question 9(c) with that in Table 4.7.8 of 2.4 (S.D. = 1.1). The difference is significant at the 0.01 level.

2 Question 5; Chemistry I, Questionnaire 2
The reasons for preferring to be able to choose when they did the experiments are as follows:

(1) It is possible to fit the laboratory work in with other activities (14 students; 45%). For example, a student has a tutorial each week but these vary in difficulty so some flexibility with the laboratory work helps to spread the workload more evenly.

(2) It is possible to take longer over an experiment if necessary (7 students; 23%) and so compensate if an experiment 'goes wrong' (4 students; 13%) or takes longer than expected (4 students). 3 Students commented in interviews that one of the problems of having the experiments strictly timetabled as in unit 2 was that there was no time to repeat an experiment if it went wrong.

(3) Some students preferred the freedom to organise their time as they wished (6 students; 19%).

In interviews 8 students commented that they liked the variety offered by the unit system. If they became bored or were doing badly in one unit they would soon be able to make a fresh start on a new unit.

4.7.4.4.2.2 Individuals/pairs

In general the policy of the course organisers was that students should work individually, unless there was insufficient apparatus\(^1\). Of the first three units students only worked in pairs in unit 3 because of the constraints of apparatus (see section 4.7.4.3.3) and because the organiser of unit 3 thought that it was beneficial for students to

---

1 Staff interviews
learn to cooperate with other students.

In interviews students were asked whether they preferred working individually or in pairs and why. Question 6 in Chemistry I, questionnaire 2 was based on the responses and is included in Table 4.7.21. The responses have been divided into those students who preferred working alone, those who did not mind and those who preferred working in pairs.

**TABLE 4.7.21**

6. This question is concerned with the advantages and disadvantages of working in pairs during this practical course.

Below are 8 statements.

If you agree with the statements, circle A.

If you disagree, circle D.

If you neither agree nor disagree, or if you cannot decide, circle N.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Preferred working alone</th>
<th>Neither</th>
<th>Preferred working in pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) I prefer working alone to working in pairs</td>
<td>9 0 0</td>
<td>7 0</td>
<td>0 15</td>
</tr>
<tr>
<td>(b) I make more mistakes when doing an experiment if working in pairs than if working alone</td>
<td>3 5 1</td>
<td>1 5</td>
<td>1 2 12</td>
</tr>
<tr>
<td>(c) Discussion with my partner gives me a greater understanding of the experiment than if I had worked alone</td>
<td>5 2 2</td>
<td>5 1</td>
<td>13 2 0</td>
</tr>
<tr>
<td>(d) I work faster when working alone than when I work in a pair</td>
<td>6 3 0</td>
<td>4 3</td>
<td>2 7 6</td>
</tr>
<tr>
<td>(e) I learn more when I work alone than when I work in a pair</td>
<td>5 3 1</td>
<td>4 2</td>
<td>2 6 7</td>
</tr>
<tr>
<td>(f) My partner and I work well as a team</td>
<td>5 3 1</td>
<td>4 3</td>
<td>13 2 0</td>
</tr>
</tbody>
</table>

1 cf. aim 33 on graph 4.7.1

2 Numbers of students
<table>
<thead>
<tr>
<th></th>
<th>Preferred working alone</th>
<th>Neither</th>
<th>Preferred working in pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>(g) I like having my partner for company during the practical classes</td>
<td>4</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>(h) Discussion with my partner is helpful when working out results and calculations</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(i) It is more difficult to organise and co-ordinate the practical work when I work in a pair than when I work alone</td>
<td>7</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

It can be seen that the majority of students got on well with their partners (g) and that most pairs worked well as teams (f). Students choose their own partners and worked with them throughout unit 3 unless the were found to be incompatible, but this rarely happened.

The majority of students found that discussion with their partners helped them understand the experiments (c) and was helpful when working out results and calculations (h).

Students who preferred to work alone found it more difficult to organise and coordinate the practical work when working in pairs (i), felt they made more mistakes working in pairs (b), and thought that they worked faster alone (e). The opposite was true of the students who preferred working in pairs.

It appears that working in pairs is very valuable for practical work which concentrates on illustrating lecture material, but, of course,
the value of working in pairs is much more limited when basic manipulative skills are being learnt. One approach which could be used to capitalise on the advantage of working in pairs but still give students the necessary practice in manipulative skills is for students to perform parallel experiments whose results are complimentary. (This would be easy to organise in some of the quantitative measurements experiments, for example.)

4.7.4.5 Overall Comments on Units 1, 2 and 3

This section describes the students' reactions to the first 3 units.

General reactions
Most students thought that the practical work was an important part of the degree course and was complimentary to the 'theoretical' chemistry (13 students\(^1\)) but some students (5\(^1\)) saw it as being less important and supplementary to the theoretical work\(^2\).

The fact that the practical course integrated the different branches of chemistry had not been noticed by many students (10 students\(^1\)) and for the most part students had no strong feelings whether it should be integrated or not; 8 preferred it integrated because they thought that one had more variety and that one was able to see the connections between the different branches of chemistry, whereas 4 students thought that the practical work would have been easier to follow if it was divided into the traditional branches of chemistry like the lecture courses (cf. section 4.7.3.5).

---

1 18 students commented on this aspect of the course in interviews.
2 Similar findings are reported in section 4.8.3.5 for Chemistry II students.
Table 4.7.22 shows where the students got help when they were doing the practical work.

<table>
<thead>
<tr>
<th>Source of Help</th>
<th>Explaining procedure</th>
<th>Helping w. practical problems</th>
<th>Helping w. understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{x}$</td>
<td>S.D</td>
<td>$\bar{x}$</td>
</tr>
<tr>
<td>(a) Senior demonstrators</td>
<td>3.2</td>
<td>1.1</td>
<td>3.0</td>
</tr>
<tr>
<td>(b) Junior demonstrators</td>
<td>2.6</td>
<td>0.9</td>
<td>2.5</td>
</tr>
<tr>
<td>(c) Other students</td>
<td>3.2</td>
<td>1.0</td>
<td>3.8</td>
</tr>
<tr>
<td>(d) Instruction sheets</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(e) Textbooks and other literature</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(f) Lectures and lecture notes</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Rating scale 1 = Often helped me
5 = Never helped me

Students tended to consult junior demonstrators about the procedures that should be used in experiments and about practical problems in preference to senior demonstrators and other students. In order to understand the experiments students usually studied the instruction sheets or perhaps consulted a demonstrator.

1 Data from Chemistry I, Questionnaire I, questions 6, 7, 10, 11.
Students with a better understanding of the experiments\(^1\) found the instruction sheets more helpful\(^2\) (significant at the 0.01 level) and tended to consult senior demonstrators more (not statistically significant) and other students less (not statistically significant).

Junior demonstrators were preferred by most students because:

1. Students found them easier to communicate with than senior demonstrators. They appeared to the students to have a more sympathetic approach and to be more like students (10 students, 32\% and 3 in interviews)\(^3\). Senior demonstrators on the other hand were often seen as being critical and authoritarian and students were afraid of showing that they did not know or understand parts of the chemistry (7 students, 23\% and 6 in interviews).

---

1 The students' perceived understanding of the experiments is given by responses to question 8, Chemistry I, questionnaire I. Students who rated their understanding higher than the mean for all students have been described above as 'students with a better understanding of the experiments'.

2 The students have been divided into 2 groups; those with above average perceived understanding and those with below average perceived understanding. The ratings of the 2 groups for questions 6, 7 and 10 in Chemistry I, Questionnaire I have been compared. The findings described above are based on the following data:

<table>
<thead>
<tr>
<th>Help with understanding practical work from:</th>
<th>students with above average understanding</th>
<th>students with below average understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Senior demonstrators</td>
<td>.26 1.2</td>
<td>3.0 1.1</td>
</tr>
<tr>
<td>(c) Students</td>
<td>3.9 0.9</td>
<td>3.3 1.0</td>
</tr>
<tr>
<td>(d) Instruction sheets</td>
<td>1.5 0.7</td>
<td>2.5 0.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>t</th>
<th>significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>N.S. at 0.05</td>
</tr>
<tr>
<td>1.85</td>
<td>N.S. at 0.05</td>
</tr>
<tr>
<td>3.30</td>
<td>S. at 0.01</td>
</tr>
</tbody>
</table>

3 The first figures are the number and percentage replies in the questionnaires. The latter figure is the additional number of students giving the opinion in interviews.
(2) Junior demonstrators were more often available than senior demonstrators\(^1\) (5 students, 16\% and 2 in interviews).

(3) Other students did not always know answers and might give wrong advice (4 students, 13\% and 1 in interview). Other students were seen as being useful to help with tutorial problems and with the procedure because they had just done the experiment themselves and had encountered the same problems (4 students, 13\% and 2 in interviews).

Senior demonstrators were preferred by some students and in particular for explaining the theory. This was because:

Senior demonstrators knew more about the experiments and therefore explained the theory better and solved problems with the experiments faster (8 students, 26\% and 3 in interviews), whereas junior demonstrators sometimes did not know as much about the experiments and sometimes gave wrong answers\(^2\) (2 students, 6\%)

Four members of academic staff in interviews and discussions commented that in the past problems had occurred with junior demonstrators not being very well acquainted with the experiments. These problems had been increased by the integrated nature of the course which required junior demonstrators to become familiar with a wide variety of experiments. The fact that the course was run in units did counterbalance this to some extent in that post-graduate students were employed as junior demonstrators for the duration of a unit. Their demonstrating duties therefore tended to be more concentrated than in courses which ran for a term giving them

---

1 Availability of demonstrators was not a problem. Students had to wait a few minutes at the most (15 students in interviews)

2 See also section 4.7.4.2.4
an opportunity to become more involved in the course. In addition all post-graduate demonstrators were required to attend a course on safety and first aid before they were allowed to demonstrate. This was held in the middle of their first year as post-graduates, which meant that in addition to being made aware of safety factors, post-graduates were unable to demonstrate in their first year and were consequently more experienced chemists when they did.

In order to acquaint the junior demonstrators with the experiments, they were given the instruction sheets before a unit began and discussed the experiments with the member of staff in charge of the unit. Also money was set aside to pay junior demonstrators to come into the laboratory before a unit began and to try out any experiments with which they were unfamiliar.

Judging from the few complaints about junior demonstrators from the students, these measures were quite successful.

It is striking that the quality and amount of help that students obtained from other students was very dependent on the circumstances. It appears that on the whole students tended to consult other students somewhat less than demonstrators and that they tended to limit their questions to the small day to day problems encountered in the laboratory. In unit 2, however, students consulted one another a lot more than demonstrators (Table.4.7.11), presumably because the demonstrators, particularly the senior demonstrators, were almost fully occupied in dealing with all the problems arising out of the students' poor understanding of the quantitative measures exercises. In unit 3, when students worked as pairs, they discussed the experiments with one another
and in the process gained a greater understanding of the experiments and helped one another in working out results and calculations (Table 4.7.21). It is interesting to note that the gain in understanding of the experiments after finishing them is greater for those units or part of units where there is more discussion amongst students\(^1\) (Table 4.7.8).

4.7.4.5.2 Preparing before coming into the laboratory

The amount of preparation that it was possible to do before an experiment was limited by the fact that in units 1 and 3 students had to finish the previous experiment before they were given a script for the next one and in unit 2, students were given the scripts for a whole week at the beginning of the week.

When the scripts were available, on at least the day before doing the experiment, students more often than not prepared for the practical work by reading the experimental scripts before coming into the laboratory, although there was considerable variation amongst the students as to the regularity of this preparation\(^2\).

Preparing beforehand meant that students had a better idea of what they were supposed to do in the experiments\(^3\). They knew the correct order of procedure (20 students, 65%). This meant that the laboratory time was saved because students were able to plan ahead better (16 students, 52%). Preparing beforehand also meant that students understood

---

1 Not statistically significant at the 0.01 level.
2 Chemistry I, Questionnaire 2, question 2.
3 Question 3
the experiments better (14 students; 45%) and their purpose (5 students; 16%) and that they were more aware of sources of error and possible pitfalls (3 students; 10%).

4.7.4.5.3 Workshops

Of the 23 Chemistry I students who were interviewed 18 commented on the workshops. The overall reaction was favourable with 12 students saying that they found them useful. This was confirmed in Chemistry I questionnaire 1, question 12. Students on the whole thought the workshops were quite successful in preparing them for the experiments which followed.

There were, however, a few problems which were followed up in Chemistry I, Questionnaire 2, question 4. The responses for this question are tabulated below.

TABLE 4.7.23

4. Please indicate whether you agree or disagree with the statements below about the workshops.

A = Agree
D = Disagree
N = Neutral, neither agree nor disagree

<table>
<thead>
<tr>
<th>(a) It was difficult to understand the workshops without having first read the experimental scripts</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>N</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

(b) I could always see the demonstration clearly

<table>
<thead>
<tr>
<th>(b) I could always see the demonstration clearly</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>N</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

1 A mean rating of 3.3 (S.D.=0.9) on a 5 point scale with 1 = not successful, 5 = very successful
One of the problems was that students had often been unable to read the experimental scripts before attending the workshops and had little idea of the experiments for which the workshops were preparing them (a). Another problem was that the workshops were held in quite large groups of 11 to 16 students and it was sometimes difficult to see demonstrations (b). Students also had difficulties remembering details of workshops if the related experiments were not done soon afterwards (c).

4.7.4.5.4 Time

One of the most frequent complaints about the course was that the practical work took a lot longer than the times indicated in the sheets. This was particularly true for units 1 and 2. This was perhaps partly due to delay when apparatus sometimes did not work properly (4 students; 13%, Chem I Questionnaire 2) or to students repeating experiments that went wrong (2 students in interviews; see also sections 4.7.4.1.6, 4.7.4.2.6 and 4.7.4.3.5).

---

1 See section 4.7.4.5.2
2 (1) See Table 4.7.4
   (2) 13 students (42%) in free response question: Chem I questionnaire 2, question 9
   (3) 6 additional students in interviews
3 (1) See Table 4.7.4.
   (2) 4 students in interviews
There was no evidence of students deciding that they had spent enough time in the laboratory and leaving practical work uncompleted so that they could devote more time to other work (see section 4.7.4.1.4). Typically if a student could not finish the practical work in the recommended 11 hours per week, he would just keep working until he did finish.

An advantage of the unit system is apparent here. Even though the workload was heavy, students only studied a unit for 3 weeks and so were unable to fall far behind with the work for each unit (3 students in interviews). The unit system thus provides a series of deadlines for the students to meet.

4.7.4.5.4.1 Effect of lack of time on mode of work

The lack of time and the fact that students were often not given experimental scripts until just before they started the experiments meant that they felt that they had insufficient time to sit down and study the scripts thoroughly before they started\(^1\). This in turn led to a tendency in more than half the experiments\(^2\) for students to carry out the experiments without thinking; to simply turn to the procedure in the sheets and follow the 'recipe' without first trying to understand the experiments.

Another factor which appeared to encourage following the 'recipe' without thinking was some experiments being particularly difficult to

\(^1\) Information from:
(1) Chemistry I, Questionnaire 1, question 9: 11 students (36%)
(2) Interviews: an additional 8 students.

\(^2\) Mean rating of 3.3 (S.D.=0.9) for question 13 in Chemistry I questionnaire
This problem must have been particularly serious in unit 2 (QM) in which the theory was more difficult to understand than in other units (see Table 4.7.8).

4.7.4.5.4.2 Differential effects of lack of time

In order to study whether students who understood the experiments better were less affected by the lack of time than 'average' students, the following correlation coefficients were calculated from data from the Chemistry I questionnaire I.

**TABLE 4.7.24**

<table>
<thead>
<tr>
<th></th>
<th>Unit 1 Perceived understanding whilst doing the experiment 2</th>
<th>Unit 3 Perceived understanding whilst doing the experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time spent doing the experimental work 4</td>
<td>-0.34</td>
<td>-0.14</td>
</tr>
<tr>
<td>Time spent writing-up the experiment 5</td>
<td>-0.17</td>
<td>-0.29</td>
</tr>
</tbody>
</table>

1 Information from:
(1) Chemistry I, Questionnaire 1, question 13: 3 students (10%)
(2) Interviews: an additional 3 students

2 Question 8a

3 Question 8d

4 Questions 1.1 and 1.3

5 Questions 2.1 and 3.1; and 2.3 and 3.3 respectively
These data indicate that students who understood the experiments better needed to spend less time on the practical work. The lack of time therefore affected the better students less (see section 4.7.5.2.23).

None of the correlation coefficients is large enough, however, to be statistically significant (at the 0.05 level) with the small numbers of students.

4.7.4.5.5 Write-up, assessment and feedback

The write-up consisted of working out results, drawing conclusions and answering questions (see section 4.7.3.4). This simplified and shortened form of report writing enabled students to do much of the write-up in the laboratory (see Table 4.7.4) where demonstrators were available to help them and where calculations were provided.

The students found that doing the write-up made them think and gave them a greater understanding of the experiments (18 students, 58%; see also Table 4.7.8 and of their purpose (2 students; 6%). Students also found that it helped them to relate the practical work to the lecture courses and reinforced material taught in the lectures (9 students; 29%). Some students (4 students; 13% and 3 in interviews) said that the questions in the experimental scripts were helpful for understanding the experiments and relating the practical work to the theoretical work. Three students (10%) also said that it gave them a sense of satisfaction if their results were good, i.e. within the limits of experimental error (cf. section 4.7.4.4.1, unit 3).

1 Chemistry I, Questionnaire 2, question 7
Clearly during the write-up many students began to make sense of the practical work which they had just done. Most of their understanding was gained through studying the experimental scripts but contact with other people, particularly senior demonstrators, was also important (Table 4.7.22). It was, therefore, beneficial that students did at least some of the write-up in the laboratory. This was encouraged by the short precise nature of the write-up and the availability of calculators.

The fact that students were not given the experimental sheets before they came into the laboratory in units 1 and 3 had a beneficial effect with respect to the write-up. Students had to write-up each experiment before they were given the sheets for the next one and therefore did the write-up soon after completing each experiment whilst it was still fresh in their minds: It would perhaps have been better if they had been given the sheets earlier so that they could understand the experiments before doing them rather than afterwards.

The methods of assessment of students' work are described in section 4.7.3.4. In units 1, 2 and 3 the assessment was based almost entirely on the students' write-up.

80% of the students (24 students\(^1\)) thought that they were not given enough information about how well they were getting on in the practical course. 73% (22 students\(^1\)) would like to have been told what grades they had got either for each experiment (4 students) or for each unit (8 students) so that they knew how they compared with the rest of the

\(^1\) Chemistry I, Questionnaire 2, question 8
class (10 students). Four students (13%) said that they would like to have had more information about where they had gone wrong and what the right answers were. It was pointed out in an interview that although it was helpful for a student to get an idea of his marks from his supervisor at the end of each term it was by then too late to improve and correct poor practical work.

It is clearly very difficult for students to judge how well they are doing in this situation which is unfamiliar to them and it may well reduce anxiety and increase motivation to provide a more concrete form of feedback about their progress.

4.7.4.6 Summary

This section is a brief summary of the main findings reported so far.

4.7.4.6.1 Good features of the course

(1) The course was successful in giving the students experience and knowledge of a wide range of basic skills and techniques. Its success can be attributed to the workshops which were used to demonstrate many techniques followed by traditional experiments which enabled the students to gain experience of the techniques in a controlled situation.

(2) (a) The unit system gave the students a variety both in subject matter and in the organisation of laboratory work which prevented them from becoming bored (usually!) (section 4.7.4.4.2).

(b) The unit system also helped the students to pace themselves (section 4.7.4.5.4).
(c) The unit system enabled demonstrators both junior (section 4.7.4.5.1) and senior (e.g. section 4.7.4.2.6) to become more involved in the practical work because their demonstrating duties were more concentrated than in a conventional course lasting for one term.

(3) Students appreciated the freedom offered by the fact that the laboratory was open for 17 hours and they were only expected to attend for 11 hours. In some units (i.e. 1 and 3) they were able to fit their laboratory work in with their other commitments and so balance their workload each week. This was a particular advantage at York with its strong emphasis on tutorials because the work involved in preparing for the weekly tutorials varied considerably (section 4.7.4.4.2.1).

The freedom offered by this flexible system also meant that students could spend longer in the laboratory if necessary, if for example the experiment went wrong or the apparatus was not working properly or if the experiment simply took longer than expected.

(4) Students gained a greater understanding of the experiments when they wrote them up and were able to relate them to work covered in lectures. Students tended to do at least part of the write-up in the laboratory, presumably because the write-up required was quite short and precise and because calculators were available in the laboratory and students were able to benefit from help given by other people, particularly senior demonstrators, in the laboratory (section 4.7.4.5.5).
4.7.4.6.2 Learning from other people

Students generally preferred to consult demonstrators rather than other students when they had problems in the laboratory (section 4.7.4.5.1). Demonstrators were generally very helpful and the junior demonstrators on the whole seemed to be quite well acquainted with the practical work, although they were obviously not as experienced as senior demonstrators.

Students found, however, that when they had to work with one another, e.g. in pairs in unit 3, and in unit 2 when the demonstrators were busy, discussion was helpful in understanding the experiments and working out the results.

4.7.4.6.3 Motivation

Several factors which encouraged motivation emerge:
(1) Relevance to the lectures or relevance to future practical work (section 4.7.4.4.1).
(2) Interest. Students felt that work that interested them was more worthwhile (section 4.7.4.4.1).
(3) Students liked to feel that they had achieved something worthwhile at the end of an experiment (section 4.7.4.4.1 and section 4.7.4.5.5).
(4) Students desired feedback so that they could compare their performance with that of other students and so that they could correct poor work (section 4.7.4.5.5).

4.7.4.6.4 Factors which limited learning

(1) The aims of this course were limited. Many of the aims included in
areas C and D cannot be achieved in a largely traditional course (section 4.7.3.2.2).

(2) The experiments generally took longer than the recommended time (section 4.7.4.5.4). Students, therefore, felt that there was insufficient time in the laboratory to study the instruction sheets. They simply turned to the instructions and followed them mechanically without thinking.

(3) Instruction sheets were often given out to the students on the day when they were expected to do the experiment. Students were therefore unable to prepare in advance (section 4.7.4.5.2).

(4) The effectiveness of the workshops was sometimes limited by the fact that students had not had time to read the instruction sheets and were therefore unfamiliar with the experiments to which the workshops were related. Some demonstrations in workshops were difficult to see and students found it difficult to remember details from the workshops if the experiments were not carried out soon afterwards (section 4.7.4.5.3).

(5) The value of unit 2 (QM) was realised by only a few students (section 4.7.4.2.6) because too many new concepts were introduced to the students in a short time and the number of demonstrators was insufficient to cope with the large number of problems that students encountered. Also the concepts taught in unit 2 (QM) were not reinforced sufficiently in later units.

(6) Organisational problems such as faulty apparatus and waiting for
calculators to become available detracted from the success of some experiments (section 4.7.4.2.6).

4.7.5  Unit 10/11

4.7.5.1  A description of unit 10/11

4.7.5.1.1  Aims of unit 10/11

The organiser of unit 10/11 said that the purpose of this unit was to explore the chemistry of a particular element or compound or type of reaction sequence using techniques learnt earlier; to bring together and interrelate earlier parts of the course.

The aims which the students thought the different experiments were trying to achieve are given in the table below.

TABLE 4.7.25

<table>
<thead>
<tr>
<th>Aims</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiments</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>10.1</td>
<td>14</td>
<td>61</td>
<td>-</td>
</tr>
<tr>
<td>10.2</td>
<td>9</td>
<td>42</td>
<td>5</td>
</tr>
<tr>
<td>10.3</td>
<td>11</td>
<td>52</td>
<td>-</td>
</tr>
<tr>
<td>10.4</td>
<td>-</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>10.5</td>
<td>14</td>
<td>54</td>
<td>5</td>
</tr>
<tr>
<td>10.6</td>
<td>5</td>
<td>26</td>
<td>10</td>
</tr>
</tbody>
</table>
(a) To learn specific chemical knowledge, e.g. to gain a greater knowledge of chromium chemistry and chromium complexes.

(b) To illustrate the theory; to give practical experience of work covered in theory courses.

(c) To gain experience of using chemical instruments and techniques

\[
n = \text{number of students} \\
\% = \text{percentage of students}
\]

4.7.5.1.2 Contents of unit 10/11

Unit 10/11 consisted of 6 experiments which were studied by students in any order. The unit lasted 6 weeks and therefore students were expected to complete one experiment per week.

Initially students were told that unit 10/11 would be divided into two halves. By the end of the first 3 weeks they should have completed 3 experiments and should have written them up.

During the first half of the unit, the course organiser found that large numbers of students were not writing up and handing in their experiments. They were leaving them to pile up and were going to write them at the end of the unit. In the course organiser's opinion this was having two bad effects:

(1) Students tended to have forgotten the experiments by the time they wrote them up and therefore did not understand them very well.

(2) All the marking had to be done at the end of the 3 week period which was very difficult for the demonstrators.
To prevent this happening the students were asked to hand in one experiment per week during the second 3 week period and were given penalty marks if their experiments were marked late. The experiments were:

10.1 Isomerism in chromium complexes
10.2 Isomeric methyl quinolines
10.3 Chromate/dichromate/hydrogen chromate equilibria
10.4 Synthesis of ethyl-3-oxobutanoate
10.5 Complexes of silver
10.6 Kinetic and analytical investigation of alkaline phosphatase

4.7.5.1.3 Resources

(a) Written materials - see section 4.7.3.3

(b) Apparatus
Students were able to do the experiments in any order subject to the availability of apparatus. There were enough sets of apparatus for approximately one sixth of the class to do any one experiment at the same time. Students worked individually on all the experiments except for one where they worked as pairs.

(c) Workshops
There were no workshops during this unit

(d) People
The laboratory was attended by 44 students. They were expected to attend the laboratory for 11 out of the 17 hours for which it was open. In actual fact they attended for about 12 hours (see section 4.7.4.1.3). At any one time one senior demonstrator and one or two
junior demonstrators were present. This gives the following overall staffing ratios:

- students : senior demonstrator 28 : 1
- students : junior demonstrator 20 : 1
- students : sen. & jun. demonstrator 11 : 1

4.7.5.1.4 Activities

4.7.5.1.4.1 Student activities

32 Observations were made of what students were doing at specific times on 4 separate days during the unit. These activities are listed in Table 4.7.26.

**TABLE 4.7.26**

<table>
<thead>
<tr>
<th>Activity (observed in 32 occasions)</th>
<th>No. of students performing activity</th>
<th>% performing activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Working alone at the bench</td>
<td>481</td>
<td>81 %</td>
</tr>
<tr>
<td>(b) Talking to other students</td>
<td>63</td>
<td>10 %</td>
</tr>
<tr>
<td>(c) Consulting or talking to a demonstrator</td>
<td>29</td>
<td>4 - 5 %</td>
</tr>
<tr>
<td>(d) Having a viva</td>
<td>12</td>
<td>2 - 3 %</td>
</tr>
<tr>
<td>(e) Other</td>
<td>7</td>
<td>1 %</td>
</tr>
</tbody>
</table>

It can be seen that students spent the vast majority of their time working at the bench. It is not possible to find out whether when students talked to one another they were discussing the practical
work although it is my impression from walking round the laboratory and talking to the students that very little else is discussed in the laboratory.

There was a significant change in the frequency of one activity throughout the day and that was the amount of time that students spent talking to one another. Up to 2.00 p.m. students spent 8% of their time talking to other students but between 2.00 p.m. and 4.30 p.m. they spent 14% of their time talking to other students. During the afternoon there were more students present and the demonstrators were fully occupied (see section 4.7.5.1.4.2); if they wanted any more help they had to consult other students.

It is interesting to note that a similar trend was noted in unit 2 (see sections 4.7.4.2.4 and 4.7.4.2.6).

4.7.5.1.4.2 Demonstrator activities

The activities of the demonstrators were also observed on 32 occasions and are shown on Table 4.7.27. It can be seen that up to 2.00 p.m. senior demonstrators and junior demonstrators spent about the same proportion of their time in direct contact with students. After 2.00 p.m. the junior demonstrators spent a larger proportion of their time in direct contact with the students than did the senior demonstrators.

It is also interesting to note that the demonstrators had more free time up to 2.00 p.m. than after 2.00 p.m., with the effects noted in the previous section.
| n (day) | n (week) | % | n (day) | n (week) | % | n (day) | n (week) | % | n (day) | n (week) | % |
|---------|----------|---|---------|----------|---|---------|----------|---|---------|----------|---|---------|----------|---|---------|----------|---|---------|----------|---|
|        |          |   |         |          |   |         |          |   |         |          |   |         |          |   |         |          |   |         |          |   |
| S. dem | 11.15 - 2.00 | 4.30 |
| J. dem | 2.00 - 4.30 |

**Table 4.7.27 Activity**
4.7.5.1.5 Assessment

This was the only unit evaluated in which the marks gained for the practical work counted towards the part I mark.

Students were assessed mainly on the basis of their notes on the experimental scripts, but some marks (1/5) were also given for the students' performance in a viva when students were asked questions to test their understanding of the experiments.

Each demonstrator was responsible for marking all the scripts for one experiment and for preparing model sets of answers for the experiment which could be used by other demonstrators who might give a student a viva at the end of the experiment.

4.7.5.1.6 Outcomes

Table 4.7.28 shows what students thought that they had gained from each experiment.

TABLE 4.7.28 Outcomes

<table>
<thead>
<tr>
<th>Experiments</th>
<th>(a) n</th>
<th>(a) %</th>
<th>(b) n</th>
<th>(b) %</th>
<th>(c) n</th>
<th>(c) %</th>
<th>(d) n</th>
<th>(d) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>10</td>
<td>43</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>39</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>10.2</td>
<td>3</td>
<td>14</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>47</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>10.3</td>
<td>11</td>
<td>52</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10.4</td>
<td>5</td>
<td>26</td>
<td>2</td>
<td>11</td>
<td>4</td>
<td>21</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>10.5</td>
<td>12</td>
<td>48</td>
<td>3</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>10.6</td>
<td>5</td>
<td>26</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>26</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>
(a) Chemical knowledge and understanding
(b) Illustration of material covered in lectures and tutorials
(c) Experience of and practice with the use of chemical techniques and instrumentation
(d) Nothing; very little

n = number of students making the statements
% = % of students making the statements

Comparison of Tables 4.7.28 and 4.7.25 shows that on the whole students saw their aims as being achieved with the exception of aims in (b). This is obviously connected with the fact that students did not see the experiments in this unit as being closely related to the lecture courses (see Table 4.7.29).

It is striking that about one third of the students thought that they had gained little or nothing from doing experiments 10.1 and 10.2. This is discussed further in section 4.7.5.1.7.

4.7.5.1.7 Detailed comments on unit 10/11

Students encountered a large number of difficulties with some experiments which is to be expected as it was the first time that this unit had run.

Experiment 10.1
30% of the students thought that they had gained little or nothing from doing this experiment. The success of this experiment appears to have been limited by the following factors:
(1) Students were unclear of the aims of the experiment.
(2) Students had insufficient chemical knowledge of the reactions
involved in the practical work and the practical work was not closely related to the lecture courses.

(3) A number of students said that they had insufficient time to spend on this experiment.

Experiment 10.2

29% of the students thought that they had gained little or nothing from doing this experiment. The success of this experiment appears to have been limited by the following factors:

(1) The experiment was difficult to perform: Over half the students mentioned difficulties in performing the experiment and this experiment was rated as the most difficult experiment in unit 10/11.

(2) 43% of the students said that they had insufficient time for this experiment, which is a larger proportion than for any other experiment in this unit.

Experiment 10.3 - few problems

Experiment 10.4

Only 2 students (11%) felt that they had gained little or nothing from this experiment. The success of this experiment does, however, seem to have been limited by the same factors as experiment 10.2.

Experiment 10.5 - few problems

Experiment 10.6

No overall conclusions are apparent from the data for this experiment.
The lack of sufficient preknowledge mentioned in experiment 10.1 and lack of relevance to the lecture courses were also significant factors in limiting the success of the quantitative measures experiments in unit 2.

4.7.5.2 Overall comments on unit 10/11

4.7.5.2.1 General reactions

Nine students were asked to compare unit 10/11 with the rest of the course. Seven of them thought that it was very similar to the rest of the course whilst two of them preferred it.

The feedback sheets indicate that the students thought that the experiments in the unit were quite interesting, that some of them were quite closely related to the lecture courses and that they were of about the right level of difficulty (see Table 4.7.29).

TABLE 4.7.29

<table>
<thead>
<tr>
<th>Experiment</th>
<th>10.1</th>
<th>10.2</th>
<th>10.3</th>
<th>10.4</th>
<th>10.5</th>
<th>10.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Response</td>
<td>23</td>
<td>21</td>
<td>21</td>
<td>19</td>
<td>26</td>
<td>19</td>
</tr>
<tr>
<td>% response</td>
<td>58 %</td>
<td>53 %</td>
<td>53 %</td>
<td>48 %</td>
<td>65 %</td>
<td>48 %</td>
</tr>
</tbody>
</table>

| Difficulty | 2.86 | 0.56 | 3.48 | 0.81 | 2.86 | 0.65 | 3.26 | 0.65 | 2.64 | 0.49 | 2.71 | 0.85 |
| Interest   | 2.73 | 0.94 | 3.29 | 1.19 | 3.33 | 0.86 | 3.37 | 0.90 | 3.08 | 0.86 | 2.65 | 1.17 |
| Relevance  | 2.70 | 0.91 | 3.57 | 0.93 | 2.76 | 1.04 | 3.83 | 0.81 | 2.62 | 0.93 | 3.59 | 1.25 |
$\bar{x}$ = Mean of ratings on five point scales
$\sigma$ = Standard deviation

Five point scales:
- Difficulty: 1 = Too easy; 5 = Too difficult
- Interest: 1 = Boring; 5 = Stimulating
- Relevance: 1 = Not related to lecture course; 5 = Closely related to lecture course

4.7.5.2.2 Time

4.7.5.2.2.1 Estimates of time spent on practical work

Students were meant to spend 11 hours per week doing all their practical work and writing it up. The actual time spent on each experiment has been estimated by three different methods, two of which are based on students' estimates and the third on observation. Each estimate is different but over 11 hours. On average students spent about 12 hours in the laboratory as well as about 3 hours writing-up the experiments, i.e. a total of 15 hours.

Estimates of the amount of time spent on each experiment are given below together with the number of complaints about the experiments being too long or rushed.

TABLE 4.7.30

<table>
<thead>
<tr>
<th>Experiment</th>
<th>No. of students asked about time</th>
<th>$\bar{x}$ (hrs)</th>
<th>$\sigma$ (hrs)</th>
<th>no. of complaints</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>17</td>
<td>12.6</td>
<td>2.1</td>
<td>3</td>
</tr>
<tr>
<td>10.2</td>
<td>13</td>
<td>14.2</td>
<td>2.0</td>
<td>11</td>
</tr>
<tr>
<td>10.3</td>
<td>17</td>
<td>10.2</td>
<td>1.8</td>
<td>7</td>
</tr>
<tr>
<td>10.4</td>
<td>9</td>
<td>13.8</td>
<td>1.9</td>
<td>9</td>
</tr>
<tr>
<td>10.5</td>
<td>16</td>
<td>9.7</td>
<td>2.6</td>
<td>0</td>
</tr>
<tr>
<td>10.6</td>
<td>13</td>
<td>10.7</td>
<td>1.4</td>
<td>0</td>
</tr>
</tbody>
</table>
4.7.5.2.2.2 Effect of insufficient time on the success of experiments

The fact that experiments 10.1, 10.2 and 10.4 are too long has already been noted in section 4.7.5.1.7 where it is seen to be having an adverse effect on the success of the experiments.

Students had to complete one experiment each week and were therefore unable to take the variation in the length of the experiments into account by spending more than one week on them. In interviews 3 students complained about the inflexibility of this system. Another 7 students (37%) made similar comments on a free response section of the questionnaire and a further student commented in a feedback sheet. Typical comments were:

"By refusing to give us more than one experiment at a time we cannot plan our time efficiently and much of it is lost."

"As with all Part I practicals it was very time consuming; interesting but marred by the fact that time was precious."

Towards the end of the unit three students commented that they found the work load for the practical course to be quite heavy at a time when their exams were approaching.

In spite of the lack of time over half of the students (58%; 11/19) completed all the experiments. The other 42% did not complete on average one experiment. Of the students who did not complete the unit all except one were present at some stage during the last 2 days of the unit: They did not complete it because they did not have time, rather than because they chose to work for their exams instead of the practical course.
4.7.5.2.2.3 Effect of insufficient time on the mode of working

The effects of students having to rush experiments was examined in more detail in units 1, 2 and 3 (section 4.7.4.5.4, page 423). In interviews 4 second year students described the effects of the shortage of time upon their method of work in unit 10/11. Typical comments were:

"What we did was follow the instructions, fill in the results and then afterwards figured out what we were doing. You were in such a rush in the labs. that you weren't actually getting much from it whilst you were doing it."

"As I am doing it I am usually too pressed for time, and I just follow the experiments through as a recipe. You don't understand it until you go through it thoroughly when you are writing it up."

It can be seen that in a situation where students have to rush, experimental difficulties such as those encountered in experiment 10.2 (section 4.7.5.1.7), will leave students with even less time to try to understand the experiments. Rather than encouraging thought about why an experiment is going wrong, the difficulties will encourage further rushing with the consequences described in the quotations above.

Interviews with 9 Chemistry II students suggested that students, who said that they understood the experiments whilst they were doing them, tended to work faster in the laboratory and had to spend less time outside the laboratory writing up the experiments. This preliminary finding was followed up in the Chemistry II questionnaire and a similar trend was noted but is not statistically significant (at the 0.05 level).
### TABLE 4.7.31 Number of hours spent on laboratory work

<table>
<thead>
<tr>
<th></th>
<th>Understood experiments in laboratory</th>
<th>Poor or partly understanding in lab.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of students</strong></td>
<td><strong>Mean</strong> 13.5 1.7</td>
<td><strong>Number of students</strong></td>
</tr>
<tr>
<td>Hours per week spent in laboratory</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Hours per week spent in laboratory writing up</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Hours per week out of laboratory writing up</td>
<td>5</td>
<td>14</td>
</tr>
</tbody>
</table>

The data from the questionnaire have also been analysed by comparing those students who got a grade of over 60% for their Part I practical work with those who got less than 60%. Students who got better marks also tended to work faster in the laboratory and spent less time outside the laboratory writing up experiments, but this was again not statistically significant (at the 0.05 level).

### TABLE 4.7.32

<table>
<thead>
<tr>
<th></th>
<th>Part I grade &gt; 60% for lab work</th>
<th>Part I grade &lt; 60% for lab work</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of students</strong></td>
<td><strong>Mean</strong> 13.2 1.1</td>
<td><strong>Number of students</strong></td>
</tr>
<tr>
<td>Hours per week spent in laboratory</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Hours per week spent in laboratory writing up</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Hours per week out of laboratory writing up</td>
<td>7</td>
<td>12</td>
</tr>
</tbody>
</table>
It would appear from these results that the lack of time had a differential effect on the students. The better students were less affected by the lack of time, whereas 'average' students had to rush more and therefore tended to work through the experiments without trying to understand them.

No firm conclusions can be drawn from these results. The differences between the different groups of students are too small to be statistically significant with the small number of students in this investigation. A similar trend, however, was noted in section 4.7.4.5.4.2.

4.7.5.2.2.4 A cause of insufficient time

In interviews 4 students commented that some of the experiments simply 'did not work'. Similar comments have been made in the detailed comments about each unit.

Clearly in a course which is new some experiments will not work well initially: No allowance seems to have been made for this when estimating the time that students are expected to spend on each experiment.

4.7.5.2.3 Who did the students consult for help?

The data related to this question are included in Table 4.7.33. A very similar overall trend to that for units 1, 2 and 3 (section 4.7.4.5.1) was noted. Students tended to consult junior demonstrators or other students about the procedures to be used in the experiments; they tended to consult junior demonstrators more about practical problems and found the instruction sheets the most useful source of help in understanding
the theory of the experiments.

In Table 4.7.33 comparisons are made between those students who thought they understood the experiments well when they were doing them and those who understood them less well. In Table 4.7.33 comparisons are also made between those students who got greater than 60% for their Part I practical marks, and those who got less than 60%.

The following trends are observed:

(1) Students who thought they understood the work better tend to consult other students a lot less (significant at 0.01 level). A similar trend was noted for students with more than 60% but it is not so strong and is not statistically significant.

(2) Students who thought they understood the work better needed less help with practical problems. There was no significant difference between students with higher and lower marks in this respect.

(3) Students who thought they understood the work better tended to consult senior demonstrators more for explaining the procedure and understanding the work (not statistically significant, except 8(c)). Again there was no significant difference between the students with higher and low marks in this respect. A similar trend was noted in section 4.7.4.5.1.

(4) The trend noted in section 4.7.4.5.1 that students with a better understanding of the experiments found the instruction sheets more helpful is not substantiated for unit 10/11.

---

1 Chemistry II, Questionnaire 1, question 9
Table 4.7.33 Sources of help

<table>
<thead>
<tr>
<th>Analysed according to perceived understanding</th>
<th>Analysed according to Part I practical grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understood expts well whilst doing them</td>
<td>Practical grade &gt; 60%</td>
</tr>
<tr>
<td>Understood expts less well whilst doing them</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Explaining what procedure should be used²:</td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>3.2</td>
</tr>
<tr>
<td>(b)</td>
<td>3.0</td>
</tr>
<tr>
<td>(c)</td>
<td>4.0</td>
</tr>
<tr>
<td>Help with practical problems³:</td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>3.8</td>
</tr>
<tr>
<td>(b)</td>
<td>3.2</td>
</tr>
<tr>
<td>(c)</td>
<td>5.0</td>
</tr>
<tr>
<td>Help to understand the theoretical material⁴:</td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>2.6</td>
</tr>
<tr>
<td>(b)</td>
<td>3.8</td>
</tr>
<tr>
<td>(c)</td>
<td>5.0</td>
</tr>
<tr>
<td>(d)</td>
<td>2.8</td>
</tr>
<tr>
<td>(e)</td>
<td>3.0</td>
</tr>
<tr>
<td>(f)</td>
<td>3.8</td>
</tr>
</tbody>
</table>

(a) = Senior demonstrators
(b) = Junior demonstrators
(c) = Other students
(d) = Instruction sheets
(e) = Textbooks and other literature
(f) = Lectures and lecture notes

1 Chem II Questionnaire, question 9
2 Chem II Questionnaire, question 7
3 Chem II Questionnaire, question 8
4 Chem II Questionnaire, question 11 (the lettering has been reorganised for clarity in Table 4.7.33)
The students' perceptions of the demonstrators were investigated with the Chemistry I students and are described in section 4.7.4.5.1. In interviews the Chemistry II students also commented on the demonstrators:

Seven of the nine students interviewed said that they had had difficulties when asking junior demonstrators questions: They felt that quite often the junior demonstrators were not very well acquainted with the experiments and were therefore unable to help them. Two junior demonstrators commented that they felt rather inadequate to cope with the experiments outside their specialist field. They could usually help the students with experimental problems but found difficulty understanding the experiments and in questioning the students during vivas. They found that they had to rely heavily on the answers that had been prepared by the demonstrator in charge of a particular experiment. These problems were accentuated by the fact that the course was new and so all the experiments were new to all the junior demonstrators. It is obviously also more difficult for a junior demonstrator to acquire the necessary knowledge of an experiment at the second year level than at the first year level.

Most (seven) students found the senior demonstrators to be helpful. It can be seen from Table 4.7.33 that in spite of this many students preferred to consult junior demonstrators rather than senior demonstrators. This is also supported by the data from observation in section 4.7.5.1.4.2. Senior demonstrators were consulted less than junior demonstrators during a period when the demonstrators were busy and instead students preferred to consult one another.

From the data in section 4.7.4.5.1 and from the fact that students who
understood the experiments well were less reluctant to consult senior
demonstrators, it would appear that students tended to avoid senior
demonstrators because they found them too critical and authoritarian.
Two Chemistry II students commented in interviews that they
deliberately avoided going to demonstrators because they did not want
the demonstrators to know that they did not understand the experiments.

In a course where help is given when requested it appears that the
better students will get the benefit of the experience of the senior
demonstrators more than the average students.

The vivas were helpful in this respect in that they were a time
when individual students came together with a demonstrator to discuss
an experiment. Four students commented in interviews that they
found the vivas helpful for clarifying points that they did not
understand.

In order that students may gain more benefit from the demonstrators
whilst they are actually performing an experiment, there must be a
change in emphasis from all the help being given to students when they
requested it, to a system where more of the initiative for helping
lay with the demonstrators.

4.7.5.3 Summary

This section briefly summarises the main findings related to unit 10/11.

4.7.5.3.1 Good features of unit 10/11

(1) The unit was on the whole quite successful in familiarising the
students with and helping them to understand specific chemical topics. It also gave experience of and practice in the use of chemical techniques and instrumentation (section 4.7.5.1.6). The students, however, did not think that the practical work illustrated material covered in lectures and tutorials (section 4.7.5.1.6, see also section 4.7.2.1.3, aim 2, graph 4.7.1).

(2) The students found the vivas helpful in clarifying points that they did not understand (section 4.7.5.2.3, page 449).

4.7.5.3.2 Learning from other people

(1) In this unit the lack of training and inexperience of junior demonstrators became a more important factor in determining how much the students learnt from the junior demonstrators (section 4.7.5.2.3, page 448). Three factors tended to make a junior demonstrator's job more difficult than in previous units studied:

(a) This unit was more integrated than previous units in that it contained experiments from all three main branches of chemistry. Junior demonstrators therefore had to cope with a wider range of content.
(b) This unit was taken in the second year and therefore required a greater depth of understanding.
(c) This was the first time that the unit had run.

(2) In spite of this students still tended to consult junior demonstrators in preference to senior demonstrators (section 4.7.5.2.3).
(3) Students who thought that they understood the experiments were less reluctant to consult senior demonstrators. This meant that better students tended to get help from more experienced people (section 4.7.5.2.3, page 449).

4.7.5.3.3 Factors which limited learning

(1) The most important factor limiting learning in this unit was the lack of time coupled with the fact that students had to complete one experiment per week and were discouraged from spending more than one week on an experiment (sections 4.7.5.1.7, 4.7.5.2.2.1 and 4.7.5.2.2.2).

The lack of time led to students working mechanically in the laboratory without thinking about the experiments (section 4.7.5.2.2.3).

One of the factors limiting the success of experiment 10.2 (section 4.7.5.1.7) was that it was difficult to perform. In a situation where time was short experimental difficulties would inevitably lead to more rushing and consequently more mechanical unthinking working.

The lack of time appears to have had a differential effect on the students. 'Average' students tended to work more slowly than the better students, and there was therefore a greater tendency for them to work mechanically.

(2) The insufficient preparation of junior demonstrators for their role in this unit has already been mentioned.

1 It also meant that senior demonstrators tended to have more contact with better students which may have given them a false impression of how well the student body was coping with the course.
(3) In some experiments insufficient chemical knowledge and lack of relevance to the lecture courses were factors which inhibited the success of experiments (sections 4.7.5.1.6 and 4.7.5.1.7).

(4) In some experiments it was not clear to the students what they were trying to achieve.

4.7.6 Conclusions and recommendations

This chapter attempts to identify the interrelationships between a number of factors which had a significant effect on the success of the course. The results of the analysis imply a number of ways of improving the course.

4.7.6.1 Motivation

The motivation of students will obviously affect how much they learn in a course. A number of factors which affected student motivation are outlined in Figure 4.7.1.

[Diagram showing interrelationships between types of experiment, feedback, standards, relevance, interest, sense of achievement, deadlines imposed by unit system, and motivation]
For the most part Figure 4.7.1 is self-explanatory, but a more detailed explanation is given in section 4.7.4.6.3. A student's sense of achievement has been related to the type of experiment. The students seem to find experiments which give experience of practical skills and techniques to be less satisfying than experiments which are related to the theory courses (section 4.7.4.4.1). Students also commented on the lack of feedback about their progress both in terms of how well they had done an experiment and in comparison with other students, i.e. they were unable to gauge their level of achievement (section 4.7.4.5.5).

4.7.6.2 Understanding

One factor which has a crucial effect on how much a student gains from doing an experiment, is the degree of understanding that a student has of the experiment, both whilst he is doing the experiment in the laboratory and afterwards when he is writing it up. A poor understanding of an experiment will make it difficult to relate practical work to theoretical work and will decrease the degree of reinforcement of theoretical work, thus decreasing success in achieving aims in area A. It was in this area that the achievement of the present course was limited.

An inadequate understanding of the experiments could also lead to students making errors in the experimental work and to them encountering unnecessary practical difficulties, e.g. experiments 1.2 and 1.3 in unit 1. This would have a limiting effect on the achievements of aims in areas A and B, particularly when time was short.
Another bad effect of poor understanding is that it tends to encourage students to work mechanically without thinking, which in turn leads to a poorer understanding. The factors affecting poor understanding are outlined in Figure 4.7.2 on page 455.

The effect of the different factors varied considerably from experiment to experiment but the factor which had the strongest effect throughout the course was the lack of time, which led to mechanical working, which in turn led to a poor understanding of the experiments.

In order to improve the students' understanding of the experiments the factors which tend to produce poor understanding could be removed and in addition factors which tend to produce a good understanding of the experiments could be reinforced. Figure 4.7.3 shows the factors which promote a good understanding of the experiments.

These factors which had a beneficial effect on the course were limited by other factors which are briefly reviewed below:

(1) Students found it easier to approach junior demonstrators than senior demonstrators, who to some students appeared to be rather critical and authoritarian. Junior demonstrators on the other hand, although easy to talk to, were less familiar with the experiments, particular in unit 10/11 where they had to cope with rather more complicated chemistry. The integrated nature of the course also meant that junior demonstrators had to be familiar with experiments outside their sub-discipline of chemistry. This was to some extent counteracted by the more concentrated nature of the demonstrating duties in the unit system and by the fact that in unit 10/11 at least, one experiment was allocated to each demonstrator so that he
Figure 4.7.3

Whilst doing the experiment:

- Instruction sheets
- Workshops
- Working in pairs
- Preparing beforehand

After doing the experiment:

- Doing the write-up
- Good understanding
- Vivas

Personal contact with demonstrators
could prepare a sheet explaining the experiment to other demonstrators. Obviously, more work has to be done in this area of preparing junior demonstrators for their role in the laboratory.

(2) The effectiveness of the workshops was limited by the following: Students were sometimes unable to read the experimental scripts before going to the workshops and therefore found them difficult to understand. The groups were sometimes too large for students to see demonstrations clearly during the workshops. Students found it difficult to remember details of workshops if they did not do the related experiments until several days later.

(3) Students found the discussions arising whilst working in pairs useful, both for understanding the experiments and for working out calculations. At present, however, working in pairs is generally limited to those experiments for which there is insufficient apparatus for students to work individually.

(4).Students were often unable to prepare for experiments because the experimental scripts were not made available to them sufficiently early.
CHAPTER 5

VIDEOTAPES IN UNDERGRADUATE CHEMISTRY LABORATORIES
This chapter describes an evaluation of the use of videotapes in two undergraduate chemistry laboratory courses, i.e. course IV described in section 4.5 and another course at Sussex University.

The evaluation is different in style from those in Chapter 4 and so has been placed in a separate chapter. The evaluation focuses on a pre-determined issue, the use of videotapes in the laboratory, and assesses the effectiveness of this method of learning in two different learning environments.

5.1 Introduction

Videotapes are being used increasingly for teaching practical skills and techniques in science at the undergraduate level. This chapter describes a study designed to explore systematically the practical advantages and problems of using videotapes in the laboratory. Little work has been done in this area. Kempa and Palmer (85) have shown that videotapes are superior to written instructions for teaching practical skills, but few other studies have been reported.

A number of reasons for using videotapes in the laboratory have been given in the literature:

1. To save staff and demonstrator time so that they can give more individual attention to students. (22,26,137,144,150).

2. Demonstrations of good quality can be produced (10,74,127,150) because they can be carefully prepared. Howland (74) points out that when demonstrators are required to give a demonstration repeatedly the quality of the demonstration tends to fall. It is also pointed
but (19,93,74,150) that the camera is able to focus on small
details that are difficult to see in a live demonstration.

3. To offer a service that is flexible, students are able to see
videotapes when and as often as they wish (22,75,26,150).

The use of videotapes for teaching practical skills and techniques
in two first-year chemistry laboratory courses was investigated -
one at Surrey University (about 30 students) and the other at
Sussex University (about 80 students).

The investigation examined:

1. The different ways in which the videotapes were used in the two
courses.

2. Opinions about the effectiveness of the videotapes as a teaching
   /learning medium.

3. The acceptability of videotapes to staff and students.

4. Some of the problems which arise when videotapes which are made in
   one institution (Sussex University) are used in another
   institution (Surrey University).

Information was gathered by observation, interviews and questionnaires.
Observation and interviews with staff were used to ascertain the
organisation and running of the courses and the use of the 11 video-
tapes. Questionnaires were given to the students to obtain detailed
information about their reactions to three of the videotapes, two of
which were used at both Sussex (150) and Surrey. Some of the questions
In the questionnaire were pursued in more depth in interviews with nine students. Staff reactions and attitudes were studied using interviews. In general, the results reported are those in which the various means of investigation reinforce each other.

5.2 The videotapes

The videotapes used in the two courses contained demonstrations, about 10 min in length, of certain basic skills and techniques such as recrystallisation, melting point determination and filtration.

At Sussex nine videotapes were used. The students viewed the videotapes as a group, in plenary sessions, on two videomonitors which were permanently fixed in the two laboratories being used. A videomonitor was also available in the balance room so that students could see videotapes again if they wished, or so that faster students could see videotapes before the rest of the students.

In the Surrey course six videotapes were available for use by students when they needed to learn a new skill or technique. Finding a suitable place for the video-monitor was a problem: students were found to be easily distracted if they watched the videotapes in the laboratory where they were working. Eventually, as a temporary measure, the videomonitor was placed in an adjacent laboratory that was not being used at the time of the practical class.

5.3 The courses

The two courses were similar in that they were first year chemistry service courses of similar length, but there were many differences.
The Sussex course was designed mainly to illustrate parts of the lecture course and to teach basic laboratory techniques, whereas the Surrey course, although including these aims, put more emphasis on abilities that would enable students to design and carry out experiments themselves. It also stressed working and cooperating with other students in a team.

The styles of the laboratory courses reflected the different emphasis of aims. The Sussex course consisted of traditional types of experiments with step-by-step instructions, and students worked individually. The Surrey course consisted mainly of one open or problem solving experiment that students tackled in groups of four or five. The student to staff plus demonstrator ratios were 20:1 and 7:1 at Sussex and Surrey respectively.

5.4 Effectiveness

The effectiveness of the videotapes as a teaching/learning medium has been assessed in this study by questionnaires and interviews with staff and students as well as by observation. The items on the questionnaire are listed in Table 5.1 and the results obtained from both questionnaires and interviews are summarised in Table 5.1. overleaf.

Views as to the effectiveness of the video-tapes may be summarised as follows:

1. The students thought that the videotapes were successful in teaching laboratory skills and techniques and were relevant.

2. Discussion with staff at both Surrey and Sussex revealed that they were satisfied with the level of competence reached by students
<table>
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<tr>
<th>UNIVERSITY</th>
<th>S U R R E Y</th>
<th>SUSSEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letter representing vi/tape</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>No. of students in sample</td>
<td>2</td>
<td>2</td>
</tr>
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<td>0</td>
</tr>
<tr>
<td>% response</td>
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</table>

<table>
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<tr>
<th></th>
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<th>(\sigma)</th>
<th>(\bar{x})</th>
<th>(\sigma)</th>
<th>(\bar{x})</th>
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<td>(1) Success in teaching laboratory skill*</td>
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<td>4.0</td>
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<td>4.0</td>
<td>-</td>
<td>4.6</td>
<td>0.7</td>
<td>4.8</td>
<td>0.4</td>
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<td>(3) Organisation and presentation*</td>
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<td>3.9</td>
<td>0.9</td>
<td>4.0</td>
<td>0.8</td>
<td>4.7</td>
<td>-</td>
<td>4.5</td>
<td>0.5</td>
<td>4.3</td>
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<tr>
<td>(4) Interest of video-tape</td>
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<td>3.1</td>
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<td>3.3</td>
<td>0.8</td>
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<td>0.6</td>
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<tr>
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<td>0.7</td>
<td>2.6</td>
<td>0.5</td>
<td>2.5</td>
<td>-</td>
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</tbody>
</table>

* The scales for (1), (3), (7) and (8) have been reversed when transposed from the questionnaires in order to clarify presentation.

\(\bar{x}\) = mean rating  \(\sigma\) = standard deviation

A = Recrystallisation
B = Choosing a solvent for recrystallisation
C = Melting point determination
D = Filtration by suction
with respect to the skill and techniques which they had learnt from video-tapes. They felt that the videotapes were at least as effective as the methods which they replaced, i.e. written instructions supplemented by individual help at Surrey and live demonstrations to the whole class at Sussex.

3. At Surrey it was observed that it was not often necessary for staff or demonstrators to intervene in a student's experiment in order to correct an incorrect technique.

In interviews nine students offered some reasons for the effectiveness of videotapes as a teaching/learning medium.

Six students compared videotapes favourably with written instructions. They felt the fact that they could see a demonstration was important:
'I looked at the videotape and could see exactly what I should do: It gives you confidence'.
'With videotapes you actually see it happening whereas if the instructions are written down you don't get a continuous pattern in your brain: You get step-by-step instructions. In a videotape you see the sequence as a continuous whole'.

Five students compared videotapes with live demonstrations:
'The explanation on videotapes is clearer than hearing the lecturers live because it is better planned'.
'I think videotapes are a much better way to teach techniques than to have somebody actually demonstrate at the front of the class because all the equipment is prepared for the videotape and no time is wasted setting up and preparing apparatus'.

5.5 Acceptability

A teaching method must not only be effective, but it must also be acceptable to both students and staff. The methods used to answer questions about effectiveness also revealed attitudes regarding acceptability.

1. All the students interviewed at Surrey reacted favourably towards the use of videotapes. Students' comments on the questionnaires were also mainly favourable. There were, however, criticisms from a minority of students who disliked the impersonal nature of the videotapes. One of the Surrey students commented:

'The only trouble is that you cannot ask questions. You are only being shown what to do and it is rather impersonal ... The presentations tended to be rather long-winded because a videotape is unable to interact with students. Live demonstrations can adjust to the teaching needs of the students but a videotape must cover all the possible problems'.

At Sussex students were able to ask questions after the videotape had been shown, but there were still criticisms by a few students:

'Videotapes lack the spontaneity of a real live demonstration with all the small individual incidents that occur that make the skill memorable. They are just too perfect and thus pass over the memory without sticking'.

The majority of the students, however, found the videotapes to be organised and presented clearly.
2. In interviews with students at Surrey it was found that they liked the fact that they could see a videotape when and as often as they liked. This method of free access did, however, have disadvantages in a course consisting mainly of an open experiment: students found it difficult to judge the pace at which they should work. They were observed to rush through the experimental work and not to plan what they were doing. They were reluctant to watch the videotapes because they felt that they had not got sufficient time to spare. This meant that staff had to encourage the students to watch the videotapes.

3. Students at Sussex also said on the questionnaires that they liked having access to the videotapes when they were needed as well as watching them in the plenary session and, in fact, the videomonitor in the balance room was in almost constant use, mainly by students looking at videotapes for a second time.

4. The students found the videotapes reasonably interesting but interviews with the nine Surrey students revealed that they all viewed the videotapes as functional, as a means to an end, rather than something of intrinsic interest. Students thought that both the amount of material in the videotapes and the speed of presentation were about optimal.

5. Although the technical quality in terms of quality of picture and sound was poor at times both at Surrey and Sussex, this was only mentioned as a problem by the Sussex students. On the questionnaires about a quarter of the students said that they found the quality of the picture distracting and a few students said that they found it difficult to hear. Clearly the quality of the picture is more important when a large number of students, in this case 40, are watching one videomonitor than when four or five are.
6. The staff and demonstrators saw the videotapes as performing three important functions:

(i) The videotapes saved staff and demonstrator time and freed them from routine work so that they could spend their time doing things that could not be done by machines, i.e. help students on an individual basis. This was also mentioned as an advantage by a number of students.

(ii) The videotapes meant that students could learn new skills and techniques at the time when they needed them. In the Surrey course, students had free access to the videotapes. At Sussex the course organiser commented that the students all watched the videotapes at the same time, but, nevertheless, using videotapes meant that the demonstrations could easily be given at any time during a practical session whereas with a live demonstration it is a lot easier to give the demonstration at the beginning of the session.

(iii) One unexpected advantage that was noted was that if a demonstrator was unfamiliar with the techniques or apparatus being used, because he had taken his first degree in a different university and sometimes a different country, he was quickly and unobtrusively able to review the technique by viewing the videotape.

5.6 Transferability

Before the course started at Surrey about 20 videotapes made in Sussex were viewed by the course organiser at Surrey, but about half of them were considered unsuitable for use at Surrey mainly because the apparatus
This section compares the reactions of the Surrey and Sussex students to two of the videotapes made at Sussex University.

The similarity in the reactions of the students at Surrey and Sussex was striking. The only significant differences between the attitudes of students at Surrey and Sussex were that the Sussex students thought that one of the two videotapes was more closely related to their laboratory course than did the Surrey students and that the other was better presented and more interesting.*

The presenter on the videotapes was the course organiser at Sussex and so the Sussex students were familiar with him whereas the Surrey students were not. This seemed to make little difference to the students' reactions to the presenter.

TABLE 5.2

Responses to the questionnaire questions:

'What are your reactions to the speaker?
Does he appear confident?
Is there anything you particularly like or dislike about his performance?'.

<table>
<thead>
<tr>
<th>University</th>
<th>Favourable Reactions</th>
<th>Neutral Reactions</th>
<th>Unfavourable Reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Number</td>
<td>% Number</td>
<td>% Number</td>
</tr>
<tr>
<td>Sussex</td>
<td>50</td>
<td>21</td>
<td>33</td>
</tr>
<tr>
<td>Surrey</td>
<td>42</td>
<td>8</td>
<td>42</td>
</tr>
</tbody>
</table>

* Significant at the 0.05 level
Videotapes were judged to be an effective medium for teaching practical skills and techniques in undergraduate chemistry laboratories. They have several features which are advantageous.

1. They save staff and demonstrators from routine teaching giving them more time to help students individually.

2. They are prepared in a concrete form and their quality is easily open to criticism and control. Each demonstration is, therefore, carefully prepared and executed.

3. Students have access to demonstrations when and as many times as they need them.

4. Videotapes that are produced in one institution can be used in another.
Chapter 6

A comparison between traditional and open courses
This chapter draws together the findings from the literature survey of the opinions of academic chemistry staff in higher education and from the six evaluations described in Chapter 4. The chapter is divided into 6 main sections: Section 6.1 is about the similarities and differences in traditional laboratory courses, section 6.2 about open or problem solving courses, and section 6.3 compares traditional and open courses with one another. Section 6.4 reviews the alternative styles of laboratory courses available for achieving different groups of aims and section 6.5 is a summary of methods available for improving the effectiveness of laboratory courses. Finally, section 6.6 outlines areas for future research.

6.1. Traditional courses

Much of the information in the survey of the opinions of academic chemistry staff is related to traditional courses.

Of the six courses evaluated 3 can be described as traditional and a further one as mainly traditional but with some open aspects. They are briefly characterised below:

<table>
<thead>
<tr>
<th>Type of Lab. course</th>
<th>Described in section</th>
<th>Code no</th>
<th>Type of students</th>
<th>Subject area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>4.4</td>
<td>III</td>
<td>Chem I</td>
<td>Inorganic</td>
</tr>
<tr>
<td>Trad + open</td>
<td>4.3</td>
<td>II</td>
<td>Chem Eng I</td>
<td>Organic+inorg.</td>
</tr>
<tr>
<td>Traditional</td>
<td>4.6</td>
<td>V</td>
<td>Chem II</td>
<td>Physical</td>
</tr>
<tr>
<td>Traditional</td>
<td>4.7</td>
<td>VI</td>
<td>Chem I+II</td>
<td>Integrated Chem.</td>
</tr>
</tbody>
</table>
6.1.1.1 Aims of present laboratory courses

In the survey questionnaire staff indicated that the main emphasis for their courses in the first 2 years lay in areas A (aim 2) and B (aim 6, 7 and 8) with emphasis also being placed on aims in area C which could be achieved within the context of traditional courses, i.e. aim 17: logical and methodical working in the laboratory aim 18: day-to-day laboratory notebook aim 19: deductions from and interpretation of experimental data aim 22: report writing.

Emphasis was also placed on some aims in area D, i.e. stimulating interest (aim 26) and developing honesty and scientific integrity (aim 28), and on one aim in area E, i.e. providing closer contacts between students and academic staff (aim 31). Again these aims could all be achieved within the context of traditional courses.

The aims of courses II, III, V and VI on the whole closely reflect these aims. Course III is unusual in that it was not designed to illustrate the lectures (Section 4.4.2.1 aim 2; area A) and in course V, aims in area B were emphasised a lot less (Section 4.6.2.1).

Of the four courses only course V emphasises aims in area E, i.e. providing closer contacts between students and academic staff (aim 31) and developing skill in working and cooperating in a team (aim 33). This reflects the very low student : staff ratio in this course.

It is interesting to note that whereas staff usually emphasise 'stimulating interest' as being quite an important aim only students in course V thought that this was an important aim in their course.
It is also surprising that students thought that aim 11 'to develop students' skill in problem-solving by experimental work' was an important aim in all four courses, whereas staff emphasised the aim in only 2 of the courses (V + VI). This suggests that what staff see as routine, students may see as problematic.

6.1.1.2 Aims of ideal laboratory courses

Staff opinions from the survey questionnaire and staff and student opinions in the evaluations indicate that they feel the main emphasis of the courses are correct and should be in areas A and B and the parts of C, D and E indicated in the previous section. The survey questionnaire (section 3.3.2.5), however, indicates that staff would like to see more emphasis placed on all the attitudinal aims in area D and some of the aims in area C to do with problem-solving (aim 11) and planning and designing equipments (aims 15 and 16); the latter two aims particularly in the second year. This desire for a change in emphasis was not felt as strongly by most of the staff in the course evaluations, but is reflected in the opinions of the students in all four courses, particularly with respect to aims in area D.

It was pointed out in section 2.2.2.1.1 of the literature survey that a common criticism of traditional laboratory courses is that they are said to be only able to achieve aims in areas A and B and to a limited extent in C. The evidence from the survey questionnaires and the evaluations indicates that for the most part this criticism is a valid one. Staff usually only try to achieve aims in areas A, B and small parts of C, D and E when using traditional courses in spite of their aspirations to put more emphasis on area D and to some extent area C (see section 3.3.2.5). In order to shift the emphasis of
aims towards areas C and D it appears that project types of work have had to be introduced (section 2.1.4.2).

6.1.2 Characteristics of traditional courses

The traditional courses evaluated had several features in common with one another and with the traditional courses described in response to the survey questionnaire:

(a) In traditional experiments the students were expected to carry out the experiments in a predetermined way. The experiments were described by instruction sheets which contained step-by-step instructions on how to perform the experiments and usually the necessary theory for the experiment. In some courses use was also made of text books or periodicals (see section 3.3.3.3). In course III, the text book itself contained step-by-step instructions.

(b) The staff and demonstrators were available to help students when necessary, usually at the request of the students (courses II, III, V, VI) sections 4.3.3.1.2, 4.4.3.1.2, 4.6.3.1.3, 4.7.4.1.3, 4.7.4.2.2, 4.7.4.3.3, 4.7.5.1.3.

(c) At the end of each experiment the students were required to do a formal 'write-up' or report, which was a complete description of the experiment (courses I, III, V), or sometimes students did a shortened form of write-up which included results, conclusions and some sort of discussion (course VI, section 4.7.3.4, see also section 3.3.4.3).
6.1.3 The student in relation to other people

6.1.3.1 The isolated nature of traditional practical work

The activities of students were observed in 3 of the 4 traditional courses and set out in Table 6.1 below:

<table>
<thead>
<tr>
<th>Activities</th>
<th>Courses</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>III</td>
<td>V</td>
</tr>
<tr>
<td>(1) Working at bench</td>
<td>88</td>
<td>53</td>
</tr>
<tr>
<td>(2) Talking to student</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>(3) Talking to staff</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>(4) Talking to demonstrator</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>(5) Talking to technician</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>(6) Oral assessment; viva</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(7) Other</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

It can be seen that providing step-by-step instructions minimises the need for students to interact with other people: in three of the courses described the vast majority of the students' time was spent working alone at the bench. Students also, however, need help from other sources and it appears that the poorer a student's understanding of an experiment, the more help he needs (course VI, sections 4.7.4.5.1 4.7.5.2.3. This section examines the factors affecting the amount of interaction between students and other participants in the courses:

(a) In course V the amount of time that students spent working alone at the bench was considerably less than in the other courses. This was to a large extent due to the fact that students worked in pairs.
This resulted in students spending 24% of their time in the laboratory discussing experiments with their partners (see section 6.1.3.4 for further details).

(b) Another factor which seems to have influenced the amount of interaction between the participants in the courses was the attitude of staff and demonstrators. It appears from Table 6.1 that the amount of student-student interaction is related to the amount of student-staff/demonstrator interaction. The atmosphere of a course, where help is given on request is very much influenced by the attitude of the staff and demonstrators. Where staff and demonstrators are enthusiastic and sympathetic to students' questions, then the students will be encouraged to ask more questions and it appears to consult one another more. The attitude of staff and demonstrators thus largely determines whether the course is a formal one, like course III where students tended to work in isolation or a less formal one where students are not afraid to ask questions.

A further effect of the attitude of the staff is related to marking. In a course where the staff are very enthusiastic they are prepared

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1 The reasons for the greater interaction in course V have been mentioned previously and it is apparent from the evaluation of unit 2 in course VI that the students had considerable difficulties and needed a lot of help. An examination of the difficulty of the different courses judging from the difficulty ratings on the feedback sheets does not indicate, however, that the amount of interaction is directly related to the difficulty of the experiments.

2 The lack of involvement of the staff and demonstrators in course III was mentioned in the evaluation report as one of the main problems of that course, with the course organiser being absent for 28% of the time and the demonstrators being allocated to marking for half their time in the laboratory.
to do marking outside laboratory hours, thus increasing their availability to the students, e.g. in course II nearly all the marking was done outside laboratory hours (section 4.3.3.1.4), whereas in course III nearly all the marking was done in the laboratory (section 4.4.2.1.3).

A related problem is that help is not always given to those students who need it most (courses III, V, VI, sections 4.4.3.2.3.2, 4.6.3.2.3.4, 4.7.4.5.1, 4.7.5.2.3). Many students were reluctant to consult staff because of a fear of showing themselves to be ignorant. They viewed the staff as being critical and authoritarian (courses V, VI, sections 4.6.3.2.3.4, 4.7.4.5.1, 4.7.5.2.3). Students, on the other hand, saw demonstrators as being more like themselves\(^1\).

The attitudes of students to the staff and demonstrators can be traced to the instructional environment in which they meet the staff and demonstrators. Usually students only consult staff or demonstrators if they have problems. Staff sometimes initiate the interaction with students, e.g. 4.4.3.1:4.3 and 4.7.4.2.4, but often in a critical or in a supervisory capacity. Demonstrators rarely do this. In a traditional course there is little opportunity for discussions of a heuristic nature: the experimental procedure is predetermined and if done correctly should achieve predetermined results.

(c) The staffing ratios can also have an effect on the amount of student-staff/demonstrator interaction. The comparative staffing ratios for the courses are given in Table 6.2 below:

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\(^1\) See also Reference (121)
TABLE 6.2

<table>
<thead>
<tr>
<th>Course ratio</th>
<th>III</th>
<th>II</th>
<th>V</th>
<th>VI</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 10/11</th>
</tr>
</thead>
<tbody>
<tr>
<td>student:staff</td>
<td>30:1</td>
<td>11:1</td>
<td>10:1</td>
<td>34:1</td>
<td>26:1</td>
<td>28:1</td>
<td></td>
</tr>
<tr>
<td>student:PG demonstrator</td>
<td>15:1</td>
<td>22:1</td>
<td>13:1</td>
<td>17:1</td>
<td>37:1</td>
<td>20:1</td>
<td></td>
</tr>
<tr>
<td>student:staff+demonstrator</td>
<td>10:1</td>
<td>7:1</td>
<td>6:1</td>
<td>11:1</td>
<td>16:1</td>
<td>11:1</td>
<td></td>
</tr>
</tbody>
</table>

Course V had the most favourable student:staff+demonstrator ratio of the courses and one which was well below the national mean for the size and year of the course. In this course there was the greatest amount of interaction between students and the staff and demonstrators.\(^1\)

At the other extreme course VI unit 2 had the highest student:staff + demonstrator ratio and in this course there were insufficient staff and demonstrators to cope with all the students' problems in spite of the fact that staff worked very hard in this course.\(^2\) The amount of student-staff/demonstrator interaction was the lowest of the 4 courses.

It is interesting to note that the student:staff + demonstrator ratios of about 10:1 or 11:1 were usually judged to be satisfactory (course VI units 2 + 10/11) but not in course III (section 4.4.3.2.4) where ineffective use was made of the demonstrators. These ratios are

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\(^1\) There was probably a similar amount of student-staff/demonstrator interaction in course II, but no records were kept of this during the evaluation.

\(^2\) The reason for the high student:staff + demonstrator ratio was that large numbers of staff and demonstrators were used to run workshops in another part of the course. This illustrates the difficulties of deciding how to use a limited supply of resources.
around the national mean (Table 3.17, section 3.3.3.17) and are similar to those desired by staff in the Ourisson report (125).

6.1.3.2 Providing more student-staff/demonstrator contact

It can be seen from the previous section that the amount of help that students get from staff/demonstrators, as well as depending on obvious constraints such as staffing ratios, also depends on a number of less obvious constraints, i.e. attitude of staff and demonstrators to their role in the laboratory and attitudes of students to staff and demonstrators. It is possible, however, in a traditional laboratory course to formalise student-staff/demonstrator contact in such a way that each student comes into contact with staff/demonstrators on a regular basis:

(a) In course VI (sections 4.7.3.4 and 4.7.5.2.3) vivas were given to students after each experiment. These were oral sessions, about 10 minutes long, during which staff or demonstrators met students on an individual basis in order to discuss each experiment with each student. The viva was used by staff and demonstrators to assess the students' understanding of the experiment and contributed about 20% to the total mark for the experiment. The students found the vivas useful in helping them to understand the experiments.

(b) Also in course VI (sections 4.7.3.3 and 4.7.4.5.3) workshops were used. These were a combination of a demonstration and a short talk lasting perhaps half an hour in all given by a member of staff or demonstrator to a group of about 10 students. Students found the workshops useful and thought that they were quite successful in
preparing them for the experiments which followed.

(c) Groups can also be used to bring students into contact with staff/demonstrators. Within the framework of a traditional course, groups, led by a member of staff or a demonstrator, are used in order to generate data more rapidly (6) and in order to familiarise students indirectly with a wide range of apparatus and techniques (51, 50). The use of groups can also promote discussion, develops skills in communicating results and helps the students' understanding of the experiments (see section 2.2.3.2).

The use of groups within the context of open or problem solving courses is discussed in section 6.2.3.3.

6.1.3.3 Replacing student-staff/demonstrator interaction

Computers and audio-visual aids can be used to replace or supplement some aspects of student-staff/demonstrator interaction.

6.1.3.3.1 The use of computers in the tutorial mode

Computer programmes can be written so that they are responsive to students' needs (course V) and so can replace some of the tutorial aspects of the staff and demonstrators role. Computers have been used to guide students in planning and evaluating experiments (course V, section 4.6.3.1.3(c); section 2.2.3.3.1) in problem solving, interpretation of spectra (section 2.2.3.3.1) and in helping students to revise and understand the theory of the experiments (course V, section 4.6.3.2.3.3).
In course V some aspects of using computers were found to be superior to the student-staff/demonstrator interaction which they were supplementing:

(a) The teaching programme had been carefully prepared and was therefore better than the equivalent scheme done by a member of staff.

(b) Students were not afraid of getting the wrong answer when interacting with the computer, whereas with staff they were.

(c) Students were encouraged by the immediate feedback and enjoyed doing the programmes.

(d) The computer exercises stimulated students working in pairs at the terminals to discuss the chemistry with one another.

The computer programmes were found by the students to be limited in that they were not as flexible as members of staff and were not able to adapt to individual students' learning needs.

Overall, the use of computers in the laboratory encouraged discussion, thought and consequent learning.

The insertion of computer programmes into traditional courses enables the emphasis of these particular exercises to be shifted from the practical details of the experiments towards the planning of the experiments and the interpretation of experimental data (aims in area C).
6.1.3.3.2 The use of audio-visual materials to supplement laboratory instruction

The data from the questionnaire survey indicate that increasing use is being made of audio-visual material in the laboratory, particularly video-tapes and tape-slides (section 3.3.4.1) and that about 20 to 25% of all chemistry laboratory courses use audio-visual material, although usually on rather a small scale.

Audio-visual materials are unresponsive and therefore can only be used to replace the instructional rather than the tutorial aspects of the staff and demonstrators' role, such as introducing an experiment or teaching basic practical skills and techniques.

In course IV (Chapter 5) the use of video-tapes for teaching basic practical skills was studied. They were judged to be an effective teaching medium and had several features which were advantageous (see also section 2.2.3.3.1):

(a) They saved staff and demonstrator time.

(b) Their quality was easily controlled and each demonstration was carefully prepared and executed.

(c) Students had access to demonstrations when and as many times as they needed them.

(d) Videotapes prepared in one institution can be used in another.

Both computer programmes and audio-visual materials have the
advantage that, like instruction sheets, they are self instructional and can be inserted into a traditional course without making any extra demands on the pedagogical skills of staff and demonstrators and in fact can save them time, freeing them to help students in other ways. They do require a large amount of time to prepare but because they can be transferred from one institution to another the workload can be shared amongst a large number of people.

6.1.3.4 Student-student interaction in traditional courses

It was pointed out in section 6.1.3.1 that students usually spend the vast majority of their time in the laboratory, in a traditional course, working alone at the bench and that the amount of student-student interaction appears to be influenced by the atmosphere created in the laboratory by the manifested attitudes of staff and demonstrators.

An examination of Table 6.1 and the evaluation reports in Chapter 4 shows that students derive a considerable amount of help from one another in the laboratory and, in fact, usually consult one another more than staff and demonstrators. In spite of this, attempts are rarely made to capitalise on student-student interaction as a learning resource.

Table 6.1 shows that the amount of student-student interaction can be vastly increased by students working in pairs. The data in section 3.3.3.1.2, however, indicate that staff generally prefer students to work alone and that if students work in pairs this is usually because

1 Course II, 4.2.3.2.2(i)+4.2.3.2.3(a); Course III, 4.4.3.1.4.1 + 4.4.3.2.3.1; Course IV, 4.5.3.1.3.1 + 4.5.3.2.5; Course V, 4.6.3.1.4.1 + 4.6.3.2.3.4; Course VI, 4.7.4.2.4, 4.7.4.4.2.2, 4.7.4.5.1, 4.7.5.1.4.1 + 4.7.5.2.3.
of constraints of apparatus or space. The evaluations of courses V (section 4.6.3.2.3.4) and VI (section 4.7.4.4.2.2) have shown, however, that working in pairs can produce substantial educational benefits.

The agreement between the findings in the two courses is remarkable. In both courses approximately the same numbers of students preferred working in pairs as preferred working alone. The majority of the students found that discussion with their partners helped them to understand the experiments and was helpful when working out results and calculations. Students who preferred working in pairs thought that they learnt more, made fewer mistakes, worked well as a team and worked faster, when working in pairs. The opposite was true of students who preferred working alone. An investigation of the students who preferred working alone, in course V, revealed that this could be because of one of two factors:

(a) The students were incompatible.

(b) The students' personal learning strategies were better adapted to working alone.

The overall picture presented is therefore that all the students benefitted in some ways from working in pairs but that some either had difficulties in cooperating with their partner or simply preferred working alone. In courses which emphasise illustrating the lectures (area A of the aims), understanding the experiment is important and it therefore appears that the large majority of students gain more from working in pairs than alone. In courses where more emphasis
is placed in area B the benefits of working in pairs are less apparent. Working in pairs can, of course, also be used to encourage the achievement of aims in area E, but these are not usually felt to be very important. (sections 3.3.2.3 + 3.3.2.5).

6.1.3.5 The problem of the untrained P.G. student demonstrator

Post-graduate student demonstrators are widely used in chemistry laboratory courses at universities (section 3.3.3.17, Tables 3.17 and 3.18) but usually little effort is made to prepare P.G. student demonstrators for their role in the laboratory. P.G. students are sometimes simply given copies of experimental scripts (courses III and V) and are assumed to be familiar with the course, having studied it themselves, as students in previous years (Ref (121) p22; course V).

Brooks et al (23) describe a short course in the U.S.A. designed to help demonstrators to undertake their role in the laboratory, and Davies (37A) has described the use of notes to help demonstrators fulfil their role in the laboratory in the U.K.

In course VI (section 4.7.4.5.1) some efforts were made to prepare P.G. demonstrators for their role in the laboratory. Before P.G. students could demonstrate in the laboratory, they had to attend a safety course and subsequently they were encouraged to go into the laboratory, prior to the students, to try out any experiments with which they were unfamiliar. Money was set aside to pay P.G.

1 In course II, one effect of the course being developed was that I was both helping to develop the course and was acting as a P.G. demonstrator on the course and was very familiar with the course.
demonstrators for their time spent in this way. In addition to this in unit 10/11 (section 4.7.5.1.5) each member of staff or demonstrator was made responsible for one experiment for which he had to prepare model sets of answers and results, which could then be used by other members of staff or demonstrators.

In course III there were considerable difficulties with the P.G. demonstrators (section 4.4.3.2.3.1). Three of the four demonstrators were from foreign universities and were completely unfamiliar with the experiments and had difficulties in explaining themselves in English. As a result they were of little help to the students who were rarely consulted. The British demonstrator, on the other hand, had previously done the course as a student and was consulted much more often. The problems with P.G. demonstrators and the resulting low level of interaction in the course led to a low level of achievement of the aims of the course (section 4.4.4).

The fact that P.G. demonstrators were clearly ill-equipped to demonstrate in the laboratory stems from two factors outside the control of the course organiser:

(a) The number of P.G. research students in this department was relatively small and so difficulties were encountered in finding sufficient P.G. demonstrators, and most of the P.G. students were foreign.

(b) The P.G. students union at this university insisted that all

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1 In Table 4.4.3, 8 out of the 9 occasions when demonstrators were talking to students were with the British demonstrator.
P.G. students be given the opportunity to do some teaching.

In such a situation the necessity to give the P.G. students some sort of training before they start demonstrating in the laboratory is more important than usual, even if this training is only at the basic level of familiarising the demonstrators with the apparatus and experiments before the course starts.

In course VI some problems with P.G. demonstrators were encountered in unit 10/11 but not in units 1, 2 and 3: Demonstrators were not very well acquainted with the experiments and were therefore unable to help the students with some problems. The demonstrators' difficulties were accentuated in this unit by the following (see section 4.7.5.3.2):

(a) Within the unit the different sub-divisions of chemistry were integrated. This made it difficult for demonstrators to cope with problems outside their specialist field.

(b) The unit was running for the first time and so none of them were familiar with the experiments from previous experience.

(c) Demonstrators had to give students vivas at the end of each experiment, in which they were trying to assess the students' understanding of the experiments. These vivas sometimes revealed inadequacies in the demonstrators' own understanding.

(d) The intellectual level of the material in unit 10/11 was higher than earlier units. As the intellectual level of the material
being covered rises through the degree course, it becomes increasingly
difficult for P.G. demonstrators to cope with the difficulties that
students encounter. From Table 3.17 and 3.18 in section 3.3.3.17
it can be seen that on a national basis the usage of P.G. demonstrators
decreases as the level of the courses increases.

In summary, the need for some kind of training of demonstrators is
accentuated in courses where P.G. demonstrators are unfamiliar with
the course content because:

(a) the course is a new one,

(b) the P.G. students did not do their first degree at the present
institution and therefore did not do the experiments themselves as
students,

(c) the course includes content not in the sub-discipline of
chemistry within which they are specialising,

(d) the intellectual level of the course is relatively high.

In traditional practical work students spend the vast majority of
their time in the laboratory at the bench following step-by-step
instructions and only consult other people if they have problems.
This means that the effects of poor training of demonstrators are
minimised: If the student does the experiment properly then he
should reach a predetermined result. He will only need to consult
other people if he does something wrong, if the apparatus does not
work or if there are inadequacies in the experimental script.
In its most basic form the role of staff and demonstrators can thus be reduced to one of maintaining an instructional system which will run itself. There are, of course, opportunities to improve the instructional system by performing more than this basic function, but without doing more than this, the course will continue to run, in the sense that students will be seen to be working through the experiments at the bench.

A second factor in a traditional course which may minimise the effects of poor training of demonstrators is the fact that students can choose who they go to for help and thus the proficiency of members of staff or some demonstrators or even other students may go some way to mitigating the effects of a poor demonstrator (e.g. course I, section 4.2.4.1).

6.1.4 The student within his learning environment

6.1.4.1 The experiment

This section examines the impact of individual experiments on the students and the success or otherwise of the experiments.

6.1.4.1.1 Aims

In none of the traditional courses evaluated were the aims of individual experiments explained to the students. The students were left to infer the aims of the experiments. In some experiments the aims were straightforward and could be inferred from the title, e.g. course VI, unit 1, but in others the aims were less obvious to
the students. In courses III and VI some students did not know what the aims of some experiments were\textsuperscript{1}. In course III (section 4.4.3.2.1(iv) + 4.4.3.2.2) this seems to be linked with the fact that the students were unfamiliar with the theoretical material in the experiment. The fact that students did not know the aims of the experiments contributed to the students feeling that they had gained little or nothing from doing the experiments.

It is pointed out in section 2.1.1 of the literature survey that aims and objectives help students to organise their learning. If the aims of an experiment are not obvious to the students and particularly if the theoretical content is unfamiliar, then the aims should be stated explicitly.

6.1.4.1.2 The content of experiments

An intrinsic problem with traditional laboratory courses is that the experiments can easily turn into 'cookery' exercises with the students following the instruction sheets without understanding the chemistry involved\textsuperscript{2}. The fact that experiments are modified by staff until they are foolproof\textsuperscript{3} means that they require little thought.

The tendency to mechanical working is reinforced if experimental difficulties are encountered by the students. Students have to spend more time on the experiment which means that they have insufficient

\begin{footnotesize}
\begin{enumerate}
\item Course III, section 4.4.3.2.1(iv); Course VI, sections 4.7.4.2.1 + 4.7.5.1.1, 4.7.5.1.6, 4.7.5.1.7.
\item Sections 2.2.2.1.2 and 3.4.1
\item Section 3.4.1
\end{enumerate}
\end{footnotesize}
time to try to understand the experiment whilst they are doing it\(^1\) and therefore tend to work mechanically. This in turn can lead to students feeling that they have not achieved the aims of the experiment. In addition, problem solving is usually not one of the important aims in a traditional course and so little, if any, credit is given for overcoming experimental difficulties\(^2\).

Another problem with traditional experiments is the difficulty of relating some of them to other parts of the course. Lack of integration with other parts of the course can lead to students viewing experiments as isolated exercises which are difficult to understand and seem pointless.

When the students had insufficient pre-knowledge\(^3\) or when the practical work was not related to work covered in the theory courses, students often found the experiments difficult to understand, which meant that they worked more slowly, found it difficult to understand the point of the experiments and felt that the experiments were not worthwhile\(^4\).

In contrast, when students thought that the practical work was related to the lecture courses, they felt that the practical work was worthwhile and appreciated being able to apply what they had learnt in the lecture courses to a practical situation. The fact that they felt that they were learning also appears to have added interest to the experiments.

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1. Course VI, sections 4.7.4.5.4 and 4.7.5.2.2.3.
2. Course VI, sections 4.7.4.5.5 and 4.7.5.1.5; Course III, section 4.4.2.1.5.
3. Course VI, sections 4.7.4.2.1(2), 4.7.4.2.6 and 4.7.5.1.7.
4. Course VI, section 4.7.4.4.1
Davies and Penton (37) describe favourable student reactions to a course in which the theoretical and practical material were integrated. The students felt that they were actually understanding and learning the material presented.

In course III, a course designed primarily to teach basic skills and techniques, students found it difficult to see the point of experiments that were not related to the theory courses\(^1\). In contrast, in course VI unit \(^2\) students thought the unit was very worthwhile because it taught them basic experimental techniques that they thought they would need later in order to be able to carry out other experiments.

The need to relate individual experiments to other parts of the course has been recognised by respondents to the questionnaire survey (section 3.3.4.1), both to produce closer integration or correlation between the laboratory and theory courses where different parts are linked together more coherently in 'integrated sequences'.

6.1.4.1.3 The 'write-up'

The write-up can serve three main functions\(^3\):

(i) Doing the write-up makes students think and gives them a greater understanding of the experiments and of their purpose. Students also found that it helped them to relate the practical work to the lecture

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1 Course III, section 4.4.3.2.1; (iii)
2 Course IV, section 4.7.4.4.1
3 Ogborn (121)
(ii) The marking of the write-up can be used to provide feedback to students about how well they are doing in the course. In all the courses evaluated the amount of feedback provided in this way was minimal, with the exception of course VI, unit 10/11 in which students had a viva at the end of each experiment.

Students thought that they were not given enough information about how well they were getting on in the course. In courses V and VI many students would like to have been told what grades they were achieving in the courses and a few would have appreciated more detailed comments on where they were going wrong in the experiments. The data obtained in the evaluation of course III indicate that students had little idea of how the marks were allocated for the experiments.

The volume of student criticism in this area indicates that improving feedback on write-ups could make a significant contribution to the educational effectiveness of traditional laboratory courses. Students could be told the distribution of marks for the experiments, where and why they had lost marks and what their final mark was. Students would then have a basis for systematically improving their performance in the laboratory.

1 Course III, section 4.4.3.2.2; Course V, section 4.6.3.2.4, Course VI, section 4.7.4.5.5.
2 Course V, section 4.6.3.2.4; Course VI, section 4.7.4.5.5.
3 Course III, section 4.4.3.2.5.
(iii) The final purpose of the write-up is to provide a means for assessment and, with the exception of course VI, assessment in all the courses evaluated was based exclusively on the write-up. In course III, however, some students questioned whether the write-up was a valid means of assessing their practical ability. It was felt that students, who were poor at practical work but good at writing it up, could achieve a good mark. In addition, 'fiddling' of results was so widespread that the validity of using write-ups for a skills course is called into question.

6.1.4.2 The organisation of the laboratory course

This section examines some of the effects of the general organisation of a laboratory course on the students.

6.1.4.2.1 Rushing

It was noticed that in both courses V and VI that students were rushing during their time in the laboratory. It was expected that the effects of rushing would be similar in both courses, but the fact that the courses were organised in different ways lead to very different effects.

In course V¹ the students were rushing in order to complete the practical work early so that they could spend more time revising for their exams at the end of term.

In order to be able to work faster students prepared for the practical work by reading each experiment in the laboratory manual before

¹ Course V, section 4.6.3.2.1.1.
coming into the laboratory. The students found that preparing in advance in this way helped them to plan and organise themselves in the laboratory. It also helped them to understand the experiments which in turn helped them to execute them more efficiently. The fact that the students decided to rush thus had a beneficial effect on their understanding in the laboratory. Other factors which helped to improve their understanding were the fact that some experiments were related to work already studied and the fact that they worked in pairs.

In course VI the students rushed because they had insufficient time to do all the experiments in the time allocated. In spite of the fact that the students saw similar advantages in studying the instruction sheets before coming into the laboratory they were often unable to do this because the instruction sheets were often not issued in advance. Students were not issued with new instruction sheets until they had had the previous experiment marked and therefore had to write-up each experiment as soon as they had done it.

In course V students often left writing-up the experiments until about two weeks after they had done them in the laboratory.

The lack of time in course VI and the inability to prepare in advance meant that the students felt that they had insufficient time to sit down and study the scripts thoroughly before they started. This led to students working mechanically, following the instruction sheets as a recipe.

1 Course VI, sections 4.7.4.5.4 and 4.7.4.5.2.
6.1.4.2.2 Understanding

A student's understanding of an experiment whilst he is doing it, can have a considerable effect on what he gains from it. The effects and causes of understanding an experiment whilst it is being performed in the laboratory are briefly reviewed here.

If a student understands an experiment whilst he is doing it, he is more likely to perceive the aims of the experiment which in turn will enable him to work systematically to achieve the aims of the experiment. The student is better able to plan his work and therefore works faster and more efficiently.

If a student does not understand the experiment whilst he is doing it there is a tendency to work mechanically, without thinking and to leave trying to understand the experiment until he does the write-up.

Factors which have been found to contribute to a good understanding of the experiment whilst it is being done in the laboratory are:

(i) Personal contact with staff and demonstrators (sections 4.4.3.2.3.2, 4.6.3.2.3.4(2), 4.7.4.2.4, 4.7.4.5.1 and 4.7.5.2.3).

(ii) Discussion with other students, particularly when working in pairs (sections 4.6.3.2.3.4(i) and 4.7.4.4.2.2).

(iii) Reading instruction sheets beforehand (sections 4.6.3.2.1.2, 4.7.5.2.3 and 4.7.4.5.2).

(iv) Relevance to work already studied (section 4.6.3.2.1.2).
Factors which have been found to lead to poor understanding are:

(i) Lack of time, caused by:
   (a) too much content
   (b) experimental difficulties due to faulty equipment
   (c) experimental difficulties due to student errors (sections 4.6.3.2.1.2, 4.7.4.5.4 and 4.7.5.2.2)

(ii) Insufficient theoretical background, caused by:
   (a) lack of pre-knowledge (sections 4.7.4.3.5, 4.7.5.1.7, 4.3.3.2.4 and 4.4.3.2.2)
   (b) difficult theoretical work (section 4.7.4.2.6)
   (c) lack of relevance to the theory courses (section 4.6.3.2.1.2 and 4.6.3.2.2.1)
   (d) too many new concepts (section 4.7.4.2.6)

(iii) Not knowing the purpose of the experiment which can in turn be caused by poor understanding (sections 4.4.3.2.1(iv), 4.7.4.2.1 and 4.7.5.1.7).

Many of the factors outlined above depend on how the laboratory course is organised internally and in relation to other parts of the degree course.

6.1.4.2.3 Ordering of experiments

The two most widely used ways of ordering the experiments are
sequentially, where all the students study the same experiment at approximately the same time and the 'circus' arrangement where different students do different experiments at the same time. Many courses use a combination of the two\(^1\). A few courses use the unit system\(^2\).

The advantages of sequential courses are:

(i) Students are able to get help from other students in the course.

(ii) P.G. demonstrators are able to familiarise themselves with the course gradually and do not have to be familiar with all the experiments at the beginning of the course, as would be required for the 'circus' arrangement.

(iii) It is easier to use group discussions and demonstrations and to, integrate the theory and practical courses.

The 'circus' arrangement is usually used when there are constraints on the availability of apparatus. For the same reason pairs are often used in the circus arrangement. Discussion with the partner helps to overcome the problems in the earlier part of the course, associated with other students, and sometimes demonstrators, being unfamiliar with the experiments and unable to help them\(^3\).

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1  Section 3.3.3.13.
2  Section 2.2.4.2.
3  Course V, section 4.6.3.2.3.4 and Course VI, section 4.7.4.4.2.2.
The unit system is flexible and can use either the 'circus' or 'sequential' arrangement, whichever seems most appropriate to the material being studied. The unit system has the advantages that it helps to pace the students because they have to complete the work by the end of each unit and that it offers more variety than a conventional course, each unit being organised by a different member of staff.

6.2 Open or problem solving courses

This section is based on information obtained from the questionnaire survey described in Chapter 3, the literature survey, particularly section 2.2.2.2 and the evaluations of the courses briefly characterised below:

<table>
<thead>
<tr>
<th>Type of laboratory course</th>
<th>Description in section</th>
<th>Code no</th>
<th>Type of students</th>
<th>Subject area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>4.2</td>
<td>I</td>
<td>Chem.II</td>
<td>Inorganic</td>
</tr>
</tbody>
</table>

6.2.1 Aims

6.2.1.1 Aims of present laboratory courses

In the survey questionnaire and in the literature staff indicated

1 Section 2.2.4.2
2 Section 2.2.2.2
3 Section 3.3.2.3
that in addition to trying to achieve the aims emphasised in traditional courses, open laboratory courses also emphasised problem solving through experimental work (area C) and attitudinal aims (area D).

The two open courses evaluated reflect this widening in emphasis to include more aims in areas C and D. In course I the emphasis was on aims in areas B and C and with also some emphasis on area D. In course IV the emphasis was on areas C and E, with also some emphasis on B and D.

The inclusion of more aims in open courses implies that they must be more efficient than traditional courses in order to achieve more aims in the same time.

6.2.1.2 Aims of ideal laboratory courses

Staff and students in courses I and IV were on the whole satisfied that the aims of the course were the right ones.

6.2.2 Characteristics of open or problem solving areas

Open courses have some common features:

(a) An open course contains open or problem solving experiments in which a problem is posed and the student is required to develop an appropriate experiment to solve the problem. For experiments to be open, there must be more than one possible way of solving the
problem, although not necessarily more than one solution\textsuperscript{1}.

(b) There are three common ways of organising open courses\textsuperscript{2}:

(i) Courses which start with traditional experiments and then finish with short open style experiments.

(ii) Courses which consist of open unstructured set experiments in which there is some choice of experiment methods. Both courses I and IV fall into this category.

(iii) Courses in which each student does one project style experiment, no more than a semester in length, which usually is chosen from a number outlined by the staff each year.

6.2.3 Student reactions to open laboratory courses

6.2.3.1 Student involvement

The nature of open laboratory courses demands greater student involvement than traditional ones. The students become actively involved in the planning of experiments; they have to decide what to do.

Students like the greater sense of involvement. They like being able to organise and choose their own experiments and as a result find open courses interesting\textsuperscript{3}. They find that the aims of the

\textsuperscript{1} Survey questionnaire (appendix A3) Section 2.2.2.2.3 Course I, section 4.2.3.1.2; Course IV, section 4.5.3.1.1

\textsuperscript{2} Section 2.2.2.2.3

\textsuperscript{3} Section 2.2.2.2.4, Course IV, section 4.5.3.2.3, Course I, section 4.2.3.2.1
courses are in close agreement with their perceptions of the aims of an ideal course\textsuperscript{1}.

The fact that students have to plan and organise their own work in an open laboratory course means that they have to think about the experiments and understand what they are doing. This can mean that they have to become more positive about relating the practical work to theoretical material\textsuperscript{2}, e.g. by studying the relevant literature\textsuperscript{3}. Nevertheless, students feel that it is important for the practical work to be related to the lecture courses\textsuperscript{4}.

One negative side effect of greater involvement is that students may concentrate on their practical work to the detriment of other work\textsuperscript{5}.

6.2.3.2 Coping with the open nature of courses

Although students enjoy the extra freedom that an open course involves\textsuperscript{6}, this does present problems. Some students find the initial format confusing. Students therefore seek guidance from staff and demonstrators, making high demands on their time. Alternatively, they may seek help from other students: In course I students usually discussed the

\begin{enumerate}
\item Section 6.2.1
\item Section 2.2.2.2.4, Course IV, section 4.5.3.2.3, Course I, section 4.2.3.2.1
\item Course I, section 4.2.3.1.2
\item Course I, section 4.2.3.2.1, Course IV, section 4.5.2.2 (aim 2)
\item Section 2.2.2.2.4
\item Course IV, section 4.5.3.2.3
\end{enumerate}
alternative experimental methods that could be used with other students and often ended up by using a method that had already been used by other students\(^1\). In course IV the experimental planning was usually done by a process of continual discussion within the student groups\(^2\).

Students can also have difficulties in pacing themselves but this problem only appeared in course IV which consisted mainly of one long experiment\(^3\). When the experiments are shorter, as in course I, it is easier for students to see how they are progressing through the course.

6.2.3.3 Students in groups\(^4\)

The use of groups in an open laboratory course can help students to cope with some of the problems and uncertainties associated with open practical work and can help to relieve some of the pressures on staff and demonstrators. Organising students into groups legitimises and encourages student discussion which takes place anyway in open courses, even when students are working individually.

Students usually work in groups in the following way: The group meets at the beginning of the experiment, under the supervision of a member of staff and it is decided what each student should do. At the end of the experiment the group meets again in order to

\(^1\) Course I, section 4.2.3.2.3  
\(^2\) Course IV, section 4.5.3.1.3.1  
\(^3\) Course IV, section 4.5.3.2.3  
\(^4\) Section 2.2.3.2; Course IV, section 4.5.3.2.5
discuss the results and conclusions of the experiments, after which the students write an account of their own work and that of the group. Course IV was unusual in that no formal meeting took place at the end of the experiment to discuss and collate results. Students therefore had considerable difficulty in collating all the data.

The main advantage of using groups in an open course is that it promotes communication, discussion and consequent understanding. Students discuss how to do the experiment, reach joint decisions and share successes and failures of the experiments. Students are always able to consult one another if they need help.

In course IV and in Biersmith's course (11), it is reported that some students had difficulties in working together in a group, although in course IV the efficiency of the groups increased as the course proceeded and the students needed less help from staff and demonstrators after the beginning of the course.

6.2.4 Demands on staff and demonstrators

The teacher's role in an open course is different from his role in a traditional laboratory. He has to be available to discuss students' plans with them and has to adopt a more consultative role which involves more, both in terms of time and teaching skills¹. The extra demands made on staff in an open course, mean that in order for it to be successful, the staff must be prepared to become more involved in the course. For example, in course IV the staff were very enthusiastic and managed to create an informal atmosphere

¹ Section 2.2.2.2.3 and Course IV, section 4.5.3.1.3.2
in which students could freely discuss problems in the course.  

The extra demands made on post-graduate demonstrators by open courses in terms of their pedagogical expertise can lead to problems in open courses. P.G. demonstrators need to be both well acquainted with the content of the experiments and be able to help the students in the planning of their experiments.

Richards (138) points out that the character and effectiveness of an open course depends on the style and quality of supervision. Staff are gradually able to acquire the necessary pedagogical skills over several years, but P.G. demonstrators are not. If P.G. demonstrators are to be used in this type of course, it is therefore essential to give them some kind of training.

A further problem with staffing is that as well as requiring better quality supervision, open courses appear to require lower student: staff and demonstrator ratios.

The need for training of P.G. demonstrators and for low student: staff + demonstrator ratios is illustrated in courses IV and I. In course IV there was a low student: staff and demonstrator ratio of 6:1 (c.f. the mean of 8.8:1 for open courses; section 3.3.3.2.1) and the two staff and one of the P.G. demonstrators were well acquainted with the course and the teaching methods to be used.

1 Course IV, section 4.5.3.2.6  
2 Course I, section 4.2.3.2.2; Course IV, section 4.5.3.2.6; section 2.2.2.2.3  
3 Section 3.3.3.2.1  
4 Course IV, sections 4.5.3.1 (introduction) and 4.5.3.1.3.2
Consequently, the course was very successful. In course I, however, when the course was originally evaluated in 1973/74 the student:: staff + demonstrator ratio was 10:1 and staff and demonstrators had insufficient time to cope with all the students' problems. Two years later the student : staff + demonstrator ratio had dropped to 6:1 and the course was staffed by the same staff and more experienced demonstrators. As a result the problems of insufficient staff and demonstrator time had disappeared.

It was pointed out in section 6.1.1.2 that staff would like to try to achieve aims in areas C and D which cannot be achieved by open courses. It appears that staffing is a major constraint limiting the use of open courses for achieving these aims. This emphasises the need to train P.G. demonstrators and therefore make best use of the resources available.

An alternative way of mitigating the problem with staffing is to relieve the staff and demonstrators of some of their more routine teaching duties in the laboratory to leave them with more time to concentrate on guiding students through the open experiments.

6.2.5 Teaching practical skills and techniques in open laboratory courses

The nature of open laboratory work means that students will be doing different experiments at different times from one another. In such a situation it becomes difficult to teach practical skills and techniques to the class as a whole and consequently less use is made of demonstrations (section 3.3.3.3). The difficulties of using demonstrations when the students are not going to be using the skills
and techniques until several days later, is illustrated in course VI\textsuperscript{1}, where students said that they had difficulties remembering details of the demonstrations. Similar difficulties can be envisaged for lectures or tutorials which run concurrently with the laboratory course.

This problem can be overcome in two ways:

(a) The course can be structured so that the class learns all the necessary skills and techniques before it starts the open part of the course.

One way of doing this is to allow students to do open experiments only after they have learnt the skills and techniques in the first one or two years of their degree course. Alternatively, a laboratory course can be structured so that students learn the necessary skills in the first part of the course which is traditional before starting the later, open part of the course\textsuperscript{2}. Such a course structure means that the openness of the course is constrained by the range of skills which the students have learnt in the earlier part of the course. Unit laboratories can be used in a similar way.

(b) A second way of teaching practical skills and techniques in an open course is by individualised learning techniques.

Two individual learning techniques currently used in undergraduate chemistry laboratories are videotapes and tape-slides\textsuperscript{3}. Videotapes\textsuperscript{4}

\begin{enumerate}
\item Course VI, section 4.7.4.5.3
\item Section 2.2.2.2.3
\item Section 3.3.3.3
\item Reference (172); Chapter 5
\end{enumerate}
have been found to be an effective medium for teaching practical skills and techniques and they incorporate the necessary features for use in an open course: They save staff and demonstrator time and enable students to learn practical skills when they need them. The integration of learning skills with the rest of the open laboratory course means that some of the applications of the skills become immediately apparent to the students.

6.2.6 Assessment

The fact that open courses are used to try to achieve a wider variety of aims than traditional courses makes assessing outcomes more difficult. With a wider variety of outcomes it is more difficult to reach a consensus view of the weightings that should be given to the different outcomes. In addition to this many open courses are innovatory and therefore the aims of the courses may still be in a state of flux, as the course organisers explore the advantages and problems of a new style of laboratory course.

In both courses I and IV students were assessed on the basis of their write-ups. Students were, however, unsure what to write\(^1\). In course I both staff and students agreed that the length of the write-ups was too long: Students tended to include everything that they felt might be expected.

Two methods were used in order to remove some of the uncertainty associated with the write-up. In course I\(^2\) assessment schedules

1  Course IV, section 4.5.3.2.2; Course I, section 4.2.3.2.3
2  Course I, section 4.2.3.2.3
were designed so that the marking was made more standard and in course IV\(^1\) an example write-up was given to students to study.

A further problem in assessing a wider variety of aims is that alternative methods of assessment have to be used. Aims in area A are concerned with understanding and illustrating theoretical material and aims in area B with acquiring basic skills needed for experimentation. Both the level of understanding and the level of competence reached in basic skills can be assessed indirectly by the write-up. When aims in areas C and D are to be assessed this becomes more difficult because aims in these areas are concerned more with the process of experimentation rather than the products.

Alternative methods of assessing open courses in the literature\(^2\) are observation of students at work in the laboratory and discussion of experiments with students in oral sessions.

A final problem associated with the greater diversity encountered in open courses, is that it is more difficult for P.G. demonstrators to assess the students. In course I staff, students and a P.G. demonstrator thought that the P.G. demonstrators did not know enough about the practical work to be marking the experiments\(^3\). The system used in course VI, unit 10/11 of allocating one experiment to each P.G. demonstrator to prepare detailed notes on the experiment might help to overcome this problem, but the basic problem is one of

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1. Course IV, section 4.5.3.1.5  
2. Section 2.2.2.2.3  
3. Course I, section 4.2.3.2.2
6.3 A comparison of traditional and open courses

It is apparent from the previous two sections that both traditional and open courses can be different in character depending on how they are organised. There are, however, some clear differences between traditional courses as a whole and open courses as a whole. These differences are summarised below:

(i) The aims of traditional courses are usually limited to areas A and B and parts of C. The aims of open courses are usually wider including areas A, B, C and D. Staff and students appear to be more satisfied with the wider range of aims offered in open courses.

(ii) Students have more opportunities to think for themselves in open courses. This means that there are more uncertainties and possibilities of making mistakes, but it also means that there is a greater sense of achievement when students are successful. Students are not able to treat an open course as a mechanical exercise which can be carried out without thinking.

(iii) Staffing problems are accentuated in open courses. More staff and demonstrators are needed and the levels of expertise required, both in the subject matter and in teaching ability, is greater than in traditional courses.

(iv) Teaching skills is easier for traditional than for open courses. In traditional courses students can be taught skills as isolated or
loosely linked exercises either as a class or in a 'circus' arrangement. In open courses students must either be taught the skills prior to the open part of the course or individualised learning techniques must be used.

(v) Assessment is more difficult in open courses because of the wider range of abilities being assessed.

6.4. Alternative laboratory styles

This section discusses the relationship between different laboratory styles and the aims which they can be used to achieve.

6.4.1 Different styles of laboratory courses

The table below indicates the main areas of emphasis of the different laboratory styles discussed in this thesis.

**TABLE 6.3.**

<table>
<thead>
<tr>
<th>Aims</th>
<th>Lab. courses</th>
<th>A</th>
<th>B</th>
<th>C1</th>
<th>C2</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Traditional</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Open</td>
<td>✔</td>
<td>?</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Project</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) Unit</td>
<td>Any selection of aims</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Audiotutorial</td>
<td>✔</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6) Keller</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) Self-service</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Key: The areas of aims A, B, C, D and E have been described in section 1.2.1. Aims in area C have been subdivided into:

C1: Aims emphasising the planning of experiments, i.e. aims 10, 11, 12, 13, 14, 15.

C2: Aims concerned with data collection and the interpretation and communication of the data, i.e. aims 16, 17, 18, 19, 20, 21, 22, 23, 30.

✓ indicates the main area of emphasis.

? indicates that some emphasis may be placed on this area.

(i) Courses for aims in areas A and B.

Too little information is available about courses (5), (6) and (7) to be able to give more than a superficial comparison with traditional courses (see section 2.2.4). Courses (6) and (7) are similar in essence to traditional laboratory courses in that they depend on step-by-step instructions and could therefore be easily introduced to replace all or part of a traditional course. The Keller plan overcomes some of the problems outlined for traditional courses because the objectives for each unit are clearly stated and a certain amount of teacher-student interaction is built into the course in the form of test-tutorials at the end of each unit. Self-service experiments have similar advantages in that the objectives are stated and students get immediate feedback about their progress.

The audio-tutorial approach offers a way of integrating theoretical and practical work by using individual learning techniques and, therefore, emphasises aims in area A. The audio-tutorial approach has not been reported in chemistry laboratory courses, although a laboratory course which integrates theoretical and practical work by using a wider range of teaching and learning methods as described in section 3.3.3.2.2.
(ii) Courses for aims in areas A, B, C and D.
Both open courses and projects can be used to achieve aims in these areas, but constraints of staffing usually preclude the use of this type of course when the aims are mainly limited to areas A and B.

(iii) Courses for a selection of aims.
Many of the courses described in the survey in Chapter 3 comprised mainly traditional experiments, but included some open experiments. This type of course has the advantage that it offers students some open experiments but makes more limited demands on the resources of the department than open courses. It also enables staff to gradually acquire the necessary teaching experience for an open course.

The unit system offers more flexibility. Different units could include any of the laboratory styles described earlier and could therefore be used to achieve a wide variety of aims by offering students variety both in content and in teaching and learning styles.

6.5 A summary of methods available for improving the effectiveness of laboratory courses

Within the different laboratory styles outlined in section 6.4, a variety of different methods of organisation and different instructional materials has been encountered during this research study.

This section describes how some of these different approaches may be applied to solving the problems outlined above.
The problem of improving laboratory instruction may be tackled in two ways:

(i) Improving the quality of teaching in the laboratory courses.
(ii) Reorganising the laboratory courses so as to offer alternative ways of teaching and learning.

6.5.1 Improving the quality of teaching

A central problem in both traditional and open courses is that P.G. demonstrators do not have adequate knowledge about the courses and do not have the appropriate teaching skills. They are therefore unable to give the students the help they need. This points to the need for some kind of training for P.G. demonstrators.

Very little work has been reported in the literature about the training of P.G. demonstrators for their role in the laboratory. In 1972 Brooks et al (23) described a short course for laboratory demonstrators and more recently Davies (37A) has described the use of notes to help P.G. demonstrators in the laboratory.

The two approaches to the training of P.G. demonstrators concentrate on different aspects of their teaching role. A course such as that of Brook et al concentrates on improving teaching skills and could therefore be organised interdepartmentally, whereas Davies' approach is more concerned with the more practical details of how to achieve the aims of a particular laboratory course and must therefore be organised departmentally.
The course of Brooks et al contains methods commonly used in teacher training, such as microteaching, videotapes of laboratory situations followed by interaction analysis and practical comments on how to deal with students in a laboratory situation.

Davies' notes concentrate on the day-to-day teaching in the laboratory. They include student handouts, aims of the laboratory and of individual experiments, practical details for carrying out the experiments, such as common pitfalls and necessary precautions, theoretical reminders and references, and organisational details, schedules and timetables. The notes are fairly short, about 1 page per day in the laboratory, so that they form a guide for demonstrators but do not tell them exactly what to do. It is emphasised that the notes alone are insufficient help for the P.G. demonstrators, but that they form a useful basis for day-to-day discussions between demonstrators and staff of the problems encountered in the laboratory.

The use of notes has the advantage over a course in that they concentrate on the immediate practical aspects of the teaching and learning situation and therefore have an immediate impact on student learning. A course, in concentrating on teaching skills, still leaves the demonstrator with the task of applying his teaching skills in a laboratory course whose aims and content may not be clear to him.

An alternative to notes, which is discussed by Davies, is to allow P.G. demonstrators to do some of the experiments in advance of the students, but he points out that this is time consuming and would not necessarily orientate the P.G. demonstrators to the main teaching points of the experiments.
6.5.2 Alternative methods of organisation and alternative resources

The most common form of instruction in the laboratory, apart from instruction sheets, is individual contact between staff or demonstrators and students. The efficiency of many laboratories could be increased by increasing the amount of formal staff/demonstrator to student contact and teaching students in groups instead of repeating the teaching over and over again with individuals. Ways of doing this, reported earlier, are short talks or discussions before each experiment and demonstrations or workshops as in course VI.

Establishing more formal instruction implies a greater degree of organisation in the laboratory, but does ensure that all the students benefit from the teaching of staff and demonstrators.

The use of such formal instruction is, however, limited to those courses where students do the experiments in the same order. If the students do the experiments in a different order from one another some form of individualised instruction is needed, such as videotapes, tape-slides or computers.

Audio-visual materials are unresponsive and therefore can only be used to replace instructional rather than tutorial aspects of the staff and demonstrator's role, such as introducing an experiment or teaching basic practical skills and techniques. This research has shown that they have the advantages that they save staff and demonstrator time, their quality is easily controlled, and they can be viewed when and as many times as needed. The main constraint
to their use in the laboratory is the time and cost of incorporating them into a laboratory course. This research has shown that videotapes prepared in one institution can be used in another, and so it may often be possible to use videotapes prepared in other institutions and so save the time involved in making them.

Computer programmes have been written that are responsive to students' needs and can, therefore, replace some of the tutorial aspects of the staff and demonstrators' role. They may be used to guide students in planning and evaluating experiments, in problem solving and in helping students to revise and understand the theory of the experiments. The use of computers in the laboratory has been found to encourage discussion, thought and consequent learning and has enabled some aims in area C related to planning experiments and interpreting experimental data to be achieved within the context of traditional courses.

One resource which is often neglected in the laboratory is the students themselves. Students usually only work in pairs when there is insufficient apparatus for students to work individually and groups are rarely used. This research has shown, however, that students can learn a lot from one another when they work in pairs or groups.

Students found working in pairs particularly helpful in understanding the practical work and for working out and interpreting results. Working in pairs is therefore advantageous in courses emphasising aims in area A, but where more importance is attached to developing psychomotor skills (area B) working in pairs is less advantageous.
Many of the aims in area C (i.e. those emphasising the planning of experiments) involve students in problem solving and decision making. In order to be able to cope with this open situation students need to be able to discuss the problems with other people. When pairs or groups are used, students are able to discuss problems with other students and therefore rely less on staff and demonstrators.

In both traditional and open courses the use of pairs or groups can promote the achievement of aims in area E, if this is desired.

Using students' to help one another appears to have the advantage that no extra cost is involved. It is, however, often difficult to predict the effects of changing one factor in the educational environment and using pairs or groups may lead to unexpected results in other areas. It is possible that the introduction of pairs or groups may make more demands on the teaching skills of staff and demonstrators. This did not appear to be the case in the courses studied in which pairs were used, but when groups were used in course IV the need to train staff and demonstrators, in some aspects of using small groups in the laboratory, became clear. Another possible effect of the use of pairs or groups is that experiments may have to be redesigned to make them suitable for pairs or groups.

A final area for improvement is in the organisation of experiments in traditional courses so that the students' time in the laboratory is spent more effectively.

This research has shown that attention to detail in the organisation
of experiments is important. Seemingly insignificant problems in
the running and organisation of experiments can have a significant
effect on the achievement of educational aims, especially when
linked with other seemingly insignificant problems. This is
exemplified by the tendency of students to work mechanically,
without thinking, in traditional courses. Many factors contribute
towards this tendency (section 6.1.4.1.2) and below is a list of
points which can help to prevent this tendency:

(i) Giving out instruction sheets before the day of the practical
so that students can study the experiment before coming into the
laboratory.

(ii) Stating the aims of the course and individual experiments.

(iii) Relating the experiments to other parts of the course
where ever possible and pointing out these relationships to the
students.

(iv) Making sure that the level of the experiments is such that
students are able to understand them and have covered the theoretical
work necessary for the experiment.

(v) Ensuring that the course is not overloaded so that the students
have sufficient time to stop and think about the experiments which
they are doing.

(vi) Eliminating experimental difficulties and problems unless
credit is given for solving these problems.
(vii) Supplying feedback to students about how well they have done the experiments and how they could improve their work.

(viii) Adopting simple formative evaluation procedures, such as the use of feedback sheets or short end course questionnaires, in order to detect problems of the organisation of experiments.

Most of the points above would involve the staff in adopting a more systematic approach to their teaching and would involve little reorganisation of resources.

The first point, however, precludes the possibility of making students write-up experiments before giving them the instruction sheets for the next experiment and could therefore lead to problems in persuading the students to write-up experiments immediately.

Point (vii) would involve staff and demonstrators in spending more time talking to students about how they had done the experiments. Since this does not normally occur where such discussions are informal, it appears necessary to set up some sort of formal discussions between staff/demonstrators and students, such as vivas as in course VI, which makes the discussions compulsory by including them in the assessment of the experiments.

6.6 Areas for future research

In this section possibilities for future research arising out of the findings of this research study are discussed.
This research started as an attempt to relate different groups of aims to different laboratory styles, but due to constraints of time, had to concentrate on only three laboratory styles; traditional laboratories, open laboratories and unit laboratories. A number of laboratory styles are as yet unexplored in any depth and future research could concentrate on evaluating their advantages and disadvantages.

A number of parameters within the different laboratory styles have been investigated, such as the use of pairs and the use of videotapes, but further research needs to be done in some areas. The study of students working in groups in course IV suggests a great deal of potential in this mode of working and further work needs to be done in this area in order to make this a more effective method of learning. Aspects of small group learning which remain unexplored by this study are the type of experiments that can be used with small groups, how the groups are best organised internally and the training of staff and demonstrators in small group teaching.

Another parameter that has not been investigated is the integration of theory and practical courses. Only a few courses appear to have achieved complete integration, either by radically retimetabling the courses or by using a very wide variety of teaching and learning methods. An evaluation of such courses would provide insight as to the problems and advantages of setting up such courses and whether more integration could be achieved in more conventional courses.

Many of the problems which are outlined in the course evaluations in Chapter 4 are simple organisational problems and once the course organisers were made aware of them were easy to eradicate.

Future work could investigate possible ways of providing feedback about
courses to course organisers. Knipe (87) has reported the use of feedback sheets in his laboratory courses. Bridge (20A), however, has described the use of a variety of evaluative techniques by teachers and such methods of self-evaluation may be applicable by laboratory course organisers.

A final and very important area for future research is the development of P.G. demonstrator training. The inadequacy of P.G. demonstrators to fulfil their role in the laboratory is a recurring theme throughout this research. This research has concentrated on student learning. Future work could concentrate on the needs of P.G. demonstrators in the laboratory and the effects of P.G. demonstrator training on student learning in the laboratory. Two possible areas for future development have been outlined in section 6.5.1. They are courses for developing teaching skills and the use of notes for in-service training.

In conclusion, it should be said that improvement of education in the laboratory depends on the status accorded to laboratory teaching by members of staff. As long as laboratory teaching continues to be the cinderella in the academic family (79), being accorded less status than research and lectures, improvement in the standard of education in the laboratory will be slow. Improvement depends on the systematic analysis of the laboratory situation and the systematic trial of the methods that are available for use in the laboratory and as such depends on the involvement and commitment of members of staff.
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APPENDIX TO CHAPTER 3

(1) Letters sent to course organisers.

(2) Questionnaire sent to course organisers.

(3) Lists of aims in the literature:
    (a) Chambers
    (b) Tremlett
    (c) Lee
    (d) Ring
Dear

The Improvement of Learning in Chemistry Laboratories

The Institute for Educational Technology and the Chemistry Department at the University of Surrey are undertaking a study into the effectiveness of laboratory work in the education of chemists. As part of this work, it is hoped to ascertain details of any recent changes in the pattern of laboratory work in degree courses in chemistry.

We would, therefore, be very grateful if you could find time to outline any changes or developments in the approach to laboratory work which have taken place in your department in the last few years.

We would also like to send a questionnaire about the aims of laboratory courses in chemistry to the members of staff who organise laboratory courses, and would be grateful if you could let us know whether your staff would be willing to complete such a questionnaire, which would take about 20 to 30 minutes to deal with. If you feel they would be, could you please send us a list of the members of staff to whom we should post a questionnaire?

Perhaps you will be kind enough to reply to J.R. Watson?

Yours sincerely,

Dr. R.A. SCHULZ
Chemistry Department.

Professor L.R.B. ELTON.

J.R. WATSON.

Institute for Educational Technology
Institute for Educational Technology

24th March 1975

Dear

In the past few years a large amount of information regarding what goes on in undergraduate physics and engineering laboratories has been collected through surveys, e.g. Chambers\(^1\) and Lee\(^2\). With the exception of some interview work carried out by Tremlett\(^3\), there appears to be no similar information at present in chemistry and this work is designed to fill this gap.

The Institute for Educational Technology and the Chemistry Department at the University of Surrey are undertaking a study into the effectiveness of laboratory work in the education of chemists. In particular we are studying recent changes or developments in chemistry laboratory teaching and learning, and the relationships between different groups of aims and the types of courses being used to achieve them.

We have recently sent a letter to the head of your department to enquire about any changes or developments which have taken place in your department in the last few years. We also asked him if he could let us know which members of the chemistry staff, who organise laboratory courses, might be willing to answer a questionnaire on laboratory work. In his reply he gave us your name.

We would be grateful if you could find time to complete the enclosed questionnaire with respect to the laboratory course which you organise. The Questionnaire should take about 20 to 30 minutes to complete.

Perhaps you will be kind enough to reply to J.R. Watson.

Yours sincerely,

Dr. R.A. Schulz
Department of Chemistry

Prof. L.R.B. Elton & J.R. Watson
Institute for Educational Technology

References:
Institute for Educational Technology

24th March 1975

Dear

In the past few years a large amount of information regarding what goes on in undergraduate physics and engineering laboratories has been collected through surveys, e.g. Chambers¹ and Lee². With the exception of some interview work carried out by Tremlett³ there appears to be no similar information at present in chemistry and this work is designed to fill this gap.

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We have recently sent a letter to the head of your departments to enquire about any changes or developments which have taken place in your department in the last few years. We also asked him if he could let us know which members of the chemistry staff, who organise laboratory courses, might be willing to answer a questionnaire on laboratory work. In his reply he gave us your name.

We would be grateful if you could find time

(1) to outline any changes or developments which have taken place in the laboratory course which you organise, in the last few years.

and

(2) to complete the enclosed questionnaire with respect to the laboratory laboratory course which you organise. The questionnaire should take about 20 - 30 minutes to complete.

Perhaps you will be kind enough to reply to J.R. Watson.

Yours sincerely,

Dr. R.A. Schulz
Chemistry Department

Prof. L.R.B. Elton
Institute for Educational Technology

References:
2 L.S. Lee 'Towards a Classification of the Objectives of Undergraduate Work in Mechanical Engineering', Thesis for Masters Degree, University of Lancaster, 1969.

Head of Institute and Professor of Science Education: L. R. B. Elton, D.Sc., F.Inst.P., F.I.M.A., F.R.S.A.
Dear

Last term we sent you a copy of the enclosed letter, and so far we have not had a reply.

We would be grateful if you could find time to reply to it, but if you feel that you do not have time to reply, could you please pass it one to a member of your staff who you feel would be interested in this survey?

We would like to encourage you to participate in the survey because it covers such a large variety of courses, both in content and in teaching and learning styles, that each questionnaire is important if a representative picture of what goes on in chemistry laboratories is to be built up.

Yours sincerely,

Dr. R.A. SCHULZ  
Prof. L.R.B. ELTON  
J.R. WATSON

Department of Chemistry  
Institute for Educational Technology

enc
We would be grateful for your help in completing this questionnaire with respect to the chemistry laboratory course which you organise.

We assure you that any information which you give us by answering this questionnaire will be treated confidentially and will not be used in any way that would identify you or your institution, without your permission.

NAME :
NAME OF INSTITUTION :

SECTION A  Details of Laboratory Course

Could you please answer the questions by ticking or circling the responses as appropriate:

Note on Project Work - If you are concerned with the organisation of project work rather than laboratory courses, please answer questions 1, 2, 3, 4, 5, 14 and 15 only in this section of the questionnaire.

1. Is the course taken by
   (a) Chemists [ ]
   (b) Others (please specify) [ ]

2. What is the subject of the practical course?
   (a) Inorganic [ ]
   (b) Organic [ ]
   (c) Physical [ ]
   (d) Other (please specify) [ ]

3. In which year is the course taken?  1  2  3  4
4. How many weeks does the course last?

5. How many hours do the students attend this laboratory course per week?

6. How many experiments are the students expected to complete during the course?

7. Approximately how many students attend each laboratory class of the course?

8. How many post-graduate demonstrators attend each laboratory class of the course at any one time?

9. How many staff attend each laboratory class of the course at any one time?

10. Does each student do each experiment at approximately the same time as other students, or do different students do different experiments at the same time? (tick appropriate box)

(a) Students do the same experiments at approximately the same time □

(b) Different students do different experiments at the same time □

(c) Students do a mixture of (a) and (b) □

11. Below is a list of different ways of learning that are auxiliary to the actual practical work. Please rate each way of learning on the scale according to its importance in the course:

1 = Not important  5 = Very important

<table>
<thead>
<tr>
<th>(a) Practical demonstrations to all, or a large part of the class, by staff or postgraduate demonstrators.</th>
<th>Not Important</th>
<th>Very Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b) Instruction sheets.</td>
<td>1 2 3 4 5</td>
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<tr>
<td>(c) Individual instruction by postgraduate demonstrators, given to the students when required.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(d) Individual instruction by the staff, given to the student when required.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(e) Help given by one student to another.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(f) Text books or periodicals.</td>
<td>1 2 3 4 5</td>
<td></td>
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<tr>
<td>(g) Video-tapes.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(h) Tape-slides.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(i) Other (Please specify)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(j) Other (Please specify)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>
12. Approximately what percentage of the postgraduate demonstrators' time in the laboratory is spent marking practical books?

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<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100 %</td>
</tr>
</tbody>
</table>

13. Approximately what percentage of the staff time in the laboratory is spent marking practical books?

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<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100 %</td>
</tr>
</tbody>
</table>

14. Please tick those of the following descriptions that are appropriate to your laboratory course. You may find that more than one description applies to your course.

(a) Traditional course

A traditional course is one in which the students are expected to carry out the experiments in a predetermined way. The experiments contain step-by-step instructions on how to perform the experiment.

(b) A course of 'open' or problem-solving experiments

In open experiments a problem is posed and the student is required to develop an appropriate experiment to solve the problem. For the experiment to be open, there must be more than one possible way of solving the problem, although not necessarily more than one solution. Obviously the degree of 'openness' can vary considerably.

(c) Projects

A project is an investigation by a student of a problem. The student may have taken part in the formulation of the problem. He chooses the experimental methods to be used and may reach one of a number of conclusions. A project is usually supervised personally by one member of staff and with its greater student involvement normally lasts several weeks or longer.

(d) A course where students work in pairs

(i) Students perform similar experiments and pool their results.

(ii) Students perform the same experiment as a pair.

(e) A course involving group work (i.e. 3 or more students per group)

Students perform similar experiments and pool their results.
(f) An integrated laboratory and lecture course
   The laboratory and lecture course are planned as a unit in which the lecture and laboratory classes are used as seems appropriate. (This does not refer to experiments which are designed after the lecture course to illustrate specific points in the lecture course.)

(g) Other
   Please give a brief description:

(h) If you have ticked more than one of the above, could you briefly comment on the balance between them:

15. Please add any other comments that you feel are necessary to describe your laboratory course.
## AIMS OF LABORATORY COURSE

The following is a list of possible aims for a chemistry laboratory course. Please rate each aim on each of the two scales. On the first scale please rate the aim depending on how important you think it actually is in this course (i.e. give your idea of the aims of the present course). On the second scale please rate the aim on the scale depending on how important you think it should be in this course (i.e. give your idea of the aims of an ideal course).

Use the scale from 1 (not an aim) to 5 (a very important aim).

<table>
<thead>
<tr>
<th>Present Course</th>
<th>Your Ideal Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

1. To teach material not included in lectures and tutorials
2. To illustrate material taught in lectures and tutorials
3. To demonstrate that chemistry is an empirical science
4. To demonstrate that chemistry is a useful science
5. To study a small area of chemistry in depth
6. To teach basic practical skills (e.g. manipulative and preparative skills and techniques)
7. To familiarise students with some important instruments and devices
8. To train students in observation
9. To make students aware of specific hazards in experimental chemistry and to teach them to take the necessary safety precautions
10. To simulate conditions in research and development laboratories
11. To develop students' skill in problem-solving by experimental work
12. To train students in experimental design
13. To develop students' ability to recognise problems which can be solved through experimental chemistry
14. To develop students' ability in making hypotheses
15. To develop students' ability in selecting techniques, procedures or apparatus appropriate for a particular experiment
1 = not an aim
5 = a very important aim

<table>
<thead>
<tr>
<th>Present Course</th>
<th>Your Ideal Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. To develop students' ability to make a critical assessment of the methods used to obtain experimental data</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>17. To teach a logical and methodical way of working in a chemistry laboratory</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>18. To train students in keeping a day-to-day laboratory notebook</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>19. To develop students' ability to make deductions from experimental data and to interpret experimental data</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>20. To develop students' ability in accepting or rejecting a hypothesis</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>21. To develop students' ability in estimating the size and significance of errors</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>22. To train students in writing reports on experiments</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>23. To develop students' ability to communicate results orally (e.g. in seminars and discussions)</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>24. To provide the students with a stimulus for independent thinking</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>25. To encourage initiative and resourcefulness in the students</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>26. To stimulate and maintain students' interest in chemistry</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>27. To encourage perseverance in experimental chemistry</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>28. To develop honesty and scientific integrity</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>29. To develop open-mindedness and flexibility of attitude (e.g. willingness to consider new facts)</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>30. To train students in extracting information from the literature (including training in the use of the library)</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>31. To provide closer contacts between students and academic staff</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>32. To provide closer contacts between students within the course</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>33. To develop students' skill in working and co-operating with others in a team</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>
SECTION C

RECENT CHANGES OR DEVELOPMENTS IN YOUR COURSE

Could you please outline any changes or developments which have taken place in the laboratory course which you organise, in the last few years?
1. To foster 'critical awareness' (e.g. the extraction of all information from the data; avoidance of systematic errors).

2. To stimulate and maintain the students' interest in physics.

3. To familiarise the students with important instruments, devices and techniques (e.g. C.R.O., transistors, vacuum techniques).

4. To train them in handling data.

5. To train them in writing reports on experiments.

6. To train them in keeping a day-to-day lab notebook.

7. To enable staff and students to meet and talk informally.

8. To illustrate and drive home material taught in lectures.

9. To train in simple aspects of experimental design.

10. To teach some 'theoretical' material not included in the lectures.

11. To impart manipulative skills (e.g. soldering, glasswork).
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.

5. Record accurately and communicate results clearly.

6. Plan effective use of available laboratory resources.

7. Acquire experiential understanding.

8. Learn the use of chemical literature.

9. Show that experiment is the basis of theory.

10. Illustrate the use of experimentation as a process of discovery.

11. Develop observational skills.

12. Develop personal responsibility and reliability for experimentation.

13. Learn from making mistakes without penalty.

14. Give stimulation and a sense of achievement.

15. Give experience of working in a laboratory.

16. Measure typical physiochemical constants.
1. To stimulate and maintain the students' interest in Engineering.

2. To illustrate, supplement and emphasise material taught in lectures.

3. To train the student to keep a continuous record of laboratory work (notebook).

4. To train the student in the formal reporting of experimental procedures adopted in laboratory practicals and the writing of technical reports.

5. To give the student training in the interpretation of experimental data.

6. To train the student to use particular apparatus, test procedures or standard techniques.

7. To provide more intimate contact between students and academic staff.

8. To stimulate the students' interest in "design".

9. To develop the students' skill in problem solving (in the multi-solution situation).

10. To simulate the conditions obtained in Research and Development Laboratories.

11. To provide the students with a valuable stimulant to independent thinking.

12. To show the use of "practicals" as a process of discovery.

13. To demonstrate the use of experimental work as an alternative to the analytical method of solving engineering problems.
14. To simulate under controlled and measured conditions certain field conditions such that important variables can be measured and deductions made from the measurements and applied to the field conditions.

15. 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.

16. To 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 which engineers encounter.
RINGS LIST OF AIMS (REF. 139)

1. To instill confidence in physics.

2. To teach basic practical skills.

3. To familiarise students with important standard apparatus and measurement techniques.

4. To illustrate material taught in lectures.

5. To teach the principles and attitudes of doing experimental physics.

6. To train students in observation.

7. To train in making deductions from measurements and interpretation of experimental data.

8. To use experimental data to solve specific problems.

9. To train students in writing reports on experiments.

10. To train students in keeping a day-to-day laboratory notebook.

11. To train students in simple aspects of experimental design.

12. To provide closer contacts between students and academic staff.

13. To stimulate and maintain students' interest in the subject.

14. To teach some 'theoretical' material not included in lectures.

15. To foster 'critical awareness' (e.g. extraction of all information from the data; the avoidance of systematic errors).
16. To develop skill in problem solving in the multi-solution situation.

17. To simulate the conditions in research and development laboratories.

18. To provide a stimulant to independent thinking.

19. To provide an opportunity to experience the process of discovery.

20. To familiarise students with the need to communicate technical concepts and solutions.

21. To provide motivation to acquire specific knowledge.

22. To help bridge the gap between theory and practice.

23. To expose students to the phenomena of physics.
APPENDIX A 4.2 Example of feedback sheet

UNIVERSITY OF SURREY

DEPARTMENT OF CHEMISTRY

Evaluation of 2nd Year Inorganic Chemistry Laboratory Course

Feedback sheet

Assignment 1

Please rate the first three items on this questionnaire on the five point scales.

1. The difficulty of this assignment:
   Too easy Too difficult
   1 2 3 4 5

2. Your interest in this assignment
   Boring Stimulating
   1 2 3 4 5

3. The relevance of this assignment to the chemistry lecture courses.
   Unrelated Closely related
   1 2 3 4 5

4. What knowledge or skills were you assumed to have before you started this assignment, that you did not have?

5. Please write down any particular difficulties which you had with this assignment.

6. Approximately how many hours did you spend in the laboratory doing this assignment?

7. Approximately how many hours did it take you to write up this assignment (including time spent looking up and reading references)?

Any other comments ......

Rod Watson
Please rate the first three items on this questionnaire on the five point scales.

1. The difficulty of this assignment

   Too easy                       Too difficult

   1  2  3  4  5

2. Your interest in this assignment

   Boring                       Stimulating

   1  2  3  4  5

3. The relevance of this assignment to the chemistry lecture courses.

   Unrelated                   Closely related

   1  2  3  4  5

4. What knowledge or skills were you assumed to have before you started this assignment, that you did not have?

5. Please write down any particular difficulties which you had with this assignment.

6. Approximately how many hours did you spend in the laboratory doing this assignment?

7. Approximately how many hours did it take you to write-up this assignment (including time spent looking up and reading references)?
8. Please circle the correct response

<table>
<thead>
<tr>
<th>Reference</th>
<th>Did you read it</th>
<th>How useful did you find the reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>NO</td>
<td>Of no use</td>
</tr>
<tr>
<td>F.H. Burstal et al J.Chem.Soc.1950, 516</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>T.V. Arden et al Nature 1948, 162, 691</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I.M. Hais and K. Macek 'Paper Chromatography' pp 733-739 and 755-756</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>D.A. Fine J. Amer.Chem.Soc. 1962, 84, 1139</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>D. Abbott and R.S.Andrews 'An Introduction to Chromatography'</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I. Smith 'Chromatographic and Electrophoretic Techniques' Vol. 1 p.800</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>R.J. Block et al 'A Manual of Paper Chromatography and Paper Electrophoresis'</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Y. Marcus and A.S. Kertes 'Ion Exchange and Solvent Extraction of Metal Complexes'</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

9. What other reference material did you use?

10. Any other comments .....
Example of an aims questionnaire

UNIVERSITY OF SURREY

DEPARTMENT OF CHEMISTRY

Evaluation of 2nd Year Inorganic Chemistry Laboratory Course

I should be grateful for your help in completing this questionnaire. The purpose of this questionnaire is to find out your opinions of the possible aims of the 2nd year inorganic chemistry laboratory course. It is part of a continuing research project to find the areas of the course which need altering and developing.

I would like to thank you for completing the questionnaire at the beginning of the course. This has already provided some interesting information which will be compared with the information obtained from this questionnaire.

Rod Watson
Institute for Educational Technology.
The following is a list of possible aims for a chemistry laboratory course. Please rate each aim on each of the two scales. On the first scale please rate the aim depending on how important you think it is in this course (i.e. give your idea of the aims of the present course). On the second scale please rate the aim on the scale depending on how important it should be in this course (i.e. give your idea of the aims of an ideal course).

Use the scale from 1 (not an aim) to 5 (a very important aim)

<table>
<thead>
<tr>
<th>no. on modified questions</th>
<th>Present Course</th>
<th>Your ideal Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1. To teach theoretical material not included in lectures and tutorials</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2</td>
<td>2. To illustrate material taught in lectures and tutorials</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>3</td>
<td>3. To help the students to bridge the gap between theory and practical</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>6</td>
<td>4. To teach basic practical skills (e.g. manipulative, preparative and instrumental skills)</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>7</td>
<td>5. To familiarise the student with important instruments, devices and techniques</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>8</td>
<td>6. To train students in observation.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>17</td>
<td>7. To teach a logical and methodical approach of doing experimental chemistry</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>16</td>
<td>8. To teach proper criteria of accuracy and significance (e.g. avoidance of systematic errors; making all the significant observations)</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>22</td>
<td>9. To train students in writing reports on experiments</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>19</td>
<td>10. To train students in making deductions from measurements and interpretation of experimental data</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Course</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
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<tr>
<td>--------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>11. To use experimental data to solve specific problems</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>18. To train students in keeping a day to day laboratory notebook.</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>23. To develop the ability to communicate results orally (e.g. in seminars and informal discussions)</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>12. To train in simple aspects of experimental design</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>26. To stimulate and maintain students' interest in chemistry</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>11. To develop students' skill in problem solving in a multi-solution situation</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>16. To foster 'critical awareness' (e.g. extraction of all information from the data; estimation of the size and significance of possible errors)</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>24. To provide the students with a stimulant to independent thinking</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>25. To encourage 'enterprise', 'initiative' and 'resourcefulness'</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>20. To develop personal responsibility and reliability for experimentation</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>10. To simulate the conditions in research and development</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>31. To provide closer contacts between students and academic staff</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>23. To show the use of 'practicals' as a process of discovery</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>3. To demonstrate the use of an experimental method as an alternative to the 'theoretical' method of solving problems</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>25. To familiarise the students with the need to communicate technical concepts and solutions</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>
26. To provide motivation for the student to acquire specific knowledge

27. To instill confidence in Chemistry

28. To train students in extracting information from the library and in particular from periodicals

Any other comments ......

Name (Optional)
I would like you to fill in yet another questionnaire. I am trying to find your opinions of this course, so that different assignments can be modified and developed. I would like to discuss your answers with you after you have completed the questionnaire.

I would like to assure you that any information which you give me either answering this questionnaire or in conversation, will not be passed on to the course organisers in any way that would identify you.

Rod Watson
Institute for Educational Technology
Please circle the appropriate answers for each question and add your comments where necessary.

1. How interesting did you find the course?
   boring  not particularly  satisfactory  quite  stimulating
            interesting  interesting

2. Which assignments did you find uninteresting?
   Why?

3. Which assignments did you find most interesting?
   Why?

4. Were there any times when you felt particularly fed-up with the course?
   yes  no
   If your answer is yes:
   a. During which week did you feel particularly fed-up with the course? (i.e. 1st week or second week, etc.)
   b. Which assignment were you doing?

5. How would you describe the difficulty of the course?
   too  slightly too  about  slightly  too
do difficult  difficult  right  too easy  easy

6. With which assignments did you have particular difficulties?

7. What were the particular difficulties?

8. Which parts of the course wasted your time? (due to bad design, waiting to use instruments, etc.)

9. Which parts of your written work for each assignment would you like to see reduced?

10. Were the demonstrators always helpful?
    very  helpful most  helpful some  seldom
         helpful  of the time  of the time  helpful

11. For which assignments do you feel you deserved a different grade from the one allocated to you when the assignment was marked?
12. How would you describe the importance of having lectures on the inorganic chemistry before the practical work is attempted?

| very important | quite important | important | not very important | unimportant |

13. How closely was the laboratory work related to the lecture course?

| very closely related | quite closely related | sometimes related | mainly unrelated | unrelated |

14. How many of the references for this course did you find you needed to look up?

all | most | some | a few | none |

15. How many pieces of reference material (e.g. books or articles in periodicals) did you use, that were not specified in the assignment sheets?

none | 1 or 2 | 3 or 4 | 5 or 6 | more than 6 |

16. What problems did you have in looking up reference material?

17. When choosing a particular method for doing an assignment, how important were the following factors in affecting your choice of a particular method?

a. Using the method someone has already used.

| very important | quite not usually not important | important | important | important |

b. Weighing up the different possibilities in your mind.

| very important | quite not usually not important | important | important | important |

c. Discussion with friends.

| very important | quite not usually not important | important | important | important |

d. Discussion with demonstrators.

| very important | quite not usually not important | important | important | important |

e. Other (Please specify)

18. To what extent did the course encourage you to use your initiative? (e.g. did you need to design your own apparatus or reaction conditions?)
19. One of the aims of the course was to provide situations that would enable you to cope with the kinds of work that you are likely to experience in your industrial year and in the final year project. Do you feel that at present the course has been successful in this? In what ways could it be improved?

20. Do you think that this questionnaire represents your views of the course fairly? Is there anything else that you would like to say?

Thank you.
Interview schedule for autumn 1973 (for students (I)).

(1) Level of interest

Was the course interesting or uninteresting? Why?

How does the course compare with other laboratory courses that you have done?

(2) Which assignments were most/least interesting? Why? How could they be improved?

(3) Did you get fed-up with the course? If so, why? Was it linked with (a) an assignment? (b) a particular time in the course? (c) the length spent doing an assignment? Would it help if the approximate length of each assignment was given?

Are there any ways of preventing you becoming fed-up with the course?

(4) Were any parts of the course too difficult/too easy? How should they be changed?

(5) What difficulties did you have with the experiments?

(6) What parts of the course wasted your time? How could this be remedied?

(7) Write-up

What is the purpose of the write-up?

What does it teach you? Can you suggest better ways of writing-up? Should the write-up be shortened?

(8) Did you find staff/demonstrators generally helpful/unhelpful? In what way were staff/demonstrators unhelpful? How could this be remedied?
(9) Assessment

Did you think that the grading of reports was fair?

If not, why do you think the grade was wrong?

What should staff/demonstrators be looking for when they grade your work?

(10) Relevance to lectures

How important do you think it is to have studied related inorganic chemistry before the practical work is attempted? Could you do the practicals without lectures? Can you suggest how this problem could be overcome? Would you like lectures beforehand? Are they essential beforehand?

(11) References

Were the references always helpful? Were they irrelevant? Which ones?

Did you look up other material? If yes, is this a good thing or should all references be included in the sheets? Why?/Why not?

(12) Does this practical course encourage discussion with other people? Did you discuss with other people? Did this encourage resourcefulness when thinking?

(13) Did the course make you use your initiative? enough/too much? How could this be altered? Do you prefer to be able to use your initiative or do you prefer to be told exactly what to do? Is this course more successful than other courses in this aim? Why?/Why not?

(14) Any other points .....
Course I (section 4.2)

Interview schedule for spring/summer 1974 (for students (II)).

(1) Did you have enough time to complete the practical work to your satisfaction?

Which parts of the course wasted your time? (e.g. poor organisation, waiting to use instruments)

(2) Were the staff/demonstrators helpful/unhelpful?

How often did staff/demonstrators not know answers to your questions?
How often were staff/demonstrators not available when required?

(3) Which parts of the write-up would you like to see reduced?

(4) Assessment

For which assessments do you feel you deserve a different grade from the one allocated to you? Why?

What percentage of the marks for the experiment were allocated for (a) results
(b) discussion in the write-up
(c) anything else

(5) How would you describe the importance of having lectures on the inorganic chemistry before the practical work is attempted?

(6) How successful was the course in the following areas:

(a) Teaching basic practical skills
(b) Familiarising you with important instruments, devices and techniques.
(c) Teaching a logical and methodical approach to doing experimental chemistry
(d) Stimulating and maintaining your interest in chemistry
(e) Encouraging initiative and resourcefulness

(7) Any other comments .....
Interview schedule for autumn 1973 (for staff/demonstrators)

(1) What are your feelings about the course? Do you feel it is successful/unsuccessful? In what areas? How could the course be improved? What are the problems and advantages of the course?

(2) What are the aims of the course? How successful is it in achieving its aims? How do you judge success?

(3) Do you find that you have sufficient time in the laboratory? If not, how could the situation be improved? What aspects of your role in the laboratory take up too much time?

(4) Do you think that the amount of time spent by the students doing the write-up is too much? What aspects of the write-up could be shortened?

(5) Did you use the marking schemes available? What do you feel should be the weighting of the different aspects of the assessment?

(6) How well do P.G. demonstrators cope with their role in the laboratory? In what ways are they inadequate? Why?

(7) Any other comments ....
APPENDIX A 4.3

UNIVERSITY OF SURREY

DEPARTMENT OF CHEMISTRY

Evaluation of 1st Year General and Organic Chemistry

Course for Chemical Engineers

I should be grateful for your help in completing this questionnaire which forms part of a research project which is being conducted jointly by the Chemistry Department and the Institute for Educational Technology. It will be used to find the areas in the course which you feel need altering and developing.

I would like to assure you that any information which you give me by answering this questionnaire will not be passed on to the course organisers in any way that would you identify you. I would also like to thank you for completing the questionnaire at the beginning of the course. This has already provided some interesting information which will be compared with the information obtained from this questionnaire.

Rod Watson
Institute for Educational Technology

The following is a list of possible aims for a chemistry laboratory course. Please rate each aim on each of the two scales. On the first scale please rate the aim depending on how important you think it is in this course (i.e. give your idea of the aims of the present course). On the second scale please rate the aim on the scale depending on how important it should be in this course (i.e. give you idea of the aims of an ideal course).

Use the scale from 1 (not an aim) to 5 (a very important aim).

<table>
<thead>
<tr>
<th></th>
<th>Present course</th>
<th>Your ideal course</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To teach theoretical material not included in lectures and tutorials</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2</td>
<td>To illustrate material taught in lectures and tutorials</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>3</td>
<td>To help the students to bridge the gap between theory and practical</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

* no. on modified questions; ** original no.
1. To teach basic practical skills (e.g. manipulative, preparative and instrumental skills)  
2. To familiarise the student with important instruments, devices and techniques  
3. To train students in observation  
4. To teach a logical and methodical approach of doing experimental chemistry  
5. To teach proper criteria of accuracy and significance (e.g. avoidance of systematic errors; making all the significant observations)  
6. To train students in writing reports on experiments  
7. To train students in making deductions from measurements and interpretation of experimental data  
8. To use experimental data to solve specific problems  
9. To train students in keeping a day to day laboratory note-book  
10. To develop the ability to communicate results orally (e.g. in seminars and informal discussions)  
11. To train in simple aspects of experimental design  
12. To stimulate and maintain students' interest in chemistry  
13. To develop students' skill in problem solving in multi-solution in situation  
14. To foster 'critical awareness' (e.g. extraction from all information from the data; estimation of the size and significance of possible errors)
<table>
<thead>
<tr>
<th>Number</th>
<th>Point</th>
<th>Present Course</th>
<th>Your ideal Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 18.</td>
<td>To provide the students with a stimulant to independent thinking</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>25 19.</td>
<td>To encourage 'enterprise', 'initiative' and 'resourcefulness'</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>28 20.</td>
<td>To develop personal responsibility and reliability for experimentation</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>10 21.</td>
<td>To simulate the conditions in research and development</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>31 22.</td>
<td>To provide closer contacts between students and academic staff</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>33 23.</td>
<td>To show the use of 'practicals' as a process of discovery</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>11 24.</td>
<td>To demonstrate the use of an experimental method as an alternative to the 'theoretical' method of solving problems</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>25.</td>
<td>To familiarise the student with the need to communicate technical concepts and solutions</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>5 26.</td>
<td>To provide motivation for the student to acquire specific knowledge</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>27.</td>
<td>To instill confidence in Chemistry</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>28.</td>
<td>To familiarise the student with lab. scale experiments, within the context of the research and development requirements of chemical engineers</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>29.</td>
<td>To illustrate the relevance of chemistry to chemical engineers</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>9 30.</td>
<td>To make students aware of the safety precautions which are necessary when performing an experiment</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>
What are your general expectations of the laboratory course?

Any other comments ..... 

Name (Optional)
Please complete the following sheet when you have seen the videotape FIlTRATION

Rod Watson

Technical quality
1. Vocal delivery
   a. Clarity of enunciation
      Perfect
      Distractions caused by mumbling, stuttering, etc.
      1 2 3 4 5
   b. Distractions caused by speaker's accent
      No distractions
      A lot of distractions
      1 2 3 4 5

2. Vocal quality
   Lively and varied pace
   Monotonous
   1 2 3 4 5

3. Quality of picture
   Very clear and attractive
   Unclear because of crowded picture, etc.
   1 2 3 4 5

4. Relationship between picture and sound
   Picture and sound complimentary
   Picture and sound not complimentary e.g. sound simply describes picture
   1 2 3 4 5

5. Speed
   Beginning
      Too slow
      1 2 3 4 5
   Middle
      Too fast
      Too slow
      Too fast
      1 2 3 4 5
   End
      Too slow
      Too fast
      1 2 3 4 5

Content and Presentation
6. Amount of material
   Too much
   Too little
   1 2 3 4 5
7. Clarity and Organisation

<table>
<thead>
<tr>
<th></th>
<th>Beginning</th>
<th>Middle</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very clear</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Incomprehensible clear</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Interest

<table>
<thead>
<tr>
<th></th>
<th>Beginning</th>
<th>Middle</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interesting</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Boring</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Other comments .....
Please rate the first three items on this questionnaire on the five point scales.

1. The difficulty of this experiment
   Too easy          Too difficult
   1  2  3  4  5

2. Your interest in this experiment
   Boring            Stimulating
   1  2  3  4  5

3. The relevance of this experiment to the chemistry lecture courses is:
   Unrelated         Closely related
   1  2  3  4  5

4. What knowledge or skills were you assumed to have before you started this experiment, that you did not have?

5. Please write down any particular difficulties which you had with this assignment?

6. Approximately how many hours did you spend in the laboratory doing this experiment?

7. Approximately how many hours did it take you to write-up this experiment?

8. Any other comments ......

Designed by Rod Watson
Institute for Educational Technology
I would like you to fill in yet another questionnaire. I am trying to find your opinions of this laboratory course, so that the experiments can be modified and developed.

I would like to assure you that any information, which you give me will not be passed on to the course organisers in any way that would identify you.

Rod Watson
Institute for Educational Technology
Please circle the appropriate answers for each question and add your comments where necessary.

1. How successful was the laboratory course in teaching you the following laboratory skills?
   a. Filtration using a Buchner funnel:
      not at all successful very successful
      1 2 3 4 5
   b. Titration
      not at all successful very successful
      1 2 3 4 5
   c. Distillation using quickfit apparatus
      not at all successful very successful
      1 2 3 4 5
   d. Recrystallisation
      not at all successful very successful
      1 2 3 4 5

2. Which of these laboratory skills were you able to perform successfully before you started this course?

3. How successful was the laboratory course in teaching you how to use the following instruments?
   a. Melting point apparatus
      not at all successful very successful
      1 2 3 4 5
   b. I.R. spectrophotometer
      not at all successful very successful
      1 2 3 4 5
   c. U.V. spectrophotometer
      not at all successful very successful
      1 2 3 4 5
d. G.L.C. machine

<table>
<thead>
<tr>
<th>not at all</th>
<th>very successful</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

e. Refractive Index apparatus

<table>
<thead>
<tr>
<th>not at all</th>
<th>very successful</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

4. What other laboratory skills or instrumental skills did you learn in this course?

5. One of the aims of the course was 'to study some aspects of chemistry in depth'. Do you think this aim was achieved in any of the experiments? If so, in which experiments?

6. How successful was the acetanilide experiment in achieving the following aim? 'To become familiar with laboratory scale experiments within the context of the research and development requirements of Chemical Engineers'.

<table>
<thead>
<tr>
<th>not at all</th>
<th>very successful</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

7. Did any other experiments achieve this aim? If so, which experiments?

8. What parts of the laboratory course wasted your time (due to inefficient organisation, waiting to use instruments, etc.)?

9. For which experiments do you think you were given the wrong mark?

10. Were the demonstrators always helpful?

<table>
<thead>
<tr>
<th>very helpful</th>
<th>helpful most of the time</th>
<th>helpful some of the time</th>
<th>seldom helpful</th>
</tr>
</thead>
</table>

11. How often was a demonstrator not available when required?

<table>
<thead>
<tr>
<th>never available</th>
<th>always available</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>
12. Are there any problems in the general running of the course which you would like to bring up?

The next few questions are trying to find your reactions to the audio-visual aids used in this laboratory course.

13. Television - Video-tape on filtration using a Buchner funnel:
   a. How relevant did you find this video-tape to the laboratory course?
      
      irrelevant very relevant
      1 2 3 4 5

   b. How interesting did you find this video-tape?
      
      uninteresting very interesting
      1 2 3 4 5

   c. Do you think that using a video-tape is an effective way of teaching laboratory skills?
      
      not effective very effective
      1 2 3 4 5

   d. Would you like to see more video-tapes included in the laboratory course?
      
      yes no

14. Tape-slide on Atomic Absorption Spectrometer
   a. How relevant did you find this tape-slide presentation?
      
      irrelevant very relevant
      1 2 3 4 5

   b. Do you think that using tape-slides is an effective way of teaching laboratory skills?
      
      not effective very effective
      1 2 3 4 5

   c. Would you like to see more tape-slides in the laboratory course?
      
      yes no

15. Do you think that this questionnaire represents your views on the course fairly? Is there anything else you would like to say?

Thank you
Interview schedule for students

(1) General reactions

How did you react to the course? What are your impressions of it?
Are there any parts of the course which you particularly liked/disliked?
Are there any particular good/bad features of the course?
How does the course compare with other laboratory courses which you have done?

(2) Was the course orientated enough towards chemical engineering?
Did you think that the laboratory and lecture courses were related?

(3) Would you like to make any comments about specific experiments?
Were there any experiments which were too easy/too difficult/boring?

(4) Did you find that any parts of the course wasted your time? How?

(5) What did you think of the A.V.A. used in the course, i.e. the videotape and tape-slide? Would you like to see more or less of this type of material included in the course?

(6) What did you think of the staff/demonstrator? Did you find them helpful? Were they always available?
Did you find that the laboratory course enabled you to get to know the lecturers better?

(7) How many experiments have you had marked? (Does it matter that you have not had any marked?)
Do you think that the experiments were marked fairly? What do you think you get your marks for?

(8) Were there any problems knowing what to write in the write-up?

(9) Any other comments .....
Evaluation of 1st Year Inorganic Chemistry Laboratory Course

Feedback Sheet

Information given on this sheet will be used to assess the experiment not yourself.

NAME ____________________________

TITLE OF EXPERIMENT ____________________________

Please rate the first three items on this questionnaire on the five point scales.

1. The difficulty of this experiment:

   Too easy      Too difficult
   1  2  3  4  5

2. Your interest in the experiment:

   Boring      Stimulating
   1  2  3  4  5

3. The relevance of this experiment to the Chemistry lecture courses:

   Unrelated      Closely related
   1  2  3  4  5

4. What knowledge, or skills, were you assumed to have before you started this experiment, that you did not have?
5. Please write down any particular difficulties which you had with this experiment.

6. What did you think was the purpose of this experiment?

7. What did you gain from doing this experiment?

8. Any other comments .....

Thank you,

ROD WATSON

January 1975
I would be grateful for your help in completing this questionnaire which forms part of a research project being conducted by the Chemistry Department and the Institute for Educational Technology. The aim of the research project is to improve teaching and learning in the Chemistry laboratory.

This questionnaire is concerned with the assessment of laboratory work, and I would like to assure you that any information given to me will not be passed on to the course organisers in any way that will identify you.

NAME

TITLE OF EXPERIMENT

Below are a number of sections which you might include in a write-up of this experiment. If a total of 20 marks were being allocated to this experiment, please indicate:

<table>
<thead>
<tr>
<th>A. 1. General presentation of the write-up.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Description of experimental procedure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Accuracy of results and quality of samples.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Organisation of data and inferences drawn from data.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Discussion of theoretical material related to the experiment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Explanation of experimental results in terms of the theory.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Actual Allocation of Marks</th>
<th>Ideal Allocation of marks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Discussion of the limitation of the experimental procedures used and possible improvements to the experimental procedures.

8. Discussion showing evidence of reading

TOTAL NUMBER OF MARKS = 20

B. Why do you think marks (if any) are given for each of the above sections?

1.

2.

3.

4.

5.

6.

7.

8.

C. For what other aspects of the practical work do you think marks are given?
D. For what other aspects of the practical work do you think marks should be given?

E. Do you think that the allocation marks vary from one marker to the other?

F. Do you have any other comments about the assessment of practical work?

Thank you very much.

ROD WATSON

January 1975
RW/GES
I should be grateful for your help in completing this questionnaire which forms part of a research project which is being conducted jointly by the Chemistry Department and the Institute for Educational Technology. It will be used to find the areas in the course which you feel need altering and developing.

I would like to assure you that any information which you give me by answering this questionnaire will not be passed on to the course organisers in any way that would identify you.

Rod Watson
Institute for Educational Technology
The following is a list of possible aims for a chemistry laboratory course. Please rate each claim of the two scales. On the first scale please rate the aim depending on how important you think it actually is in this course (i.e. give your idea of the aims of the present course). On the second scale please rate the aim on the scale depending on how important you think it should be in this course (i.e. give your idea of the aims of an ideal course).

Use the scale from 1 (not an aim) to 5 (a very important aim).

<table>
<thead>
<tr>
<th>Aim</th>
<th>Present Course</th>
<th>Your ideal course</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To teach material not included in lectures and tutorials</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2. To illustrate material taught in lectures and tutorials</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>3. To demonstrate that chemistry is an empirical science</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>4. To demonstrate that chemistry is a useful science</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>5. To study a small area of chemistry in depth</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>6. To teach basic practical skills (e.g. manipulative and preparative skills and techniques)</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>7. To familiarise students with some important instruments and devices</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>8. To train students in observation</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>9. To make students aware of specific hazards in experimental chemistry and to teach them to take the necessary safety precautions</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>10. To simulate conditions in research and development laboratories</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>11. To develop students' skill in problem-solving by experimental work</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>12. To train students in experimental design</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Item</td>
<td>Present course</td>
<td>Your ideal course</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>---------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>13. To develop students' ability to recognise problems which can be solved through experimental chemistry</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>14. To develop students' ability in making hypotheses</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>15. To develop students' ability in selecting techniques, procedures or apparatus appropriate for a particular experiment</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>16. To develop students' ability to make a critical assessment of the methods used to obtain experimental data</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>17. To teach a logical and methodical way of working in a chemistry laboratory</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>18. To train students in keeping a day-to-day laboratory notebook</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>19. To develop students' ability to make deductions from experimental data and to interpret experimental data</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>20. To develop students' ability in accepting or rejecting a hypothesis</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>21. To develop students' ability in estimating the size and significance of errors</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>22. To train students in writing reports on experiments</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>23. To develop students' ability to communicate results orally (e.g. in seminars and discussions)</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>24. To provide the students with a stimulus for independent thinking</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>25. To encourage initiative and resourcefulness in the students</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>26. To stimulate and maintain students' interest in chemistry</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td></td>
<td>Present course</td>
<td>Your ideal course</td>
</tr>
<tr>
<td>---</td>
<td>---------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>27. To encourage perseverance in experimental chemistry</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>28. To develop honesty and scientific integrity</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>29. To develop open-mindedness and flexibility (e.g. willingness to consider new facts)</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>30. To train students in extracting information from the literature (including training in the use of the library)</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>31. To provide closer contacts between students and academic staff</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>32. To provide closer contacts between students within the course</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>33. To develop students' skills in working and cooperating with others in a team</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

What are your general expectations of this laboratory course?

Any other comments ......

Thank you
Evaluation of 1st Year Inorganic Chemistry Practical Course

I should be grateful for your help in completing yet another questionnaire. I have now analysed the information gathered about the inorganic practical course last term, and there are a few outstanding questions which your response to this questionnaire will help to answer.

I would like to assure you that any information which you give me by answering this questionnaire will not be passed on to the course organisers in any way that would identify you.

Rod Watson
Department of Chemistry
and Institute for Educational Technology

Name ......................

1. How often did the following help you to learn specific skills and techniques (i.e. accurate titration, weighing on an automatic balance, use of a sintered glass crubicle, etc., etc.)?

<table>
<thead>
<tr>
<th>Method</th>
<th>Often helped</th>
<th>Never helped</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Instruction sheets</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>b. Textbook by Vogel</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>c. Member of staff</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>d. Demonstrators</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>e. Other students</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

What other methods were helpful in teaching you specific skills and techniques?
2. This question is concerned with the extent to which the instruction sheets and the textbook by Vogel were adequate in telling you what procedures to use, i.e. in telling you what you should do.

How often was it necessary to consult staff, demonstrators, or other students about the procedure?

a. Never, or only one or twice during the whole course □

b. Occasionally, one or twice during each practical class □

c. Quite often, several times during each practical class □

d. Very often, frequently during each practical class □

3. How often did the following groups help you by explaining what procedure should be used?

<table>
<thead>
<tr>
<th></th>
<th>Often helped me</th>
<th>Never helped me</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Member of staff</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>b. Demonstrators</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>c. Other students</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

4. To what extent did you understand the theoretical material connected with the practical experiments, when you were doing them in the laboratory?

a. My understanding was good □

b. I partially understood them □

c. My understanding was poor □

5. To what extent did you understand the theoretical material connected with the practical experiments, after you had written them up?

a. My understanding was good □

b. I partially understood them □

c. My understanding was poor □
6. How often did the following help you to understand the theoretical material connected with the practical experiments?

<table>
<thead>
<tr>
<th></th>
<th>Often helped</th>
<th>Never helped</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Instruction sheets</td>
<td>1 2 3 4 5</td>
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<tr>
<td>b. Textbook by Vogel</td>
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</tr>
<tr>
<td>c. Member of staff</td>
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<td></td>
</tr>
<tr>
<td>d. Demonstrators</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>e. Other students</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

Was anything else important in helping you to gain an understanding of the theoretical material connected with the practical experiments?

7. To what extent were the following aims achieved for you in this course?

<table>
<thead>
<tr>
<th></th>
<th>Not achieved at all</th>
<th>Achieved to a great extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. To teach basic practical skills (e.g. manipulative and preparative skills and techniques)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>b. To familiarise you with some important instruments and devices</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>c. To train you in observation</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>d. To teach a logical and methodical way of working in a chemistry laboratory</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>e. To develop your ability to make deductions from experimental data and to interpret experimental data</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

8. Looking back on the course, are there any other comments that you would like to make?

Thank you
STUDENT INTERVIEW

Introduction
1. What are your reactions to this laboratory course?
2. Are there any particular good features that strike you about the course?
3. Any bad features?
4. How does it compare with other laboratory courses that you have done?

Outcomes
5. What do you think you are getting out of the course? What are you learning?
   Which of the skills and techniques could you do already? How do standards compare with previous work?
6. How much of the course is repetition of previous work?
7. In what way did you learn in this course?

Interest
8. How interesting do you find the course? Do you find it more interesting than other laboratory courses at university? At school? Why? Why not?
9. Do you find the laboratory course more or less interesting than lectures? Why? Why not?

Relevance
10. How closely is the laboratory course related to lectures? Would you like to see it more closely related? Why?

Importance
11. How important do you consider laboratory work to be in your degree course? How important is this course? How does laboratory work compare with lectures and tutorials for importance?
Difficulty
12. How difficult do you find this course? Have you had any particular difficulties? Is there anything that has wasted your time?

13. Do you find this course at all demanding? Does it make you think for yourself/use your initiative?

Time
14. Is there enough time/too much time for the practical?

15. Is your time used efficiently?

Assessment
16. What do you get marks for in this practical course?

17. What else do you think marks should be given for?

18. Do you think many people fiddle their results? Do you?

Improvement
19. In what ways could the laboratory course be improved?

Aims
20. What do you think are the aims of this laboratory course?

Demonstrators/Staff/Students/Technicians
21. Do you find them helpful? In what ways? What do you see as being their role in the laboratory?

22. How do you get on with the technicians?

23. Do you get much help from other students? In what ways?

24. Do the demonstrators/staff have enough time?
STAFF INTERVIEW

Involvement/Planning

1. How did you get to be running the course?

2. How long have you been running the course?

3.a. Did you design the course? How did you go about designing the course? How did you decide what to include?

   b. Have you changed the course? Why? How? How did you decide what to change?

4. Are there any trends in the way in which the course has changed over the years?

5. What constraints are there on you when planning and running a course?

6. What are you trying to achieve in this course? Detailed aims.

Details of course

7. Subject, year, no. of hours per week, no. of weeks, staffing/demonstrators, no. of students

8. Individuals/Pairs/Groups. Why?

9. Do students do the same experiment at the same time or do they do different experiments? Do they have any choice?

10. Type of course - Traditional (skills/lecture), Open/Problem solving, Projects, Integrated, Other.

11. Why have you chosen this format?

12.a. What teaching methods auxiliary to the actual practical work are important? Instruction sheets, Audio-visual, demonstrators, individual help by staff/demonstrators, student help, books

   b. Are there any seminars or lectures to back-up the laboratory work?

13. How are the instruction sheets laid out - open/closed, questions.

14. Why have you chosen this format? (i.e. 12 and 13)

   Are there any particular constraints?
   advantages with reference to organisation?
   advantages with reference to achievement of aims?

15. How do staff/demonstrators spend their time in the laboratory?

   What are their respective roles?
Assessment

16. How are the students assessed? Why are they assessed in this way? What do you look for in the assessment?

17. How do the students do their write-ups?

18. Is the assessment assessing the aims?

19. Are there any aims that are difficult to assess? What are your thoughts on these?

20. Who does the assessing: demonstrators or staff? Why?

21. How much time is spent during the practical class by demonstrators/staff on assessing?

22. How much does the course mark count towards the degree? What do you think of this? Does this affect the way the students work?

Organisation

23. What are the main organisational problems? Equipment? Space?

24. Are there any problems with demonstrators? Are they well acquainted with the experiments? How helpful are they for the students?

25. Are there any problems with technicians?

Student reactions

26. What do the students think of the course? How do you know? Are their comments taken into consideration when changing the course?

27. How does the course cope with different standards of students? Is this a problem?

Aims

28. What are the aims of the course?

29. How successful is the course in achieving its aims?

30. How do you judge success? How do you observe the students becoming more competent in the different areas?

31. Is there anything that you would like to achieve but are not? Is anything over-emphasised, underemphasised?
Changes

32. Are there any changes that you would like to make? What?

33. Why haven't you made them already?

34. What discourages people from making changes?

35. What encourages people to make changes? What do you think motivates people to change laboratory courses?
Information given on this sheet will be used to assess the experiment not yourself.

NAME

TITLE OF EXPERIMENT

Please rate the first three items on this questionnaire on the five point scales.

1. The difficulty of this experiment:
   Too easy       Too difficult
   1  2  3  4  5

2. Your interest in the experiment:
   Boring       Stimulating
   1  2  3  4  5

3. The relevance of this experiment to the Chemistry lecture courses:
   Unrelated       Closely related
   1  2  3  4  5

4. What knowledge, or skills, were you assumed to have before you started this experiment, that you did not have?
5. Please write down any particular difficulties which you had with this experiment.

6. What did you think was the purpose of this experiment?

7. What did you gain from doing this experiment?

8. Any other comments?

Thank you,

ROD WATSON

January 1975.
EVALUATION OF THE USE OF VIDEO-TAPES IN CHEMISTRY LABORATORIES.

This questionnaire forms part of a research project being carried out by the Chemistry Department and the Institute for Educational Technology. The main aim of the project is to improve teaching and learning in the chemistry laboratory. I would be grateful for your co-operation in filling in this questionnaire, which will be used to evaluate the video-tapes used in this course, NOT to assess your performance.

NAME

TITLE OF VIDEO-TAPE

Please rate the items below on the five point scales and add your comments as appropriate.

1. The interest of the video-tape.
   Boring	Stimulating
   1	2	3	4	5

2. The speed of presentation
   Too slow	Too fast
   1	2	3	4	5

3. The amount of material included in the video tape.
   Too much	Too little
   1	2	3	4	5

4. The organisation and presentation of the material.
   Very clear	Incomprehensible
   1	2	3	4	5

5. The relevance of the video-tape to the laboratory course.
   Unrelated	Closely related
   1	2	3	4	5
6. Which parts of the video-tape do you feel should not have been included?

7.a. In what way(s) was the apparatus in the video-tape different from your own apparatus?

7.b. Did this matter?

8. Audibility of video-tape.
   
   Easy to hear       Difficult to hear
   1  2  3  4  5

9. Quality of picture.
   
   Very clear       Unclear
   1  2  3  4  5
10. Was there anything connected with the technical quality of the video-tape that distracted you or made it difficult to learn from the video-tape? If so, what?

11. What knowledge or skills, related to this aspect of practical Chemistry was it necessary to have before watching this video-tape that you did not have?

12. Please write down any particular difficulties which you had when performing the skill described in the video-tape.
13. What are your reactions to the speaker? Does he appear confident? Is there anything you particularly like, or dislike, about his performance?

14. How successful do you feel the video-tape was in teaching you the laboratory skill?

<table>
<thead>
<tr>
<th>Very successful</th>
<th>Unsuccessful</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

15. Any other comments:

Thank you,

ROD WATSON

January 1975
I should be grateful for your help in completing this questionnaire which forms part of a research project which is being conducted jointly by the Chemistry Department and the Institute for Educational Technology. It will be used to find the areas in the course which you feel need altering and developing.

I would like to assure you that any information which you give me by answering this questionnaire will not be passed on to the course organisers in any way that would identify you.

ROD WATSON
Institute for Educational Technology
The following is a list of possible aims for a chemistry laboratory course. Please rate each aim on each of the two scales. On the first scale please rate the aim depending on how important you think it actually is in this course (i.e. give your idea of the aims of the present course). On the second scale please rate the aim on the scale depending on how important you think it should be in this course (i.e. give your idea of the aims of an ideal course).

Use the scale from 1 (not an aim) to 5 (a very important aim).

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<tr>
<th>Present Course</th>
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18. To train students in keeping a day-to-day laboratory notebook
19. To develop students' ability to make deductions from experimental data and to interpret experimental data
20. To develop students' ability in accepting or rejecting a hypothesis
21. To develop students' ability in estimating the size and significance of errors
22. To train students in writing reports experiments
23. To develop students' ability to communicate results orally (e.g. in seminars and discussions)
24. To provide the students with a stimulus for independent thinking
25. To encourage initiative and resourcefulness in the students
26. To stimulate and maintain students' interest in chemistry
27. To encourage perseverance in experimental chemistry
28. To develop honesty and scientific integrity
29. To develop open-mindedness and flexibility of attitude (e.g. willingness to consider new facts)
30. To train students in extracting information from the literature (including training in the use of the library)
31. To provide closer contacts between students and academic staff
32. To provide closer contacts between students within the course
33. To develop students' skill in working and co-operating with others in a team
34. To illustrate the relevance of chemistry to chemical engineers
35. To familiarise the student with laboratory scale experiments within the context of the research and development requirements of chemical engineers
STUDENT INTERVIEW

Introduction

1. What are your general reactions to this laboratory course?

2. Are there any particularly good features that strike you about the course?

3. Any bad features?

Outcomes

4. What do you think you are getting out of the course? What are you learning?

Interest

5. How interesting do you find the course? Do you find it more or less interesting than other laboratory courses that you have done? Why? Why not?

6. Do you find the laboratory course more or less interesting than lectures? Why? Why not?

Relevance

7. How closely is the laboratory course related to the lecture courses?

8. Is it relevant to you as a chemical engineer?

Importance

9. How important do you consider this laboratory course to be? ... compared with lectures?

Difficulty

10. How difficult to you find this course?

   Do you find it demanding?

Aims

11. What do you think are the aims of this laboratory course?
12. Do you find them helpful? In what ways? Are there any problems?

Video-tapes

13. What are your reactions to the use of video-tapes in the laboratory? Would you like to see more or less use made of them?

14. How do video-tapes compare with other ways of learning skills? What do you see as their advantages/disadvantages?

15. Do you find them interesting/boring?

16. Have you had any difficulties understanding or remembering what is on the video-tapes?

17. What did you think of the technical quality of the video-tapes? Picture? Sound?

Groups

18. How do you like working in groups? Does it have any advantages/disadvantages?

   Is the size of your group about right?
1. Relationship with lectures

(a) Is the laboratory course related to the lectures? In what way? Do lectures refer to particular experiments in laboratory or are the experiments just based on material in the lectures?

(b) Does the practical work help you to understand the theory? In what way? Does the theory help you understand the practicals?

(c) What does the practical course add to the lecture course? What does the lecture course add to the practical course?

2. Method of work

(a) What parts of the book have you looked at? Have you looked at any parts of the experiments which you have not done yet?

(b) Do you study the experiments that you are going to do before you come into the laboratory? For how long? What help is this?

(c) What do you think of working in pairs? What are the problems and advantages?

3. Understanding

(a) How well do you understand the experiments whilst you are doing them? What factors are important in helping you to understand and which prevent you from understanding the experiment?

(b) Have you ever encountered 'switch-off'? Does this happen to you often? Why does it happen?

(c) What do you think of the system of having a lot of staff in the laboratory at the beginning of the session?

4. Are there any particular features of this course that you like or dislike? What? Why?
What are your general reactions to the course?
STUDENT INTERVIEW SCHEDULE 2

Introduction

1. What are your reactions to this laboratory course?

2. Are there any particular good features that strike you about the course? Any bad features? Advantages? Problems?

3. How does it compare with other laboratory courses that you have done?

Aims

4. What do you think are the aims of the laboratory course?

Sources of help

5. What do you think of having a large number of staff in the laboratory for the first hour?

6. In the first hour, do you approach the staff or do they just come up and ask you what you are doing? (How do they approach you? Do they ask you if you have any problems? Do they try to see if you understand?)

7. What exactly do you gain from being there?

8. Who would you contact (staff/demonstrators/students/technicians) (a) if you have difficulties following the instruction sheets or difficulties using the apparatus? (b) if your experiment goes wrong and you didn't get the results that you expected? (c) if you have difficulties understanding the experiment?

9. WHY would you consult one group of people rather than another?

10. What do you think of working in pairs? What are the problems and advantages?

11. Have you used any of the Calchem packages yet? What did you think of them? How do they differ from using the laboratory manual? (time, thinking, enjoyment)

Preparing for experiments

12. Do you read the experiments in the manual before you come into the laboratory? Which parts of the manual have you read? Do you read
any textbooks beforehand? How does all this help you when you are in the laboratory? What do you think of the laboratory manual/instructions?

Understanding

13. How well do you understand the experiments whilst you are doing them?

14. What factors are important in helping you to understand the experiments and what factors hinder you from understanding the experiments? (Pre-knowledge - Have you done the theory in previous years? In this term's lectures? Have staff/demonstrators/students helped you to understand it? Do you discuss it with your partner?)

15. In other courses that I have studied I have noticed that students sometimes work through experiments without really understanding them. They simply follow the instructions like a recipe. Does this ever happen with you? Why? (Easy, time, understanding, exams?)

Relationship with lectures

16. Is the laboratory course related to the lecture courses? In what way? Do lecturers refer to particular experiments in the laboratory or are the experiments just based on material in the lectures?

17. Does the practical help you to understand the theory? In what way? Does the theory help you to understand the practical? In what way? What does the practical course add to the lecture courses? What do the lecture courses add to the practical?

17a Importance

Assessment/write-up

18. How long after the experiments do you write them up? Why? What is the value of the write-up to you? Do you use textbooks? Why RUSH?

19. What do you get marks for in the practical course?

20. Have you adopted any particular strategies for getting marks? Do people fiddle results? Do you?

21. What value is the assessment to you? (Detailed feedback, general impression)

Outcomes

23. What are you getting out of the laboratory course?
FEEDBACK SHEET

Information given on this sheet will be used to assess the experiment not yourself.

NAME ____________________________

TITLE OF EXPERIMENT ............................

..................................................................

Please rate the first three items on this questionnaire on the five point scales.

1. The difficulty of this experiment:

   Too easy   Too difficult
   1  2  3  4  5

2. Your interest in the experiment:

   Boring   Stimulating
   1  2  3  4  5

3. The relevance of this experiment to the Chemistry lecture courses:

   Unrelated   Closely related
   1  2  3  4  5

4. What knowledge, or skills, were you assumed to have before you started this experiment, that you did not have?

5. Please write down any particular difficulties which you had with this experiment.
6. Any other comments?

Thank you

ROD WATSON

Institute for Educational Technology
University of Surrey
I would be grateful for your help in completing this questionnaire. I have started to analyse the information that you have given me this term in the feedback sheets and interviews, but there are still a number of outstanding questions which you could help me to answer by filling in this questionnaire.

I would like to assure you that any information which you give me by answering this questionnaire will not be passed on to the course organiser in any way that would identify you.

Rod Watson
Department of Chemistry
and Institute for Educational Technology
University of Surrey
1. This question is concerned with the advantages and disadvantages of working in pairs during this practical course.

Below are 8 statements.

If you agree with the statements circle A
If you disagree circle D
If you neither agree nor disagree, or if you cannot decide circle N.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) I prefer working alone to working in pairs A</td>
<td>N D</td>
</tr>
<tr>
<td>(b) I make more mistakes when doing an experiment in pairs than if working alone A</td>
<td>N D</td>
</tr>
<tr>
<td>(c) Discussion with my partner gives me a greater understanding of the experiment than if I had worked alone A</td>
<td>N D</td>
</tr>
<tr>
<td>(d) I work faster when working alone than when I work in a pair A</td>
<td>N D</td>
</tr>
<tr>
<td>(e) I learn more when I work alone than when I work in a pair A</td>
<td>N D</td>
</tr>
<tr>
<td>(f) My partner and I work well as a team A</td>
<td>N D</td>
</tr>
<tr>
<td>(g) I like having my partner for company during the practical classes A</td>
<td>N D</td>
</tr>
<tr>
<td>(h) Discussion with my partner is helpful when working out results and calculations A</td>
<td>N D</td>
</tr>
</tbody>
</table>
If you have done one of the Calchem computer programmes, please answer questions 2, 3, 4, 5 and 6.

2. Please rate each of the following items according to whether you think it is an important advantage of the Calchem programmes.

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Not an advantage</th>
<th>Important advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) There is no fear of getting the wrong answer; the computer does not get angry or impatient with you</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(b) You work through the theoretical work in a logical manner</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(c) The computer responds personally your answers</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(d) Your complete 'conversation' with the computer is recorded on paper for you</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(e) You get immediate feedback about whether you have given the right or wrong answer</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(f) You are told why you have got the answers right or wrong</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(g) It makes you think</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>(h) You learn by discussing your answers with your partner</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

3. What other advantages did the Calchem programmes have over normal methods of learning?
4. Please rate each of the following items according to whether you think it is an important problem of the Calchem programmes.

(a) It took a long time to complete the programme

(b) The computer sometimes does not understand your answers

5. What other problems were there?

6. What did doing the Calchem programme add to the practical work?

7. In what way does the fact that you have exams at the end of this unit affect the way that you work in the laboratory?

8. Please tick the appropriate box to indicate whether you think it is better to have lectures before or after the related practical work in the following areas:

<table>
<thead>
<tr>
<th></th>
<th>Lectures essential before practical</th>
<th>Lectures preferred before practical</th>
<th>Does not matter</th>
<th>Practical preferred before lectures</th>
<th>Practical essential before lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Thermochemistry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Kinetics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Electrochemistry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) Spectroscopy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9. What are the main advantages in having lectures before a related practical experiment?

10. What are the main advantages in doing an experiment before the related lectures?

11. What are the main problems in doing an experiment before the related lectures?

12. What percentage of the experiments are related to theoretical work covered in previous years rather than this term's work?

   0%  20%  40%  60%  80%  100%

13. Apart from gaining marks did you gain anything from doing the write-ups for each experiment? What?

14. Do you feel that the time spent writing-up the experiment is well spent?

   YES □    NO □

   If you have answered no, in what way would you like to see the write-up modified?

15. On average approximately how long after you completed an experiment in the laboratory did you write it up?
16. Does it matter if there is a gap between doing the experiment and writing it up?

   YES □       NO □

If you have answered yes, in what way does it matter?

17. Do you feel that you are given enough information about how well you are getting on in the laboratory course?

   YES □       NO □

If you have answered no, please explain what information you would find useful.

18. Are there any other comments that you would like to make about the practical course?
The following is a list of possible aims for a chemistry laboratory course. Please rate each aim on each of the two scales. On the first scale please rate the aim depending on how important you think it actually is in this laboratory course (i.e. give your idea of the aims of the present course). On the second scale please rate the aim on the scale depending on how important you think it should be in laboratory course (i.e. give your idea of the aims of an ideal course).

Use the scale from 1 (not an aim) to 5 (a very important aim).

1 = not an aim
5 = a very important aim

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<tr>
<th>Aim</th>
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<th>Your ideal course</th>
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<td>1 2 3 4 5</td>
</tr>
<tr>
<td></td>
<td>Present course</td>
<td>Your ideal course</td>
</tr>
<tr>
<td>---</td>
<td>----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>24.</td>
<td>To provide the students with a stimulus for independent thinking</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>25.</td>
<td>To encourage initiative and resourcefulness in the students</td>
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<td>To encourage perseverance in experimental chemistry</td>
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</tr>
<tr>
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<td>To develop open-mindedness and flexibility of attitude (e.g. willingness to consider new facts)</td>
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</tr>
<tr>
<td>30.</td>
<td>To train students in extracting information from the literature (including training in the use of the library)</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>31.</td>
<td>To provide closer contacts between students and academic staff</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>32.</td>
<td>To provide closer contacts between students within the course</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>33.</td>
<td>To develop students' skill in working and co-operating with others in a team</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>
Appendix A 4.7

Chemistry II Questionnaire 624
Chemistry I Questionnaire 1 631
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Staff interview schedule 645
Student interview schedule for Chemistry II 3-11-1975 647
Student interview schedule for Chemistry II 17-11-1975 650
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Appendix A 4.7

Chemistry II Questionnaire

EVALUATION OF PART I CHEMISTRY LABORATORY COURSE

I would be grateful for your help in completing yet another questionnaire. I have begun to analyse the information that you have given me during this term in feedback sheets and interviews, and there are a few outstanding questions which your response to this questionnaire will help to answer.

I would like to assure you that any information which you give me by answering this questionnaire will not be passed on to the course organiser in any way that would identify you.

Could you please try to complete this questionnaire as soon as possible and return it to me via the questionnaire boxes in Labs. C and D?

Rod Watson
Department of Chemistry
and Institute for Educational Technology
University of Surrey
This questionnaire is divided into two parts: Part A is concerned with units 10 and 11 only. Part B is concerned with the whole of the part I laboratory course.

PART A: UNITS 10 AND 11

1. On average approximately how many hours per week have you spent in the laboratory working on units 10 and 11

2. Of this time spent in the laboratory approximately how many hours per week were spent writing up the experiments?

3. How many hours per week were spent outside the laboratory writing up experiments?

4. How many experiments have you not completed in units 10 and 11?

5. Approximately how much of the uncompleted experiments did you get done?

   0  $\frac{1}{4}$  $\frac{1}{2}$  $\frac{3}{4}$  almost all

6. This question is concerned with the extent to which the instruction sheets were adequate in telling you what procedures to use, i.e. in telling you what you should do.

   How often was it necessary to consult senior demonstrators, junior demonstrators or other students about the procedure?
a. Never, or only once or twice during units 10 and 11
b. Occasionally, one or twice during each practical class
c. Quite often, several times during each practical class
d. Very often, frequently during each practical class

7. How often did people from the following groups help you by explaining what procedure should be used?

<table>
<thead>
<tr>
<th>Often helped me</th>
<th>Never helped me</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Senior demonstrators</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>b. Junior demonstrators</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>c. Other students</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

8. When you encountered practical problems (e.g. the experiments produced unexpected results or no results!) how often did people from one of the following groups help you to sort out the problem?

<table>
<thead>
<tr>
<th>Often helped me</th>
<th>Never helped me</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Senior demonstrators</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>b. Junior demonstrators</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>c. Other students</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

9. To what extent did you understand the theoretical material connected with the practical experiments, when you were doing them in the laboratory?

a. My understanding was good
b. I partially understood them
c. My understanding was poor

10. To what extent did you understand the theoretical material connected with the practical experiments, after you had completed them and
finished writing them up?

a. My understanding was good □
b. I partially understood them □
c. My understanding was poor □

11. How often did the following help you to understand the theoretical material connected with the practical experiments?

<table>
<thead>
<tr>
<th></th>
<th>Often helped me</th>
<th>Never helped me</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Instruction sheets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Textbooks and other literature</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>c. Lectures and lecture notes</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>d. Senior demonstrators</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>e. Junior demonstrators</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>f. Other students</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

Was anything else important in helping you to gain an understanding of the theoretical material connected with the practical experiments?

12. Are there any other comments that you would like to make on units 10 and 11?
PART B: ALL THE PART I LABORATORY COURSE

The following is a list of possible aims for a chemistry laboratory course. Please rate each aim on each of the two scales. On the first scale please rate the aim depending on how important you think it actually is in this part I laboratory course (i.e. give your idea of the aims of the present course). On the second scale please rate the aim on the scale depending on how important you think it should be in this part I laboratory course (i.e. give your idea of the aims of an ideal course).

Use the scale from 1 (not an aim) to 5 (a very important aim).
1 = not an aim
5 = a very important aim

<table>
<thead>
<tr>
<th>Present course</th>
<th>Your ideal course</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. To teach material not included in lectures and tutorials 1 2 3 4 5 1 2 3 4
2. To illustrate material taught in lectures and tutorials 1 2 3 4 5 1 2 3 4
3. To demonstrate that chemistry is an empirical science 1 2 3 4 5 1 2 3 4
4. To demonstrate that chemistry is a useful science 1 2 3 4 5 1 2 3 4
5. To study a small area of chemistry in depth 1 2 3 4 5 1 2 3 4
6. To teach basic practical skills (e.g. manipulative and preparative skills and techniques) 1 2 3 4 5 1 2 3 4
7. To familiarise students with some important instruments and devices 1 2 3 4 5 1 2 3 4
8. To train students in observation 1 2 3 4 5 1 2 3 4
9. To make students aware of specific hazards in experimental chemistry and to teach them to take the necessary safety precautions 1 2 3 4 5 1 2 3 4
10. To simulate conditions in research and development laboratories 1 2 3 4 5 1 2 3 4
11. To develop students' skill in problem-solving by experimental work 1 2 3 4 5 1 2 3 4
<table>
<thead>
<tr>
<th></th>
<th>1 = not an aim</th>
<th>5 = a very important aim</th>
<th>Present course</th>
<th>Your ideal course</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.</td>
<td>To train students in experimental design</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>13.</td>
<td>To develop students' ability to recognise problems which can be solved through experimental chemistry</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>14.</td>
<td>To develop students' ability in making hypotheses</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>15.</td>
<td>To develop students' ability in selecting techniques, procedures or apparatus appropriate for a particular experiment</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>16.</td>
<td>To develop students' ability to make a critical assessment of the methods used to obtain experimental data</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>17.</td>
<td>To teach a logical and methodical way of working in a chemistry laboratory</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>18.</td>
<td>To train students in keeping a day-to-day laboratory notebook</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>19.</td>
<td>To develop students' ability to make deductions from experimental data and to interpret experimental data</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>20.</td>
<td>To develop students' ability in accepting or rejecting a hypothesis</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>21.</td>
<td>To develop students' ability in estimating the size and significance of errors</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>22.</td>
<td>To train students in writing reports on experiments</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>23.</td>
<td>To develop students' ability to communicate results orally (e.g. in seminars and discussions)</td>
<td>1 2 3 4 5</td>
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<td>1 2 3 4 5</td>
</tr>
<tr>
<td>24.</td>
<td>To provide the students with a stimulus for independent thinking</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>25.</td>
<td>To encourage initiative and resourcefulness in the students</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Item</td>
<td>Present course</td>
<td>Your ideal course</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------------</td>
<td>----------------</td>
<td>-------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. To stimulate and maintain students' interest in chemistry</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. To encourage perseverance in experimental chemistry</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. To develop honesty and scientific integrity</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. To develop open-mindedness and flexibility of attitude (e.g.</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>willingness to consider new facts)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30. To train students in extracting information from the literature</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(including training in the use of the library)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31. To provide closer contacts between students and academic</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>staff</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32. To provide closer contacts between students within the course</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33. To develop students' skill in working and co-operating with</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>others in a team</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please feel free to make any other comments about the part I laboratory course.

Thank you.
I would be grateful for your help in completing this questionnaire. I have analysed the information that you gave me last term in the feedback sheets and interviews, but there are still a number of outstanding questions which you could help me to answer by filling in this questionnaire.

I would like to assure you that any information which you give me by answering this questionnaire will not be passed on to the course organiser in any way that would identify you.

Rod Watson
Department of Chemistry
and Institute for Educational Technology
University of Surrey
NAME ..........................  

1. On average approximately how many hours per week have you spent in the laboratory working on units 1, 2 and 3?  

2. Of this time spent in the laboratory approximately how many hours per week were spent writing up the experiments?  

3. How many hours per week were spent outside the laboratory writing up the experiments?  

4. Which unit or part of a unit do you think has been the most worthwhile so far? Why?  

5. Which unit or part of a unit has been the least worthwhile so far? Why?
6. How often did people from the following groups help you by explaining what procedure should be used, i.e. by explaining what you should do during the experiments?

<table>
<thead>
<tr>
<th></th>
<th>Often helped me</th>
<th>Never helped me</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Senior demonstrator</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>b. Junior demonstrator</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>c. Other students</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
</tbody>
</table>

7. When you encountered practical problems (e.g. the experiments produced unexpected results or no results!) how often did people from one of the following groups help you sort out the problem?

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
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<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>c. Other students</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
</tbody>
</table>

8. To what extent did you understand the theoretical material connected with the practical experiments, when you were doing them in the laboratory?

<table>
<thead>
<tr>
<th></th>
<th>Poor understanding</th>
<th>Good understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Unit 1</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>b. Unit 2 (chromatography)</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>c. Unit 2 (statistics)</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>d. Unit 3</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
</tbody>
</table>

9. To what extent did you understand the theoretical material connected with the practical experiments, after you had completed them and finished writing them up?

<table>
<thead>
<tr>
<th></th>
<th>Poor understanding</th>
<th>Good understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Unit 1</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>b. Unit 2 (Chromatography)</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>c. Unit 2 (Statistics)</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
<tr>
<td>d. Unit 3</td>
<td>1  2  3  4  5</td>
<td></td>
</tr>
</tbody>
</table>
10. How often did the following help you to understand the theoretical material connected with the practical experiments?

<table>
<thead>
<tr>
<th></th>
<th>Often helped me</th>
<th>Never helped me</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Instruction sheets</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>b. Textbooks and other literature</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>c. Lectures and lecture notes</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>d. Senior demonstrators</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
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<td>e. Junior demonstrators</td>
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<td></td>
</tr>
<tr>
<td>f. Other students</td>
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<td></td>
</tr>
</tbody>
</table>

11. If you have indicated a preference to consult one of the three groups (i.e. senior demonstrators, junior demonstrators or students) rather than another in questions 6, 7 and 10, please explain why you consulted one group of people rather than another.

12. How successful were the workshops (demonstrations) in preparing you for the experiments which followed them?

<table>
<thead>
<tr>
<th></th>
<th>Not successful</th>
<th>Very successful</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

Please describe any factors that limited the success of the workshops:
13. Second year students have described a tendency to carry out experiments without thinking; to simply turn to the procedure and follow the 'recipe' without first trying to understand the experiment. How often does this happen with you?

<table>
<thead>
<tr>
<th></th>
<th>In no experiments</th>
<th>In all experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

Why do you think this happens?

14. Are there any other comments that you would like to make on units 1, 2 and 3?

Thank you.
EVALUATION OF PART I CHEMISTRY LABORATORY COURSE

I would be grateful for your help in completing this final questionnaire. I have analysed the information that you have given me this term in questionnaires and in interviews. Your answers in this questionnaire will help me sort out a few remaining questions.

I would again like to assure you that any information which you give me by answering this questionnaire will not be passed on to the course organiser in any way that would identify you.

Thank you very much for all your help up to now: it is very much appreciated.

Rod Watson
Department of Chemistry
and Institute for Educational Technology
University of Surrey
1. Next term I will produce a summary of my findings. Would you like me to send you a copy?

YES [ ] NO [ ]

If you have answered yes, please state which College you are in.

College ....................

2. How often do you prepare for the practical work by reading the experimental scripts before you come into the laboratory, when the experimental scripts are available at least a day before you do an experiment?

Never [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] Always

3. In what ways does reading the experimental script before you come into the laboratory to do an experiment, help you in the laboratory?

4. Please indicate below whether you agree or disagree with the statements below about the workshops.

A = Agree
D = Disagree
N = Neutral

Agree Disagree

(a) It was difficult to understand the workshops without having first read the experimental scripts A N D
(b) I could always see the demonstrations clearly

(c) It was difficult to remember details of a workshop if I did not do the related experiment until several days later

5. Do you prefer to have the experiments in a unit timetabled so that you do them at a fixed time or do you prefer to be able to do them at a time that you decide?

(a) Timetabled at a fixed time

(b) A time that I decide

(c) I do not mind

If you have chosen (a) or (b) please explain why.

6. This question is concerned with the advantages and disadvantages of working in pairs during this practical course. Below are eight statements.

If you agree with the statements, circle A

If you disagree, circle D

If you neither agree nor disagree, or if you cannot decide circle N.

(a) I prefer working alone to working in pairs

(b) I make more mistakes when doing an experiment if working in pairs than if working alone

(c) Discussion with my partner gives me a greater understanding of the experiment than if I had worked alone
A = Agree  
D = Disagree  
N = Neutral  

(d) I work faster when working alone than when I work in a pair  
A   N   D

(e) I learn more when I work alone than when I work in a pair  
A   N   D

(f) My partner and I work well as a team  
A   N   D

(g) I like having my partner for company during the practical classes  
A   N   D

(h) Discussion with my partner is helpful when working out results and calculations  
A   N   D

(i) It is more difficult to organise and co-ordinate the practical work when I work in a pair than when I work alone  
A   N   D

7. Please explain what you gain (apart from course marks) from doing the write-up for each experiment, i.e. working out your results, answering the questions, etc.

8. Do you feel that you are given enough information about how well you are doing in the part I laboratory course?

   Yes [ ] No [ ]

   If you have answered no, please explain what kind of information you would find useful.

9. Are there any other comments that you would like to make on the laboratory course?
The following is a list of possible aims for a chemistry laboratory course. Please rate each aim on each of the two scales. On the first scale please rate the aim depending on how important you think it actually is in this laboratory course (i.e. give your idea of the aims of the present course). On the second scale please rate the aim on the scale depending on how important you think it should be in the laboratory course (i.e. give your idea of the aims of an ideal course).

Use the scale from 1 (not an aim) to 5 (a very important aim).

<table>
<thead>
<tr>
<th>Aim</th>
<th>Present course</th>
<th>Your ideal course</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To teach theoretical material not included in lectures and tutorials</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2. To illustrate material taught in lectures and tutorials</td>
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</tr>
<tr>
<td>5. To study a small area of chemistry in depth</td>
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<td>6. To teach basic practical skills (e.g. manipulative and preparative skills and techniques)</td>
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</tr>
<tr>
<td>7. To familiarise students with some important instruments and devices</td>
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<td>8. To train students in observation</td>
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<td>9. To make students aware of specific hazards in experimental chemistry and to teach them to take the necessary safety precautions</td>
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<td>10. To simulate conditions in research and development laboratories</td>
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<tr>
<td>11. To develop students' skill in problem-solving by experimental work</td>
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<td>12. To train students in experimental design</td>
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<td></td>
<td>Present course</td>
<td>Your ideal course</td>
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<tr>
<td>13. To develop students' ability to recognise problems which can be solved through experimental chemistry</td>
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<td>14. To develop students' ability in making hypotheses</td>
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<td>15. To develop students' ability in selecting techniques, procedures or apparatus appropriate for a particular experiment</td>
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<td>16. To develop students' ability to make a critical assessment of the methods used to obtain experimental data</td>
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<td>17. To teach a logical and methodical way of working in a chemistry laboratory</td>
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<td>18. To train students in keeping a day-to-day laboratory notebook</td>
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<td>19. To develop students' ability to make deductions from experimental data and to interpret experimental data</td>
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<td>20. To develop students' ability in accepting or rejecting a hypothesis</td>
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<td>21. To develop students' ability in estimating the size and significance of errors</td>
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<td>22. To train students in report writing on experiments</td>
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<tr>
<td>23. To develop students' ability to communicate results orally (e.g. in seminars and discussions)</td>
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<td>24. To provide the students with a stimulus for independent thinking</td>
<td>1 2 3 4 5</td>
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<td>25. To encourage initiative and resourcefulness in the students</td>
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<td>26. To stimulate and maintain students' interest in chemistry</td>
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<td>1 2 3 4 5</td>
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<td>27. To encourage perseverance in experimental chemistry</td>
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<tr>
<td>No.</td>
<td>Objective</td>
<td>Present Course</td>
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<td>28.</td>
<td>To develop honesty and scientific integrity</td>
<td>1 2 3 4 5</td>
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<td>29.</td>
<td>To develop open-mindedness and flexibility of attitude (e.g. willingness to consider new facts)</td>
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<td>30.</td>
<td>To train students in extracting information from the literature (including training in the use of the library)</td>
<td>1 2 3 4 5</td>
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<tr>
<td>31.</td>
<td>To provide closer contacts between students and academic staff</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>32.</td>
<td>To provide closer contacts between students within the course</td>
<td>1 2 3 4 5</td>
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<tr>
<td>33.</td>
<td>To develop students' skill in working and co-operating with others in a team</td>
<td>1 2 3 4 5</td>
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</tbody>
</table>
Information given on this sheet will be used to assess the experiment not yourself.

NAME ............................................................
TITLE OF EXPERIMENT ............................................................

Please rate the first three items on this questionnaire on the five point scales.

1. The difficulty of this experiment:
   - Too easy
   - Too difficult
   1 2 3 4 5

2. Your interest in the experiment:
   - Boring
   - Stimulating
   1 2 3 4 5

3. The relevance of this experiment to the Chemistry lecture courses:
   - unrelated
   - Closely related
   1 2 3 4 5

4. What knowledge, or skills, were you assumed to have before you started this experiment, that you did not have?
5. Please write down any particular difficulties which you had with this experiment.

6. What did you think was the purpose of this experiment?

7. What did you gain from doing this experiment?

8. Any other comments ........

Thank you,

Rod Watson
Institute for Educational Technology
University of Surrey
Introduction

(1) How long has the course been running in units? Why is this system used?

(2) Why was it decided to introduce a new course last year? Who decided? Who did the planning? How?

(3) How did you get to be involved in this particular course?

Organisation

(4) Are certain people responsible for individual units or are all the units designed by the course organiser? How is each unit structured? (Are they structured?)

(5) How many students are there? Staff/student ratio?

(6) How much group work? How much in pairs? Why?

(7) What do you give by the way of:
   (a) practical demonstrations
   (b) tape slides?

   How much? When?

Aims

(8) The main emphasis of this course appears to be on the appraisal and processing of results? (Aims 16,19,21) How do you go about achieving these aims?

(9) Next most important are basic practical skills (Aims 6,8,9) and finally more general experimental abilities (Aims 15,18). Is this a correct picture? How does the emphasis in aims change as the course proceeds? What is the last term teaching?

(10) How successful is the course in achieving its aims? How do you know?

(11) The aims questionnaire indicates that Dr. H. would like a course which is more open, in which the students make more decisions themselves. Is this correct? Why is not the course organised in this way now?
Assessment

(12) How are the students assessed? Why is it done in this way? Is this assessing the aims?

(13) To what extent do the students play the system, e.g. fiddle their results?

(14) How much does the assessment count towards the final or part I total assessment? Does this effect the students' attitudes to the laboratory?

General reactions

(15) What do you consider to be the main advantages of the way in which you run the laboratory?

(16) What are the main problems or disadvantages? Is there enough staff and demonstrator time in the laboratory to deal with all the students' problems? Are there any problems with demonstrators? Either with their pedagogical standards or their ability to answer questions?

(17) Technicians? - what part do they play? Problems?

Student reactions

(18) What are the students' reactions to the course? How do you know? Interest; Difficulty; Relevance to lecture course; Importance of practicals.

(19) Are there any problems with students being at different standards or having different background knowledge?

Calculators

(20) Are there any advantages apart from the saving of students' time?
STUDENT INTERVIEW (for Chem. 2) 3 November 1975

Introduction

(1) What are your reactions to this laboratory course?
(2) Are there any particular good features that strike you about the course?
(3) Any bad features?
(4) How does it compare with other laboratory courses that you have done?

Outcomes

(5) What do you think you are getting out of the course? What are you learning?
   Which of the skills and techniques could you do already? How do standards compare with previous work?
(6) How much of the course is repetition of previous work?
(7) In what way did you learn in this course?

Interest

(8) How interesting do you find the course? Do you find it more interesting than other laboratory courses at university? at school? Why? Why not?
(9) Do you find the laboratory course more or less interesting than lectures? Why? Why not?

Relevance

(10) How closely is the laboratory course related to lectures? Would you like to see it more closely related? Why? (If not, does this matter?)

Importance

(11) How important do you consider laboratory work to be in your degree course? How important is this course?
How does laboratory work compare with lectures and tutorials for importance?

**Difficulty**

(12) How difficult do you find this course? Have you had any particular difficulties? Is there anything that has wasted your time?

(13) Do you find this course at all demanding? Does it make you think for yourself?/use your initiative?

**Time**

(14) Is there enough time/too much time for the practical? How long do you usually spend in the laboratory? From when until when? Breaks?

(15) Is your time used efficiently?

**Assessment**

(16) What do you get marks for in this practical course?

(17) What else do you think marks should be given for?

(18) Do you think many people fiddle their results? Do you?

**Improvement**

(19) In what ways could the laboratory course be improved?

**Aims**

(20) What do you think are the aims of this laboratory course?

**Demonstrators/Staff/Students/Technicians**

(21) Do you find them helpful? In what ways? What do you see as being their role in the laboratory?
(22) How do you get on with the technicians?

(23) Do you get much help from other students? In what ways?

(24) Do the demonstrators/staff have enough time?
Who do you tend to consult most: staff/demonstrators/students/technicians? What for? Why?

Understanding

(25) To what extent do you understand experiments whilst you are doing them?

(26) Do you write-up experiments whilst you are doing them or at the end?

(27) Do you gain your understanding after writing-up?

(28) Did you do more than one experiment at once? Did you find this confusing? Did you know what you were doing? Did you understand it?
General reactions

(1) What are your reactions to this laboratory course?

(2) Are there any particular good or bad features that strike you about the course? Advantages, disadvantages, problems?

Time

(3) How much time do you spend working within the laboratory per week? What time do you go in? What time do you leave?

(4) Do you do the write-up in the laboratory or at home? How much time do you spend out of the laboratory writing up? Why?

Understanding

(5) To what extent do you understand experiments whilst you are doing them? How is this affected by when you write it up? Do you gain your understanding whilst writing up?

(6) Do you do more than one experiment at once? Did you find this confusing?

Demonstrators

(7) What do you think of the demonstrators?

(8) Who do you go to for help? Junior demonstrators/Senior demonstrators or other students for
   (a) procedure
   (b) problems
   (c) understanding explanation

(9) Do you always go to demonstrators or do they ever come over to see what you are doing?

(10) What do demonstrators actually do whilst they are in the laboratory?

(11) How much time do you spend with demonstrators? Is this mainly in the viva?
(12) How are you assessed?

(13) How much feedback do you get from
   (a) demonstrators
   (b) supervisor?

(14) Do you fiddle your results? Why?

Structure

(15) What do you think of doing a new topic each 3 weeks?

(16) What do you think of the fact that the course is integrated?

(17) What do you think of changing which laboratory you work in every so often?

(18) What do you think of the workshops? How do they operate?
    Outcomes )
    Relevance } See previous interview schedules
    Importance )
Demonstrators

(1) Have there been parts of the course when the demonstrators have not been available when you needed them? When?

(1a) Are they always able to help?

(2) For a particular experiment you might come in contact with a demonstrator during the experiment when you need help or at the end in the viva. Which of these is more important? Why? What do you think of the vivas? Are they helpful to you? In what way?

(3) Do you prefer to consult students or junior or senior demonstrators? Why?

Do you prefer to go to junior demonstrators or senior demonstrators for viva? Why?

(Do you always get the kind of help that you want?)

Understanding

(4) A lot of students seem to go through the practical work in the laboratory without really understanding it: they simply follow the instructions. Does this happen to you? Why do you think it happens?

(How does the amount of time you have affect the way that you work through the experiments? Do you like to finish all the experiments? Why?)

(5) Do you prepare the experiments beforehand by reading the scripts?

Structure of the Course

(6) Workshops.

What are your reactions to the workshops/demonstrators? What do you learn? Are there any problems which prevent you learning in workshops?
(7) Integration
The different areas of chemistry: inorganic, organic and physical, are meant to be integrated in this course. Are they?

Are there any advantages/disadvantages in having an integrated course?

(8) Unit system
(a) What do you think of starting a new topic each 3 weeks? Does it have any advantages/disadvantages over a 10 week course?
(b) What do you think of the 3 alternative structures in units 1, 2 and 3?
   (i) Students do the experiments in the same order at their own pace and work individually
   (ii) Circus arrangement - tightly scheduled - individual
   (iii) Students do the experiments in any order at their own pace and work in pairs

Do you prefer any of these ways of organising things? Why? (Freedom of order (choice), pace, individual/pair)

Working in pairs: What are the problems/advantages?
   (Problems - disagreements, pace
   Advantages - help with knowing what to do discussion + understanding)

Do you prefer working in pairs or alone?

Assessment

(9) What value is the assessment to you? (Feedback - via supervisors)

(10) Are there any problems with the assessment?

(11) Have you adopted any particular strategies for getting more marks? (e.g. fiddling, going to junior demonstrators)

(12) Does the fact that demonstrators assess your work as well as help you, affect your attitudes to them? Does it make you reluctant to consult them? Why?

General

(13) Relevance - Does it matter that it is not closely related to lectures and tutorials?

(14) Importance with regard to lectures and tutorials?