PRACTICAL WORK IN THE ORDINARY NATIONAL CERTIFICATE IN CHEMISTRY

by

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PRACTICAL WORK IN THE O.N.C. IN CHEMISTRY

SUMMARY

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June 1976

S U M M A R Y

This thesis is concerned with an investigation of the situation in practical work within the Ordinary National Certificate in Chemistry as presently offered within the Colleges of Further Education in Scotland. It is one of the very few investigations which have been carried out within this particular sector of Scottish education.

The initial chapters consider the overall situation as it exists at the present time and reference is made to the philosophy and organisation of the Ordinary National Certificate course in general and to the practical aspects of the course in particular. The course is seen to be concerned with a pure rather than an applied chemistry approach.

The students who pursue the Ordinary National Certificate course are in full time employment in industry and attend a college on a day release basis. While the course was not designed to meet specific industrial needs it appeared relevant to consult industry with respect to their view of the content of the Ordinary National Certificate course. This was done and the results are included in the text of the thesis.

The /

The investigation developed from an initial overall survey of the lecturer's and the students' views of the benefits which both parties considered were to be gained from the exercises carried out in the laboratory. From this point the educational value of a random set of experiments is looked at in more detail in terms of attainment or objectives identified by the students who were given no specific objectives for the experiments concerned. This approach is then developed in relation to the role of prior knowledge of the objectives in relation to the attitude of the students and the sense of purpose which they derive from practical chemistry. As is indicated in the text this part of the investigation was less successful than was hoped. However, in spite of apparent short-comings in the practical area it is suggested that there is evidence that the students are deriving some benefit from their laboratory work.

In conclusion it is suggested that the presentation of practical work could be improved to the educational benefit of the students and possible ways of effecting this improvement are proposed.

C O N T E N T S

A C K N O W L E D G E M E N T S

The author would like to acknowledge the help given to him during the period leading up to the presentation of this thesis. Thanks are due therefore:-

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A B S T R A C T

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C H A P T E R 1

PRACTICAL WORK IN THE ORDINARY NATIONAL CERTIFICATE IN CHEMISTRY

CHAPTER 1

PRACTICAL WORK IN THE ORDINARY NATIONAL CERTIFICATE IN CHEMISTRY

1.1 Educational Background of the Thesis

This thesis is presented at a time of change in the Further Education scene in the United Kingdom. The contents are concerned with a specific area of Further Education in Scotland, namely, practical work within the Ordinary National Certificate Course (O.N.C.) in Chemistry. This course is due to be replaced by the beginning of the academic session 1977/78 when completely new courses and curricula will have been developed following on the recommendations of the Hudson Report.(1) The thesis is presented with respect to the situation which exists at the present time and it is hoped that many of the points raised will remain relevant to new courses since it can be assumed that while the curriculum may change there will be a place for practical chemistry in the new course structure.

1.2 The Ordinary National Certificate in Chemistry Course Structure

The Ordinary National Certificate (O.N.C.) together with the subsequent and more advanced Higher National Certificate (H.N.C.) are stages on one of the qualification routes available to the potential professional chemist who for one reason or another undergoes higher education in the non-university sector.

While the term 'National' is embodied in the title the Certificates are not truly so since there are distinct differences in administration and course content between the English and the Scottish situations. Indeed, in England there are regional differences while in Scotland the system of administration, curriculum structure and examinations is common to the whole country and is therefore 'national' on a Scottish basis. It is an aspect of the Scottish situation which is considered /

considered in this thesis.

The O.N.C. and H.N.C. courses in chemistry like the equivalent courses in other subjects are pursued by students who, for one reason or another, have gone into full time employment after leaving school. They may then wish to, or are obliged to, take up the study of a subject which is relevant to their occupation. The educational background of the O.N.C./H.N.C. student may vary and he may have attained 'O' grade passes in relevant subjects, and not infrequently, 'H' grade passes. Very recently it has been shown by Hardaker[2] that his survey of the qualifications of the current (1976) O1 and O2 students indicates a higher level of school attainment than has been supposed in the past. The quality of the student's school attainments influence his point of entry in the O.N.C. course. The majority of students enter into the O1 year with A, B, or C band passes in physics, chemistry and mathematics at 'O' grade, while O1 exemption is available to those with similar band passes in the S.C.E. 'H' grade. Students in the latter grade can be at a disadvantage with respect to practical chemistry in the O2 year because of educational differences compared with fellow students who have followed the O1 route to the O2 year.

The O.N.C. consists of two years of study namely the O1 and the O2 year. The broad course structure[3] is shown in Table 1, the students attending on a day release basis.

Table 1 /

Table 1

O.N.C./H.N.C. Course Structure

Stage	Subject	Minimum hours of tuition (including practical) per session (academic year)
01	Chemistry Physics Mathematics	80 hours 80 hours 80 hours
02	Inorganic Chemistry I Organic Chemistry II Physical Chemistry I	240 hours

The 01 course which has some attainment equivalence with 'H' grade subjects is pursued by a mixed group consisting mainly of chemists but including metallurgists and applied physicists. The 02 year is pursued by chemistry students alone.

1.3 Ordinary National Certificate in Chemistry Course Philosophy

It is relevant with respect to the main purpose of this thesis to consider briefly some of the factors which have had a bearing on the present curriculum, a curriculum which has been evolving since the O.N.C. in Chemistry was first introduced in 1924.

Stark[4] who was involved in recent years in developing the present curriculum has pointed out that while the O.N.C. and H.N.C. are relevant and of interest to the young employee in the chemical and allied industries, in fact the curriculum has been influenced almost entirely by those immediately concerned with or involved in the education of the potential professional chemist, i.e. the Royal Institute of Chemistry, the Scottish Education Department and their Inspectorate and /

and the staff of the Colleges of Further Education. Industry has had little or no direct part in the planning of the curriculum. (The indications are that in designing new courses the Scottish Technical Education Council (SCOTEC) will be involving the industrial view to a much greater extent than in the past.)

The O.N.C., and the subsequent H.N.C., have therefore been orientated towards a pure rather than an applied chemistry course and have probably produced or attempted to produce technologists rather than technicians. The current thinking about job specifications and educational developments suggests[1] that a technologist is a person who holds a degree or equivalent professional qualification in science or engineering and who is responsible for the application of scientific knowledge and methods in industry. For technologist education it has in the past been considered appropriate to provide a course leading to a qualification, the H.N.C. which has been considered to have some equivalence with an Ordinary Degree of a university. At one time the O.N.C. was considered to be both an end in itself and a qualification for entry to the H.N.C. course. This position has changed in recent years and the O.N.C. is now essentially a qualifying course and nothing more. The broad curriculum planning of the O.N.C./H.N.C. courses has been concerned with establishing the relevant body of knowledge necessary in order to develop the potential professional chemist, i.e. technologist. The body of knowledge involves both theoretical and practical chemistry although the curriculum is more open ended with respect to the latter compared with the former. However, it is important to stress that the accent has been on education, the O.N.C./H.N.C. courses never having been conceived as training programmes in any sense.

It is interesting to compare the curriculum philosophy of the O.N.C./H.N.C. and compare this with the City /

the City and Guilds of London Institute whose Course 086 for Chemical Technicians[5] attempts to analyse the role of the technician in the chemical industry, translates this into a course which emphasises and develops the skills required and then identifies the relevant support theory. The Chemical and Allied Industry Training Board[6] recommend a procedure not unlike that of the City and Guilds with reference to the training of scientific laboratory technicians. Indeed SCOTEC in its course planning is pursuing a similar approach in that the knowledge and skills required by industry are being considered in the planning of the new courses.

There may be a case for adopting something of this approach more generally for technicians and technologist education and training. It seems difficult if not pointless to separate education and training or technician/technologist. Indeed Hudson[1] in attempting the separation says of technicians that "educationally as well as industrially it is impossible to give a comprehensive definition".

This thesis is concerned then with the education of the young chemist with the possession of the Ordinary National Certificate as his initial educational goal. In particular the thesis is concerned with the place, purpose and organisation of practical work in the chemical laboratory.

1.4 The Background to Practical Work in the O.N.C. in Chemistry

In the Schemes of Work for National Certificate and Diploma courses in Chemistry[3] the preamble to laboratory work attempts to spell out the philosophy and intent of the practical schemes.

Sensibly the department or lecturer is given, within broad guide lines, some freedom of action in the choice of experiment. This flexibility should work to the advantage of the student given that the departments or /

or lecturers show sufficient ingenuity and curriculum awareness in a practical sense. (It should be noted and it will be stressed again at a later stage that organisational problems do exist in the laboratory and these can adversely affect lecturer and student.)

For purposes of guidance the Schemes of Work[3] provide a list of suggested learning Objectives. These are listed below although the additional explanatory information supplementing each 'objective' has been omitted.

Suggested Learning Objectives

(1) A knowledge of the safety hazards and of safe working methods, the development of a safety conscious attitude.

(2) The ability to obtain, pursue and communicate information.

(3) An enthusiastic, inquisitive attitude to chemistry.

(4) A knowledge of the fundamental structure of chemistry as a subject.

(5) The ability to observe accurately and objectively.

(6) A knowledge of important laboratory techniques: the ability to use equipment efficiently and to interpret experimental results.

(7) The ability to work independently and as a member of a team.

(8) The ability to apply knowledge.

(9) A knowledge of the relevance of college laboratory work.

(10) A knowledge of crystal and molecular structure through the use of atomic and molecular models.

The above list is, of course, in no sense hierarchical and it should be noted that these 'objectives' are not objectives in a behavioural sense. The Schemes of Work stress that the teacher should be conscious of this and should, in fact, plan each laboratory exercise with its own 'specific sub-objectives set at a level matching /

matching the degree of maturity of each group of students and designed to contribute to the main objectives'.[3]

The evidence which became available during the investigation and which is discussed at a later stage, indicated that, in many cases, the lecturers were unaware of the structure of a behavioural objective and referred to a somewhat vague experimental aim rather than a precise statement of expected student learning or attainment. If, as has been suggested by McCallum,[7] the statement of objectives is relevant to providing a sense of purpose for the student engaged in practical work then certainly some of the O.N.C. students may be at a disadvantage.

That behavioural objectives are not part of the normal pattern of laboratory instruction sheets was evident in all cases. The instructions follow a fairly standard pattern of aims, related theory, procedure and safety. In some cases additional items on comprehension are included and are required to be completed by the student after perusal of lecture notes or books.

The laboratory periods in the 01 year are fairly broadly based and include elements of physical,inorganic and organic chemistry. In the 02 year there are clearly defined areas devoted to the three main branches of chemistry and in addition the students are required to complete a minimum of two integrated experiments designed to illustrate the 'unity of chemistry'.[3] The students normally operate as individuals in inorganic and organic chemistry when in general all the class is involved in specific exercises at any one time. In the case of physical chemistry, and because of the limitations of equipment availability, a group of students operating in pairs may be involved in different experiments at any one time. This point is relevant to the suggestion[3] that the illustration and amplification of lecture material is one of the more important purposes /

purposes of laboratory work. Integration of practical work and lecture material is difficult in many areas of the O.N.C. course as presently constituted. In other areas it is impossible.

1.5 The Assessment of Laboratory Work

Laboratory assessment is carried out on an individual college basis in the 01 year while in the subsequent 02 year a selection of laboratory reports may be called in by the external assessor as part of his supervisory remit. The guide lines are more specific for the 02 stage than they are for the 01 stage. In the former experimental work has to be carried out in Inorganic, Physical and Organic Chemistry and in addition in an Integrated Chemistry area. Students in the 01, 02 years need not be assessed along the formal lines proposed in all their practical work but have to be so in the 02 year in a minimum of eight experiments covering two items from each of the four branches, the total assessed experiment time being not less than the total available laboratory time, i.e. all laboratory work is assessed but not necessarily on the same basis all the time. There is evidence, however, that in some colleges all the practical work is assessed according to the SCOTEC proposals. The introduction of continuous assessment which is being used increasingly in a variety of subjects throughout Scottish Further Education Colleges was designed to replace the former end of term practical exam which is considered, with some justification, to be unfair and unrealistic. There are few if any who would favour a return to this sort of assessment in the O.N.C. in chemistry.

C H A P T E R 2

AN INDUSTRIAL VIEW OF THE ORDINARY NATIONAL CERTIFICATE IN CHEMISTRY

CHAPTER 2

AN INDUSTRIAL VIEW OF THE ORDINARY NATIONAL CERTIFICATE IN CHEMISTRY

While, as has previously been stated, the O.N.C. is not vocationally orientated the majority of students are in full time employment in the chemical and allied industries. (Some will be employed in the steel industry, regional authorities, etc.)

It was considered to be relevant to assess the opinion of industry with regard to their view of the purpose and content of the O.N.C. course.

Accordingly a questionnaire (Table 2) and covering letter were sent to appropriate senior members of the staff of the following organisations:-

Ciba-Geigy (U.K.) Ltd.
U.K.A.E.A. (Dounreay)
B.P. Chemicals International Ltd.
I.C.I. Ltd. (Organics Division)
Organon Laboratories Ltd.

'Appropriate' infers those who would have day to day contact with O.N.C. students.

Thirty-five replies were received and the responses are summarised in Table 3. In addition to responding to the questions approximately twenty individuals availed themselves of the opportunity of adding comments. It is not proposed to summarise these comments although it was evident that the main observations related to the need for maintaining a balanced course in the three aspects of chemistry allied with a firm grasp of principles, an ability in basic practical skills and skill in accurate and objective reporting.

Table 2 /

Table 2

A Questionnaire for Industry on the Purpose and the Content of the O.N.C. in Chemistry

Would you please indicate your responses to the following questions by ticking the appropriate columns.

IN ANSWERING THE QUESTIONS PLEASE REMEMBER THAT WE ARE CONCERNED ONLY WITH THE O.N.C. IN CHEMISTRY.

Please feel free to qualify your answers or to comment on the questions in the space provided or separately if you so desire. I do realise that there are problems in composing and in answering questionnaires.

The junior chemist at the end of the O.N.C. should :-	Disagree strongly	Disagree	Not sure	Agree	Agree strongly
(a) Have had a broadly based chemical education, i.e. containing physical, organic and inorganic chemistry.					
(b) Have had a chemical education in which syllabus content is clearly linked with the needs of industry.					
(c) Have had a practical element in his chemical education.					
(d) Have had a practical element in his chemical education designed as far as possible to be integrated with the course theory.					
(e) Have had a practical element planned as a separate entity with its own objectives and with no conscious effort to integrate with the theory syllabus.					

(f) /

	Disagree strongly	Disagree	Not sure	Agree	Agree strongly
(f) Be able to demonstrate that he has learned skills in using basic chemical apparatus and laboratory techniques.					
(g) Have a knowledge, if only on a black box basis, of the use and appreciation of instrumental methods of analysis.					
(h) Have completed a course of study which is an end in itself.					
(i) Have completed a course of study which is only a qualification required before continuing to more advanced study, i.e. H.N.C. etc.					
(j) Be able to demonstrate skills in communication by report writing.					
(k) Be able to demonstrate skills in verbal communication.					
(l) Be able to demonstrate an appreciation of the place and implications of science (chemistry) in society.					

Please add any comments you feel are relevant. (Separate material will be welcome.)

Name : _ _ _ _ _ _ _ _

Position: _ _ _ _ _ _ _ _

Company : _ _ _ _ _ _ _ _

THANK YOU FOR YOUR ASSISTANCE

Table 3

A Questionnaire for Industry on the Purpose and Content of the O.N.C. in Chemistry

The junior chemist at the end of the O.N.C. should :-	Disagree strongly	Disagree	Not sure	Agree	Agree strongly
(a) Have had a broadly based chemical education, i.e. containing physical, organic and inorganic chemistry.				15	20
(b) Have had a chemical education in which syllabus content is clearly linked with the needs of industry.		9	5	17	4
(c) Have had a practical element in his chemical education.				14	20
(d) Have had a practical element in his chemical education designed as far as possible to be integrated with the course theory.		1	2	16	15
(e) Have had a practical element planned as a separate entity with its own objectives and with no conscious effort to integrate with the theory syllabus.	9	20	2	2	-
(f) Be able to demonstrate that he has learned skills in using basic chemical apparatus and laboratory techniques.				15	20
(g) Have a knowledge, if only on a black box basis, of the use and appreciation of instrumental methods of analysis.		1	3	30	1
(h) Have completed a course of study which is an end in itself.	2	15	4	13	1

(i) /

	Disagree strongly	Disagree	Not sure	Agree	Agree strongly
(i) Have completed a course of study which is only a qualification required before continuing to more advanced study, i.e. H.N.C. etc.		9	1	19	6
(j) Be able to demonstrate skills in communication by report writing.		3	6	20	6
(k) Be able to demonstrate skills in verbal communication.		2	5	22	6
(l) Be able to demonstrate an appreciation of the place and implications of science (chemistry) in society.	3	8	11	13	

Comments on the Questionnaire

In considering and commenting on the responses the agree/strongly agree and disagree/strongly disagree responses have been taken together in each case.

Question (a) It should be a source of encouragement to those who have been responsible for compiling the O.N.C. to note that there is evidence of support for a broadly based course.

Question (b) This appears to be inconsistent with (a) above and with the additional comments made on the questionnaire, i.e. a more positive disagree bias might have been expected. However, the inconsistency may reflect a problem of interpretation of the word "linked". Links in chemical education could mean -

(i) designing a course with an applied chemical content in which reference is made to industrial aspects and in the extreme case to specific local industrial situations. Such an approach would /

would be of doubtful value and would certainly be difficult to operate to the satisfaction of industry, the Colleges and the student.

(ii) in a broader view 'link' being considered as a part of a total educational/training effort with a college based component concerned with principles and an industrial component concerned with specific applications. There is a case for a conscious effort being made to form this type of link and in the present situation much will depend on the individual lecturer.

Questions (c) and (d) Here the response is in line with what would be expected. In general it is assumed that a chemistry course must have a practical element and that this should be ideally linked with the relevant theory. In practice, as has been mentioned in Chapter 1, this ideal is aimed at but is not necessarily achieved. In addition, all aspects of a syllabus, e.g. the O.N.C. syllabus, do not necessarily lend themselves to practical exercises although remaining fundamental to the overall course of study.

Question (e) The response is not surprising because, by convention, it is assumed that theory and practice must run together. However, it is quite possible to conceive of a course of study with a lecture/demonstration approach for basic fundamentals and a parallel course concerned with practical skills.

Question (f) This response is in line with the response to item (d).

Question (g) An interesting response and possibly one which is worth pursuing. This is an area where there could be an attempt to link with industry since many of the present day students may only see instrumental methods applied to quality control and research in their daily work and may consider, wrongly, it is suggested, that the basic equipment of the chemical laboratory is irrelevant and of historical interest.

Questions (h) /

Questions (h) and (i) A basic inconsistency exists in these responses since it is impossible to have things both ways. (The role of the O.N.C. has already been discussed in a previous chapter.)

Questions (j) and (k) It would have been surprising if the response had been otherwise.

Question (l) This is the one response where opinion is clearly divided and it may reflect the suspicion which is often voiced regarding 'liberal studies' as being peripheral and of doubtful value. There is, however, a case for widening the horizons of the students beyond learning the technology. This can be done by a re-design of the curriculum or on a more haphazard basis leaving it to the individual teacher to make use of any opportunities which arise in the prescribed syllabus. There is also the possibility of liberalising the main subject by simulation methods which might, for example, lead the student to an awareness of the sociological implications of his major course topic(s).

CHAPTER 3

LITERATURE SURVEY

CHAPTER 3

LITERATURE SURVEY

The purpose of the investigation was to examine the philosophy, organisation and presentation of practical work in the O.N.C. in Chemistry in relation to the benefits which the student derived from this course of study.

As far as the author knows there have been no in depth studies of any aspect of the O.N.C. in Chemistry in Scotland. However, the fact that the controlling body, SCOTEC, has recently introduced changes in the examination format in theory papers in the O.N.C. is probably indicative of their awareness of the poor performance of O.N.C. students in recent years.

In considering the relevance of the available literature on the educational value and purpose of practical work it appears reasonable to consider what other investigations have found in relation to practical work in other areas of higher education.

There is one reservation. That is that the mode of attendance and the external administration of a practical course may limit the extent to which an O.N.C. practical scheme could be modified even if specific modifications were considered to be worthy of a trial. Thus, there are the restraints of a national award and the restrictions which this must impose on innovations by any one College. At the end of the day the examination passes are all important!

Stone(8) like many other authors has one or two points to make with regard to the purpose and content of practical courses in chemistry. He also makes reference to other points of view. Thus Cottrell(9) suggests that practical work on its present scale "has neither the educational advantages nor the practical utility /

utility which are usually ascribed to it". While Cottrell is thinking in terms of university chemistry his comment may be pertinent to other areas. The Open University[10] has suggested in proclaiming their "quality" against the "quantity" of others that most conventional laboratory work is poorly designed as an educational tool and is accordingly, and not surprisingly, inefficient in educational value/hour spent. Stone continuing in his theme suggests that there is a need for an objective look at what is going on and what is being achieved in practical courses and suggests that the majority would agree that practical work is concerned with the development of manipulative skills, the development of the powers of making critical observations, the development by the student in interpretation and presentation of scientific results and finally as a means of illustrating theoretical courses. This is a reasonable set of aims or broad statements of intent. Stone is not, it is assumed, presenting a hierarchy of aims and he suggests that we are less than honest in telling our students what the objectives of the laboratory course are. Possibly we are not sure ourselves and evidence will be produced subsequently to support this point of view in the context of the O.N.C. course.

Too often the educational value of the laboratory is challenged and the demand made for the encouragement of students' initiative and training in place of the historical approach of the pursuit of a set of instructions. By inference this suggests that the answer may lie in some form of discovery learning. Jevons[11] has a word of caution on this suggesting that it is not "the long-sought panacea". The author would make the point that if the inclusion of practical work is accepted in principle then the student has to have a basic set of skills before he can embark into any sort of discovery/investigational situation. In addition /

addition Jevons, cautioning against an over optimistic expectation from discovery learning, suggests that the student, and he is talking of schools, will get out of his discovery what the teacher puts into his preparation. The author would agree with this view. It is indeed or has to be a contrived situation determined by the likely background knowledge the student possesses, his maturity and the need for safety. Jevons plea is for the laboratory to act more as a focus of interest rather than as a major source of knowledge.

Beard(12) has reviewed a range of the attitudes and opinions which exist with regard to the place of practical work and its possible educational merit in the field of higher education. It is suggested by Beard that there is evidence indicating that in laboratory teaching many students are given practical work in which the need to think is minimal. (It is to be noted that in an attempt to overcome this sort of problem, lecturers in the O.N.C. course are encouraged to set comprehension questions as part of the laboratory write up. However, questions on comprehension could be set without going through a laboratory exercise since the questions tend to bear on related theory.)

Again Beard referring to Gavin(13) suggests that laboratory work should be condemned where getting the right answer appears to be more important than the work itself. This view would certainly be supported by lecturers in the O.N.C. field. The latter would not agree with Gavin that the choice of experiments is on the grounds of expediency although, for example, the lack of equipment can influence the organisation of physical chemistry practical work. Is it valid to argue that, as suggested by Beard, practical work gives students direct experience of the basic material of the subject and of complex apparatus? It is valid to so argue but is it educationally relevant? Beard, agreeing with Jevons would suggest that looking up a text /

text book for the correct answer might be more relevant than spending hours obtaining a less than satisfactory result. Yet, could we not use the wrong result in terms of encouraging the student to think through the reasons for the wrong answer rather than have him striving possibly by devious means, to produce the perfect report?

Tremlett(14) in a wide ranging review of practical work reveals a general dissatisfaction with its purpose and operations. The dissatisfaction, it is to be noted, is wide ranging in the experimental sciences and not only in the United Kingdom but in other countries too. This particular review also outlines a range of the investigations carried out to determine the students' view of practical work in general. It would seem that while most students in the experimental sciences acknowledge the need for some practical work the general view based on their experiences is not one of unbounded enthusiasm. The reasons for this include the spin off from a staff attitude which does not take practical work seriously, inhibition of student initiative (real or assumed!) no correlation with practical work outside the university in real life, poor reward in terms of knowledge gained for time spent and "our laboratory periods are spent following sheets which tell us what to do, how to do it, what it all means .... " not untypical of what still goes on in terms of practical work. Many of the views expressed above would be echoed by lecturers and students involved in the O.N.C. in Chemistry and maybe Tremlett is correct when he says the criticisms were symptomatic of an approach to tertiary level laboratory teaching internationally. It is worth noting too, that, within a department there can be wide divergences of opinion on the aims of practical work. This raises a point of interest. It is healthy educationally that departmental members do not behave like automatons yet the student, especially the new student, may suffer accordingly if there is not at least a compromise departmental policy and expressed attitude /

attitude of encouragement in practical work.

That divergences do exist between educational institutions and their attitude towards the purposes or desired purposes of practical work is stressed by Tremlett. In addition there is evidence that a students' concept of priorities of the aims of practical work may differ considerably from those of the teaching staff. Do we ask the students often enough or are academic staff sufficiently sure of their grounds to state that they know best? Tremlett would suggest that within the universities and colleges of technology the students are too often kept in the dark with regard to the aims of the practical work.

Eaborn[15] has shown that in the survey of undergraduate opinion 25% of the responses indicated that too much time was spent in the laboratory. The suggestion is made that "the primary objective of laboratory work is to give the student a feeling for the nature of chemical experimentation and to produce in him a general laboratory confidence and technical competence based on practical dexterity and trained powers of observation. It is not necessary for the new graduate to have experience of any specific range of analytical or synthetic procedures but only that he should be able to set about such procedures with the minimum of supervision, given access to the library." The author is not impressed by these suggestions and it might be argued that the Eaborn Committee does not really know what it wants or rather, it would be interesting to see how they would put their ideas into effect in undergraduate education. They continue to make distinctions which are very fine in stating, "we do not accept, as is sometimes maintained, that the primary function of laboratory work is to illustrate principles, but we certainly agree that, when practicable the choice of experiments should be such as to illuminate theory and thus relate to the lecture courses."

Tietze, /

Tietze,[16] following on the investigations of Tremlett, has reviewed the practical situation in the tertiary education area although the emphasis is on universities, and polytechnics. Tietze suggests that the academics give first priority to the teaching of experimental skills (29%) and the illustration and amplification of lecture material (26%) as prime functions of practical work. The figures relate to faculty answers to the question, 'What is the main purpose and aim of undergraduate laboratory work?'

McCallum[7] has investigated the student attitudes to practical work in the first year of a university course. It is interesting to note that the prime mover in the laboratory may well be the risk of failure rather than any benefit which they may derive for themselves. The investigation involved organic chemistry and a group of 421 students. The purpose was to establish what objectives, if any, the students considered had been relevant to the experiment just completed. Other questions were asked regarding time spent, worthwhileness and enjoyment. Working on a limited number of experiments it was apparent that the lecturer objectives were not at all clear to the students as demonstrated by their responses compared with the lecturers' hopes. The author uses the word 'hopes' deliberately! If there are no objectives hope may be the only alternative. In addition, on matters relating to the affective domain the results were disappointing. Subsequently, a group of students, when told beforehand what the objectives were, performed more satisfactorily on objective attainment. While they were still liable to miss out on some objectives they appeared, relative to the control group, to get more out of the experiment in terms of affective objectives.

Farthing[17] expresses a rarely heard view of the relevance of practical work in chemical education. Here the laboratory /

the laboratory is seen as a training ground in the disciplines for developing some of the skills necessary in the wider aspects of production in the chemical industry, skills which are far removed from the laboratory bench. This particular aspect may be very relevant although it is not commonly referred to by other authors or investigators. Possibly it is a teaching point which could be emphasised to students not as a justification for practical work but because it could be basically correct and might bring a sense, or an additional sense, of purpose to practical work.

Kempa(18) has some interesting suggestions to make on his experiences with and the possible application of visual media as a means of helping to instruct students in many aspects of practical work. The media are designed to instruct the students in those skills which he may otherwise learn by trial and error but which he should be able to carry out and understand why he is using them. Possibly this area is worthy of pursuit. Are there aspects of experimentation which can be adequately illustrated to students for their observation, interpretation and formulation of concepts? Is the actual operation of carrying out an experiment necessarily a virtue?

Flinn(19) reviews the position with regard to the possible approaches or emphases which should be designed into the approach to practical chemistry in the non-university area. The variation in emphasis is seen to be necessary to accommodate variations in course interest and purpose. Thus in the general course in science "practical work should lead to the development of the students' powers of observation and the correct reporting of observations, the importance of accuracy and precise measurement being emphasised. The approach to the theoretical content of the syllabus should be through practical work or demonstration."

In the /

In the. O.N.C., and in England, this is structurally different from the situation in Scotland, "the main purpose of the practical work is to support the theory" ... and should consist mainly of a series of problems the solution of which depends on using facts and principles covered in the theoretical syllabus. "With Chemical Technicians one of the main aims of the course should be to familiarise students with a considerable range of techniques, e.g. setting up apparatus to work at its maximum efficiency and give results of maximum accuracy."

As Flinn points out the differences are related to the question of emphasis rather of specifically different aims. The author is of the opinion that distinctions of the type outlined can be highly artificial and almost meaningless. There is always a danger of believing that the student label pre-determines a limited ability.

It would appear that while there is agreement on the items which would be included in an aims of practical work list there is considerable divergence of opinion on the priorities to be assigned to these items. In addition, the students, and it is they who ultimately matter, would historically appear to have had less guidance than they might have reasonably expected or been given.

No evidence has been found of any investigation having been carried out in the Further Education sector of higher education and the investigation reported hereforth is concerned with practical chemistry in the Ordinary National Certificate in Chemistry in Scotland.

C H A P T E R 4

THE ORDINARY NATIONAL CERTIFICATE IN CHEMISTRY – A DISCUSSION WITH LECTURERS IN COLLEGES OF FURTHER EDUCATION

CHAPTER 4

THE ORDINARY NATIONAL CERTIFICATE IN CHEMISTRY - A DISCUSSION WITH LECTURERS IN COLLEGES OF FURTHER EDUCATION

At the outset of the investigation discussions were held with a number of the lecturers involved in teaching chemistry in five of the colleges of Further Education. The choice of colleges was arbitrary but the five represent a good cross section of all the Scottish colleges involved in the O.N.C. course.

The discussions were intended to be no more than an introduction to the proposed area of investigation and a wide range of personal opinions was revealed. Some of the points appeared to be relevant to the investigation and are noted below:-

(1) The educational background of the students varies. This can result in a feeling of failure since the students have come from a system which in spite of fundamental structural changes appears still to be geared to the needs and aspirations of the more academic pupil. However, as previously noted, more recent information has indicated that the O.N.C. student group also contains individuals who have relatively good qualifications and hence the student body involves a fairly wide spectrum of school subject attainment.

(2) The unevenness of the educational system in school can result in students with the same nominal pass in 'H' grade chemistry showing a wide variation in practical skills because of the inherent variability in the application and operation of the 'H' grade curriculum. This situation is on occasion highlighted in the 02 year of the O.N.C. course where those students who /

who have entered direct from school rather than through an 'O' grade pass and the O1 year are found to have deficiencies in their basic practical skills. Their colleagues in college will have had the advantage of practical work in the O1 year together with the possibility of relevant practical experience in industry for that year.

(3) The opinions on the overall content and purpose of the practical element in the O.N.C. also varied. One of the problems appears to be that, while there is a willingness on the part of the college staffs to question and discuss what is being done, there appears to be no method for encouraging discussions among the lecturers for the benefit of the curriculum and hence the students.

(4) Among the teaching staff one opinion expressed was that in relation to the practical work of the O.N.C. too much was being attempted and it might be better if less was attempted with the purpose of emphasising the development of particular skills. Opposed to this is the suggestion that basic skill development can be integrated with and monitored through a range of experiments. The variety in the latter, it is suggested, overcomes the boredom problem.

In the latter situation the initial exercises are seen to be designed and essential for teaching basic skills, e.g. titration, separation, purification, safety, etc. Subsequently these skills are developed as a means towards an end and not as an end in themselves. It would appear that if the practical situation is to be used to reinforce the theoretical material variety is essential. As previously indicated, desirable though integration may be, it can prove to be impossible because of the limited availability of equipment. Thus in the O2 year and in physical chemistry in particular, integration with respect to /

to complete classes is impossible, different students working on different experiments at the same time.

(5) The method of assessment may also have an indirectly adverse effect on the meaningfulness of the practical work. The method of assessment proposed by SCOTEC(3) and which colleges follow to a lesser or greater extent has been discussed in Chapter 2. It should be noted that colleges are not obliged to work to the proposals all the time, but must do so for the basic set of experiments which form the SCOTEC acceptable minimum which set may be called in for examination by the external assessor.

The views of the lecturers with regard to the assessment problem vary and include:-

(a) The SCOTEC proposals may not be ideal and are time consuming, but they do provide an assessment vehicle. Those who support this view in fact follow the SCOTEC scheme for all experimental work.

(b) The SCOTEC procedure is too rigid and really at the end of the day is a global mark not just as meaningful?

(c) The need to provide a complete and probably stylised report inhibits both teacher and student. This point of view then develops to the idea of the student submitting a rough note book containing the procedures followed, the observations noted, the mistakes made, the calculations, etc. This approach, it is suggested would result in a more meaningful record of what was done, in fact, and not what was finally achieved by slavish and patient following of a recipe. Indeed, such an approach may more readily identify the students' strengths and weaknesses /

weaknesses and therefore be educationally more sound than are the demands of the neat report.

That there is a variety of opinions on assessment procedures is encouraging because out of this may come innovation. However, it is less encouraging to note an inconsistency in the overall attitude towards the role of practical chemistry with regard to the students' education. It would appear that in some cases the time allocated to practical work can be sacrificed should it be considered that more time is required for theoretical material. This is not surprising in a situation where it is the written examination which counts in the award of an O.N.C. at the end of a course of study which is demanding because of its content.

Opposed to this situation is the college where it is made clear to the students that the performance in practical work must be to the satisfaction of the college if the student <u>wishes to sit the final 02 examinations.</u> The staff at another college indicated that they were under pressure to pass students in the practical work in spite of, rather than because of, their performances.

If it is accepted that these views are based on fact and not on hearsay then there is a case for a rationalisation and agreement on the philosophy, the purpose and the presentation of practical work in the O.N.C. in Chemistry or in any other course which may be introduced in the future.

If practical work is to be considered as a relevant part of the course it should be done seriously. If it is to be used as a potential block on students' progress then the assessment procedures should be examined because student evaluation becomes very critical at the pass/fail interface in practical work as in other assessment areas. If there is 'too much' practical then it should be reduced in quantity but not quality.

If /.

If it is considered to be quite irrelevant and unnecessary, practical work should be omitted from the curriculum. If, on the other hand, the total effort expended on the theoretical and practical elements is seen as a unified whole then this should be made clear to the students. Without such guide lines the students will put theoretical and practical chemistry into separate boxes. Thus ask a student in a theory examination a question based on work carried out in the laboratory — unless there has been coverage in both lecture room and laboratory the student will protest about the unfairness of the examination system! It can never be assumed that the inter-relationship between theory and practice is as obvious as it appears to be.

C H A P T E R 5

THE AIMS OF PRACTICAL WORK

- SOME SUBJECTIVE VIEWS OF STUDENTS AND LECTURERS

CHAPTER 5

THE AIMS OF PRACTICAL WORK

- SOME SUBJECTIVE VIEWS OF STUDENTS AND LECTURERS

5.1 Lecturers' Views of the Aims of Practical Work

After the completion of the preliminary discussions with the lecturers it was decided to look at the broad aims of practical chemistry as viewed by the lecturers and the students. In this situation it appeared relevant to consider broad aims rather than behavioural objectives which tend to have more relevance in relation to specific experiments rather than to, say, a whole year's work although it is not being argued that specific objectives have no place in the latter.

For this part of the investigation a covering letter and a questionnaire (Table 4) were sent to all colleges, and hopefully all lecturers involved in the O.N.C. in Chemistry. The thirty-three replies received represent not less than 90% of the teaching staff.

Table 4

A Questionnaire on General Aims

Practical Work	Does not	Does in part	Clearly does
(a) Allows students to 'do' chemistry in a way which they cannot 'do' history etc.			
(b) Promotes a personal sense of responsibility in the student, i.e. it changes attitudes for the better.			
(c) Illustrates and reinforces the work of the theory class.			

(d) /

	Does not	Does in part	Clearly does
(d) Develops manipulative, preparative and instrumental skills.			
(e) Stimulates thought about chemistry.			
(f) Forms a link with the students' role in industry.			
(g) Develops in the student an appreciation of accuracy.			
(h) Stimulates the student through achievement in the laboratory.			
(i) Develops observational skills in the student.			
(j) Promotes a proper attitude towards safety.			
(k) Promotes the ability to record and report observations.			
(l) Develops in the student an ability to draw conclusions from observations and results.			

Please comment briefly on any aspects which have been omitted from the above list and which you consider are achieved in practical chemistry in the O.N.C.

The composition of the questionnaire was based on the SCOTEC learning objectives for practical chemistry. (3) In addition, two other topics (a) and (f) were included. Item (a) was added because indeed a sense of /

of involvement in chemistry may be a virtue of practical work as compared with being told about chemistry in the 'lecture' situation. Reference has been made to an 'industrial link' in item (f). As previously indicated in Chapter 1 the O.N.C. was planned as an educational rather than a training course in any sense. However, the more perceptive student might well recognise that his chemical education must be linked with his normal daily work if in fact the overall but non-integrated purpose of the industrial and the college element is ultimately to produce a professional chemist.

In addition, as can be seen from Table 4, the lecturers were encouraged to add comments where relevant. Those who did comment re-iterated many of the points mentioned in Chapter 3 but also added the following useful points regarding the role of the laboratory:-

(i) Student/teacher relationships can develop in the practical situation and as a result -

(ii) Student problems can be more readily identified and remedial action taken.

(iii) Student attitudes can be modified.

(iv) The student tends to be over-influenced by the emphasis on the neat tidy report and may lose some of the potential benefits inherent in the practical situation.

5.2 The Ordinary National Certificate in Chemistry The Students' View of the Aims of Practical Work

Subsequent **to** the receipt of the lecturers' questionnaires a similar document (Table 5) was sent to the 01 and 02 students in all the Scottish colleges involved in the O.N.C. in Chemistry.

The responses are illustrated in Table 6 (01 students, 225 total) and in Table 7 (02 students, 272 total). This represents about 75% of the total student population in these years.

The /

The lecturer responses are illustrated in Table 8 and all three groups are brought together in Figure 1.

Table 5

General Questionnaire for Students on the Aims of Practical Work in the Ordinary National Certificate

Practical Work -	It did in part only	It clearly did	It did not do so
(a) Allowed me to 'do' chemistry in a way I could not 'do' history etc.			
(b) Promoted a sense of responsibility in me and changed my attitude towards chemistry.			
(c) Illustrated and reinforced the work of the theory class.			
(d) Helped me to develop my preparative, manipulative and instrumental skills.			
(e) Stimulated my thinking about chemistry.			
(f) Helped to form a link with my job in industry.			
(g) Developed my appreciation of accuracy.			
(h) Helped to stimulate me when I successfully completed experiments.			
(i) Helped me to develop observational skills.			
(j) Promoted my appreciation for the need for safety in the laboratory.			
(k) Helped me to learn how to record and report on observations.			
(l) Helped to improve my ability to draw conclusions from observations.			

Table 6

General Questionnaire on Practical Aims
Student Responses (01 students)

Practical Work -	It did in part only	It clearly did	It did not do so
(a) Allowed me to 'do' chemistry in a way I could not 'do' history etc.	91 (41)	92 (42)	41 (18)
(b) Promoted a sense of responsibility in me and changed my attitude towards chemistry	91 (41)	37 (17)	93 (42)
(c) Illustrated and reinforced the work of the theory class	109 (48)	74 (33)	44 (19)
(d) Helped me to develop my preparative, manipulative and instrumental skills	105 (47)	62 (28)	55 (25)
(e) Stimulated my thinking about chemistry	101 (46)	50 (23)	70 (31)
(f) Helped to form a link with my job in industry	73 (33)	42 (19)	109 (48)
(g) Developed my appreciation of accuracy	100 (45)	77 (35)	45 (20)
(h) Helped to stimulate me when I successfully completed experiments	82 (37)	65 (29)	75 (34)
(i) Helped me to develop observational skills	117 (53)	52 (23)	53 (24)
(j) Promoted my appreciation for the need for safety in the laboratory	63 (28)	120 (54)	39 (18)
(k) Helped me to learn how to record and report on observations	83 (37)	120 (54)	20 (9)
(l) Helped to improve my ability to draw conclusions from observations.	121 (54)	71 (32)	31 (14)

% response in brackets

Table 7

General Questionnaire on Practical Aims
Student Responses (02 students)

Practical Work -	It did in part only	It clearly did	It did not do so
(a) Allowed me to 'do' chemistry in a way I could not 'do' history etc.	127 (47)	110 (40)	34 (13)
(b) Promoted a sense of responsibility in me and changed my attitude towards chemistry	112 (41)	34 (12)	126 (47)
(c) Illustrated and reinforced the work of the theory class	150 (55)	83 (30)	39 (15)
(d) Helped me to develop my preparative, manipulative and instrumental skills	125 (46)	79 (29)	68 (25)
(e) Stimulated my thinking about chemistry	122 (45)	45 (17)	97 (38)
(f) Helped to form a link with my job in industry	80 (30)	41 (15)	151 (55)
(g) Developed my appreciation of accuracy	116 (43)	94 (35)	64 (22)
(h) Helped to stimulate me when I successfully completed experiments	123 (45)	73 (26)	78 (29)
(i) Helped me to develop observational skills	147 (54)	69 (25)	62 (21)
(j) Promoted my appreciation for the need for safety in the laboratory	66 (24)	136 (49)	74 (27)
(k) Helped me to learn how to record and report on observations	111 (41)	125 (46)	38 (13)
(l) Helped to improve my ability to draw conclusions from Observations	141 (52)	74 (27)	49 (21)

% response in brackets

Table 8

General Questionnaire on Practical Aims
Lecturer Responses

	Does not	Does in part	Clearly does
(a) Allows students to 'do' chemistry in a way which they cannot 'do' history, etc.	2 (6)	7 (21)	23 (69)
(b) Promotes a personal sense of responsibility in the student, i.e. It changes attitudes for the better	8 (24)	22 (66)	3 (9)
(c) Illustrates and reinforces the work of the theory class	0	19 (57)	14 (42)
(d) Develops manipulative, preparative and instrumental skills	0	14 (42)	19 (57)
(e) Stimulates thought about chemistry	8 (24)	22 (66)	3 (9)
(f) Forms a link with the students' role in industry	13 (39)	16 (48)	4 (12)
(g) Develops in the student an appreciation of accuracy	6 (18)	17 (51)	10 (30)
(h) Stimulates the student through achievement in the laboratory	9 (27)	21 (62)	3 (9)
(i) Develops observational skills in the student	1 (3)	21 (63)	11 (33)
(j) Promotes a proper attitude towards safety	0 (0)	21 (63)	12 (36)
(k) Promotes the ability to record and report observations	2 (6)	12 (36)	19 (57)
(l) Develops in the student an ability to draw conclusions from observations and results	4 (24)	25 (75)	4 (12)

% response in brackets

Figure 1 Comparison of Lecturers' and Students' Opinions on General Aims

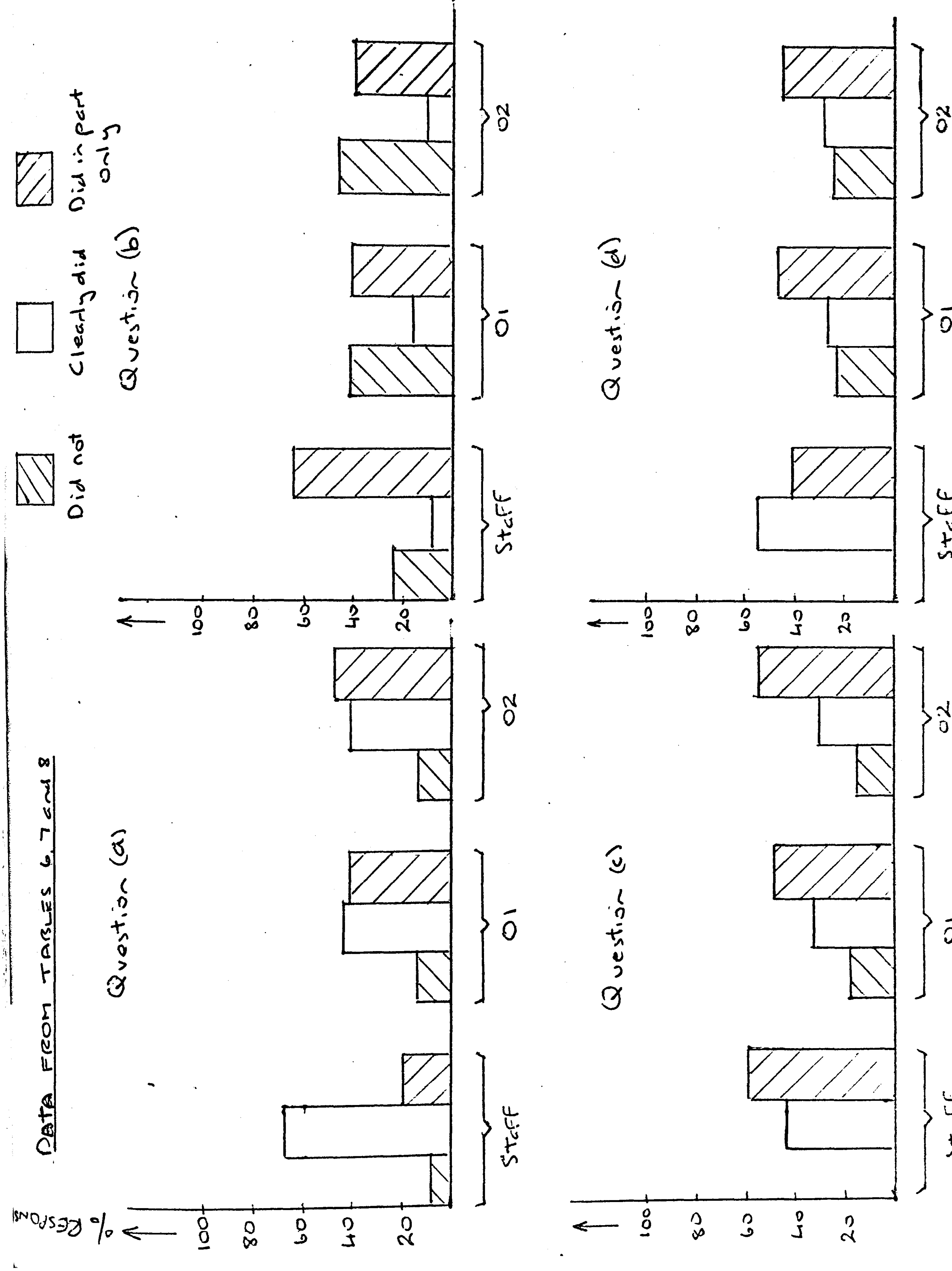


Figure 1 (cont'd)

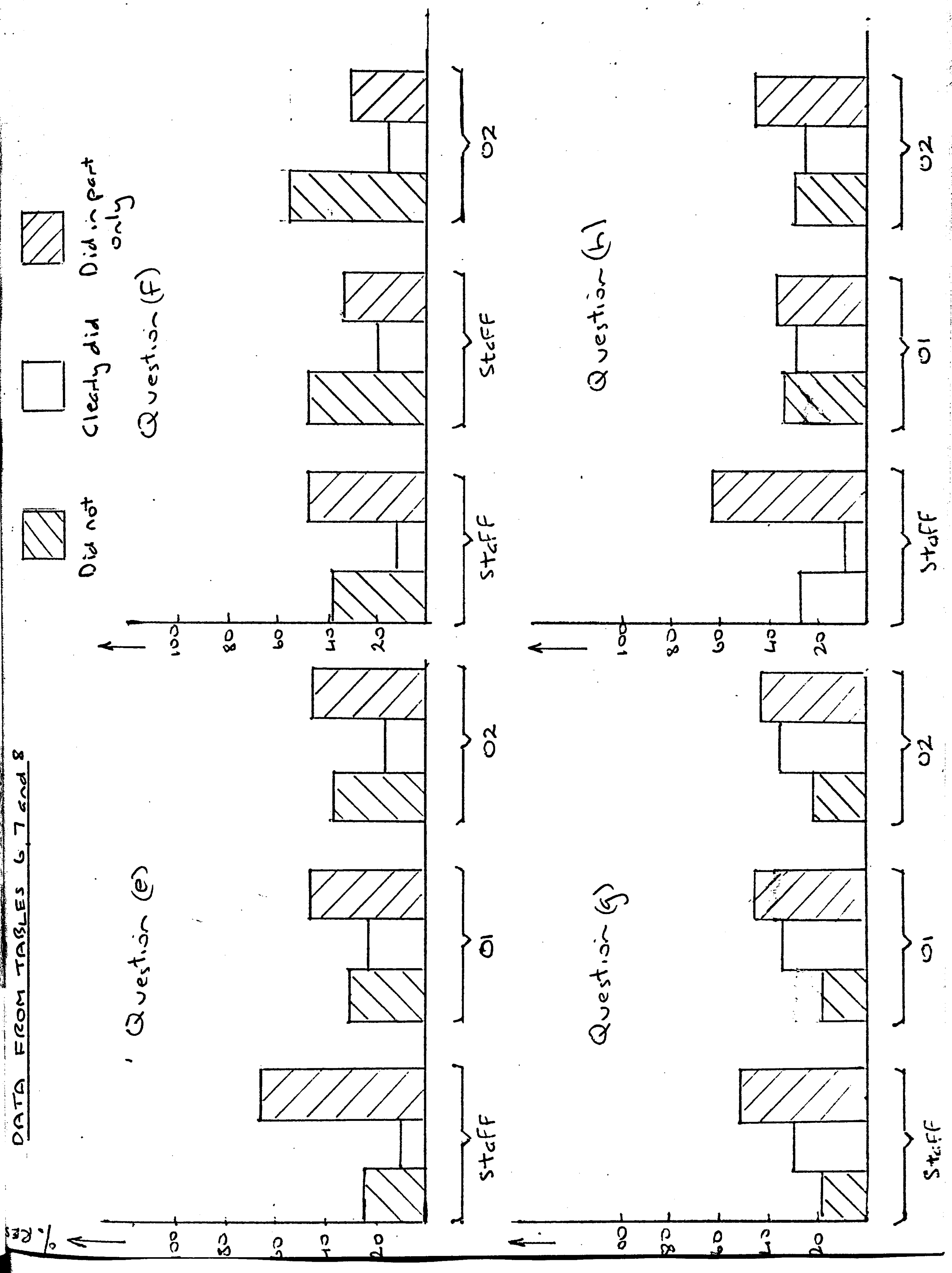
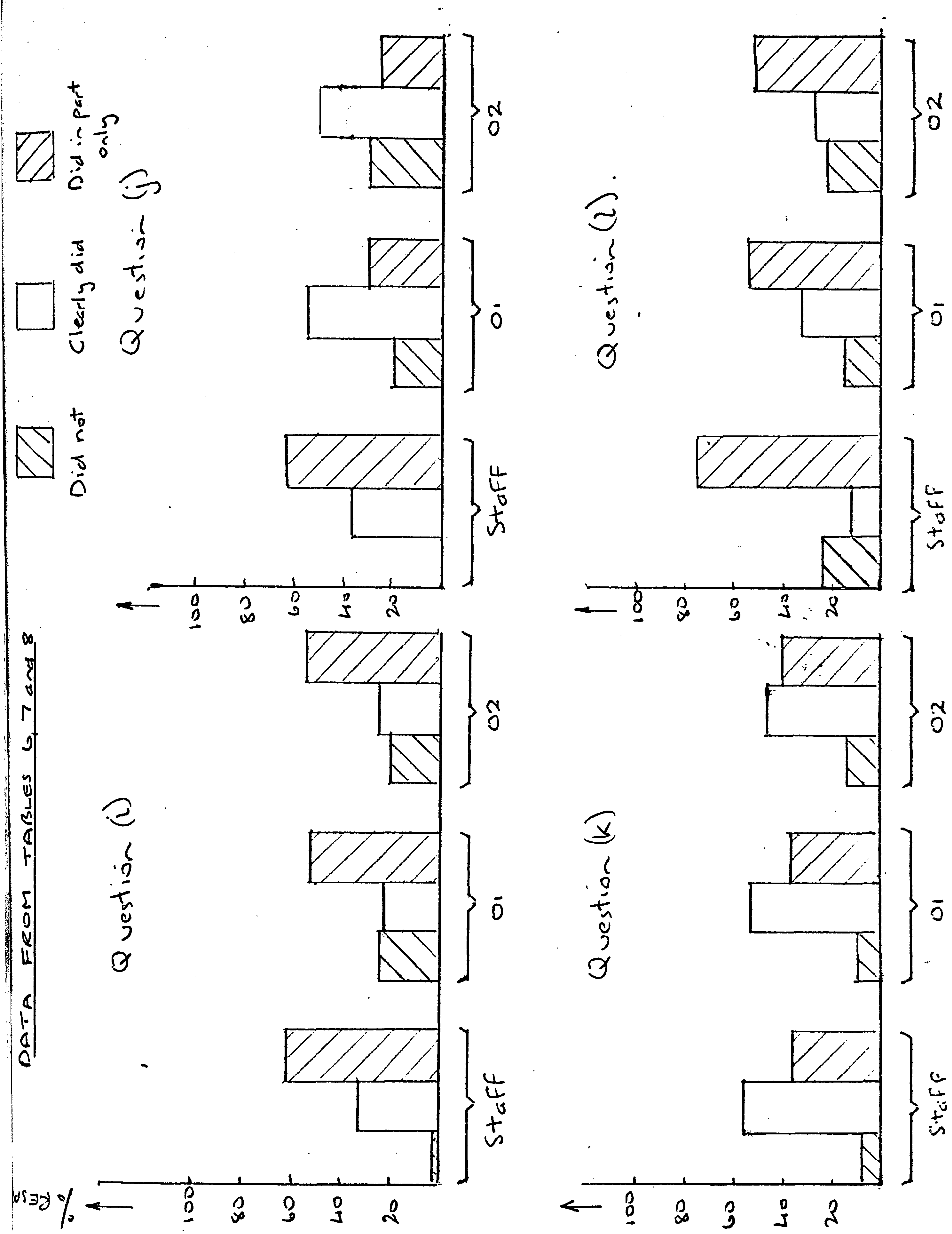


Figure 1 (cont'd)



The questionnaire is general in nature and that in itself is a problem in that the students are being asked to consider and take an overview of a whole year's work in the laboratory. However, the questionnaire is based on the specified broad aims of the practical course and accepting that as a reasonable basis it would be of concern if a strongly negative or 'failed to do so' response was evident in the questionnaire returns.

However, considering the returns the following points emerge.

(a) There are no differences of any real significance between the O1 and O2 students. This is a little surprising since it might have been expected that the greater experience and maturity of the O2 students might have shown in a contrast of response compared with O1 students. This could be due to the following:-

(i) The attitudes and experiences of both O1 and O2 students are, for better or for worse, similar.

(ii) A maturity factor is either irrelevant or non-existent.

(iii) The questionnaire could not by its design differentiate between the two groups.

(b) There are differences between the lecturer attitude and the students' attitude, the lecturer taking in some but not all cases a more optimistic view of the benefits gained from practical work.

On the basis of aims which are clearly achieved the staff is more convinced on matters of involvement [Question (a)], reinforcement of theory [Question (c)] , development of skills [Question (d)] and possibly on safety aspects [Question (j)] . Significantly in relation to the overall purpose of the laboratory the lecturers are less convinced on the ability to draw conclusions from observations [Question (l)] and on the /

stimulation of thinking about chemistry [Question (e)].

It is not surprising that there are differences between students and lecturers in relation to the clear attainment of certain aims and not others. The problem here is for the lecturer to take an objective view and to try to separate what he feels is supposed to be achieved from what is actually being achieved.

CHAPTER 6

AN EXAMINATION OF STUDENT ACHIEVEMENT IN SPECIFIC EXPERIMENTS

CHAPTER 6

AN EXAMINATION OF STUDENT ACHIEVEMENT IN SPECIFIC EXPERIMENTS

6.1 Introduction

The next stage of the investigation was concerned with a more specific examination of a range of experiments being carried out by O1 and O2 students in five of the colleges covered in the initial stages. The selection was restricted deliberately for reasons of easy access for interview if so desired. In the event no such student contact was made and a questionnaire approach was again adopted.

As indicated in Chapter 3 there is apparently no great agreement on the relative importance of the benefits to be derived from practical work. There is, however, some agreement on the areas which are probably relevant and accordingly the questionnaire used (Table 9) was based on a list of aspects or experiences which might prove beneficial to the student in practical work.

The students were asked to complete the questionnaire after the relevant experiment although the precise timing of this procedure could not be controlled. This may be relevant.

If the questionnaire is completed immediately after the experiment then the answers may be more reliable when the experiences and opinions are still fresh in the student's mind. A delay in answering would, in terms of the value of the investigation, be relevant if all students were perceptive and thought seriously about the work recently completed. The student who after a short time forgets what his experiences were may adversely affect the value of the questionnaire. It could also be argued that such a situation would cast doubts /

doubts on the usefulness to that student of the particular experiment just completed. It has to be recognised that there are possible weaknesses in the questionnaire approach, but unfortunately the interview as a possible alternative was logistically impossible in this investigation.

In terms of presentation of the practical work the lecturers involved were asked to pursue their normal course of instruction in the laboratory.

Table 9

Practical Work in the O.N.C. in Chemistry

A Schedule of Questions on Experimental Objectives

COLLEGE — — — — — — — — — —

COLLEGE EXPERIMENT (or Project) NO. OR TITLE — — — — — — — — — — — — —

YEAR 01 / 02 * GROUP / INDIVIDUAL EXPERIMENT*

(*Delete as appropriate)

STUDENT'S NAME : —

PLEASE CONSIDER THE QUESTIONS CAREFULLY BEFORE ANSWERING

In this experiment (or project) :-	Disagree strongly	Tend to disagree	Not sure	Tend to agree	Agree strongly
(1) Accurate observations and measurement were essential to the success of the experiment.					
(2) Accurate observation alone, i.e. without measurement, was essential to the success of the experiment.					

(3) /

	Disagree strongly	Tend to disagree	Not sure	Tend to agree	Agree strongly
(3) I found the whole experiment pointless and boring.					
(4) I had to consult literature or lecture notes in order to understand the purpose of the experiment.					
(5) I had to consult literature or lecture notes in order to understand the procedure followed.					
(6) The laboratory instruction sheet gave me all the information I required for the experiment and the report.					
(7) I had to interpret my observations and/or measurements before completing my report, i.e. I had to think before I wrote.					
(8) I was helped in my understanding of the lecture material.					
(9) It was very obvious to me that the experiment was designed to contribute to my overall knowledge and understanding of chemistry.					
(10) I became interested in an aspect of chemistry which was new to me.					
(11) I learned to use a piece of equipment or laboratory technique for the first time.					
(12) I had to use techniques or equipment with which I was already familiar.					
(13) I increased my knowledge of the use of safe working procedures in the laboratory.					

Disagree strongly	Tend to disagree	Not sure	Tend to agree	Agree strongly

(14) I thought the report which I had to submit was an imposition and a waste of time.

Please indicate in the space below any aspect about the experiment not mentioned above which you found stimulating or otherwise.

THANK YOU FOR YOUR HELP

6.2 The Approach to Objectives

Before considering the results of the questionnaire it should be noted that part of the purpose of this area of the investigation was to note if the students' responses in any way indicated a recognition or attainment of the objectives which the lecturer considered to be relevant to each practical exercise which they carried out and which in addition were covered by the investigation. The lecturers were asked to identify primary and secondary objectives. This classification did not signify degree of importance but rather emphasised the uniqueness of the primary objectives. Thus, a new aspect of practical work would be defined by primary objectives on the first or second occasion but if that aspect, e.g. using a burette, became, in later experiments, a means towards an end, then its proper use might be a secondary objective. The achievement /

achievement of that objective would still be vital to the success of the experiment.

One other problem was to design a questionnaire which was sufficiently wide to embrace all the likely relevant and educationally worthwhile areas and then to translate the stated objectives in terms of the questionnaire options. The particular difficulties are discussed below for individual experiments, but typical of the translation problems is:-

(a) An objective which does not specifically mention 'safety' but uses terms like 'hazards' and 'precautions' should show a positive response to item (13) in the questionnaire.

(b) An objective which requires the student to describe a mechanism or to account for the use of particular materials should result in a positive response to items (4) or (5) etc.

In some cases it proved impossible to translate effectively and it was not attempted.

6.3 Investigational Procedure

To recapitulate the investigational procedure was as follows:-

(a) Lecturers were asked to proceed normally in terms of laboratory procedures.

(b) Lecturers were asked to provide a list of their objectives for each experiment defining where possible primary and secondary objectives.

(c) The students were asked to complete a questionnaire relating to the possible educational benefits which they might derive from any one experiment.

(d) An attempt was made to translate the lecturers' objectives into the 'language' of the questionnaire.

6.4 Specific Experiments - A Review

These are detailed below in terms of -

(a) The experiment (with an investigation reference number);

(b) The objectives for the experiment;

(c) The questionnaire response shown as a graph relating the questionnaire topic (Table 9R) to the student responses. The student response has been taken as the total number of students responding to a questionnaire topic by the 'tend to agree' and the 'strongly agree' responses. The responses have been joined purely to highlight peaks and troughs.

(d) The total student numbers (shown on each graph);

(e) The lecturers' objectives translated in terms of the questionnaire and shown as
   (i) primary objectives (1)
   (ii) secondary objectives (2)
   (iii) author's suggested objectives not defined by the lecturers;

(f) Comments on the responses.

For convenience Table 9 has been repeated below as Table 9R.

Table 9R

Practical Work in the O.N.C. in Chemistry

A Schedule of Questions on Experimental Objectives

COLLEGE   COLLEGE EXPERIMENT (or Project) NO. OR TITLE

---------- --------------

YEAR 01 / 02 *   GROUP / INDIVIDUAL EXPERIMENT *

(*Delete as appropriate)

STUDENT'S NAME : ______________________

PLEASE CONSIDER THE QUESTIONS CAREFULLY BEFORE ANSWERING

In this /

In this experiment (or project) :-	Disagree strongly	Tend to disagree	Not sure	Tend to agree	Agree strongly
(1) Accurate observations and measurement were essential to the success of the experiment.					
(2) Accurate observation alone, i.e. without measurement, was essential to the success of the experiment.					
(3) I found the whole experiment pointless and boring.					
(4) I had to consult literature or lecture notes in order to understand the purpose of the experiment.					
(5) I had to consult literature or lecture notes in order to understand the procedure followed.					
(6) The laboratory instruction sheet gave me all the information I required for the experiment and the report.					
(7) I had to interpret my observations and/or measurements before completing my report, i.e. I had to think before I wrote.					
(8) I was helped in my understanding of the lecture material.					
(9) It was very obvious to me that the experiment was designed to contribute to my overall knowledge and understanding of chemistry.					
(10) I became interested in an aspect of chemistry which was new to me.					

(11) /

	Disagree strongly	Tend to disagree	Not sure	Tend to agree	Agree strongly
(11) I learned to use a piece of equipment or laboratory technique for the first time.					
(12) I had to use techniques or equipment with which I was already familiar.					
(13) I increased my knowledge of the use of safe working procedures in the laboratory.					
(14) I thought the report which I had to submit was an imposition and a waste of time.					

Please indicate in the space below any aspect about the experiment not mentioned above which you found stimulating or otherwise.

THANK YOU FOR YOUR HELP

The experiments are now considered individually.

EXPERIMENT 1 Synthesis of t-butyl chloride

The lecturers' objectives are as follows:-

The student should be -

(a) capable of synthesising t-butyl chloride in 60-70% yield.

(b) able to use a separating funnel in a safe and efficient manner.

(c) able to state the hazards involved in using a separating funnel particularly where a gaseous by-product (isobutane and CO_2) and/or corrosive reagents are used.

(d) able to carry out a fractional distillation in a safe and efficient manner.

In addition the secondary objectives in this case were that the student will be -

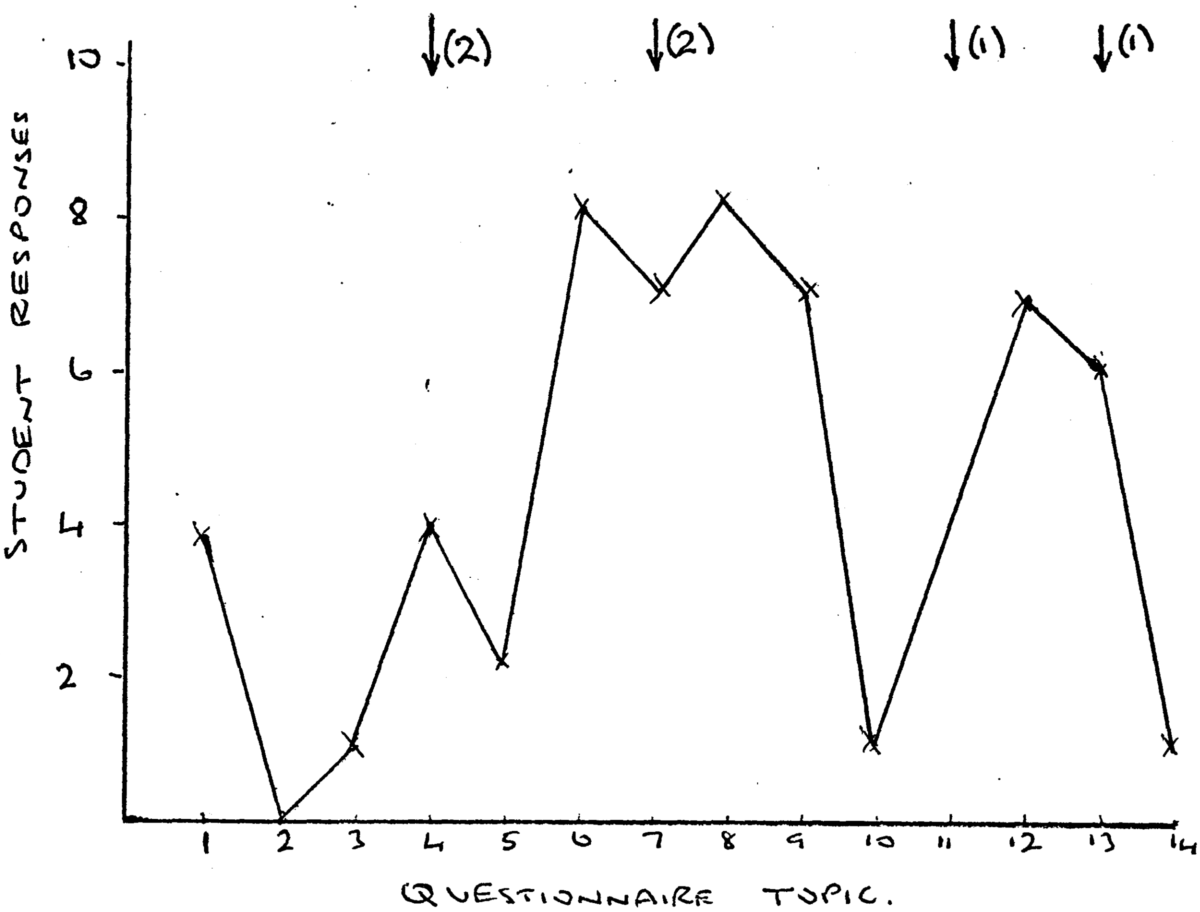
(e) able to describe the main methods of synthesising alkyl halides from alcohols.
(f) able to describe the mechanisms of the reaction.
(g) able to explain the ease of the reaction in the case of tertiary alcohols and why the product gives a precipitate with alcoholic silver nitrate.
(h) able to show that he knows that by-products are often formed in reactions rather than one exclusive product.

The objective attainment graph is shown in Figure 4.

The objective related questionnaire topics would in this case appear to be Question 11 and Question 13 since the primary objectives emphasise techniques, procedures and safety. In addition the secondary objectives underline knowledge and understanding and the relevant topics, it is suggested, would be Question 4 and Question 7. (It is to be noted that in the instruction sheets for this experiment a specific book reference was mentioned.) Overall there has been a mixed response. While the safety aspects (Question 13) have been appreciated by 9 students, the technique aspects have fared badly. While 9 of the students considered that some thought had to be given to the exercise only 5 considered that consultation of lecture notes or books was required in spite of the reference quoted.

It is also to be noted that while the need for observation and/or measurement would be an essential part of the experiment, the majority of the students thought otherwise. Yet somehow in spite of this, the students /

Figure 4 Experiment 1 Synthesis of t-butyl chloride (13 students (02)



FIGS 4-24 OBJECTIVE IDENTIFICATION

↓(1) LECTURER'S PRIMARY OBJECTIVE(S)

↓(2) LECTURER'S SECONDARY OBJECTIVE(S)

↓(?) AUTHOR'S SUGGESTED OBJECTIVE(S)

the students claimed to have derived some 'knowledge and understanding' benefit from their practical work, as is suggested by the response to Question 8 and Question 9. Confusing indeed!

<u>EXPERIMENT 2</u> Preparation of ethyl acetate

The lecturers' objectives are as follows:-

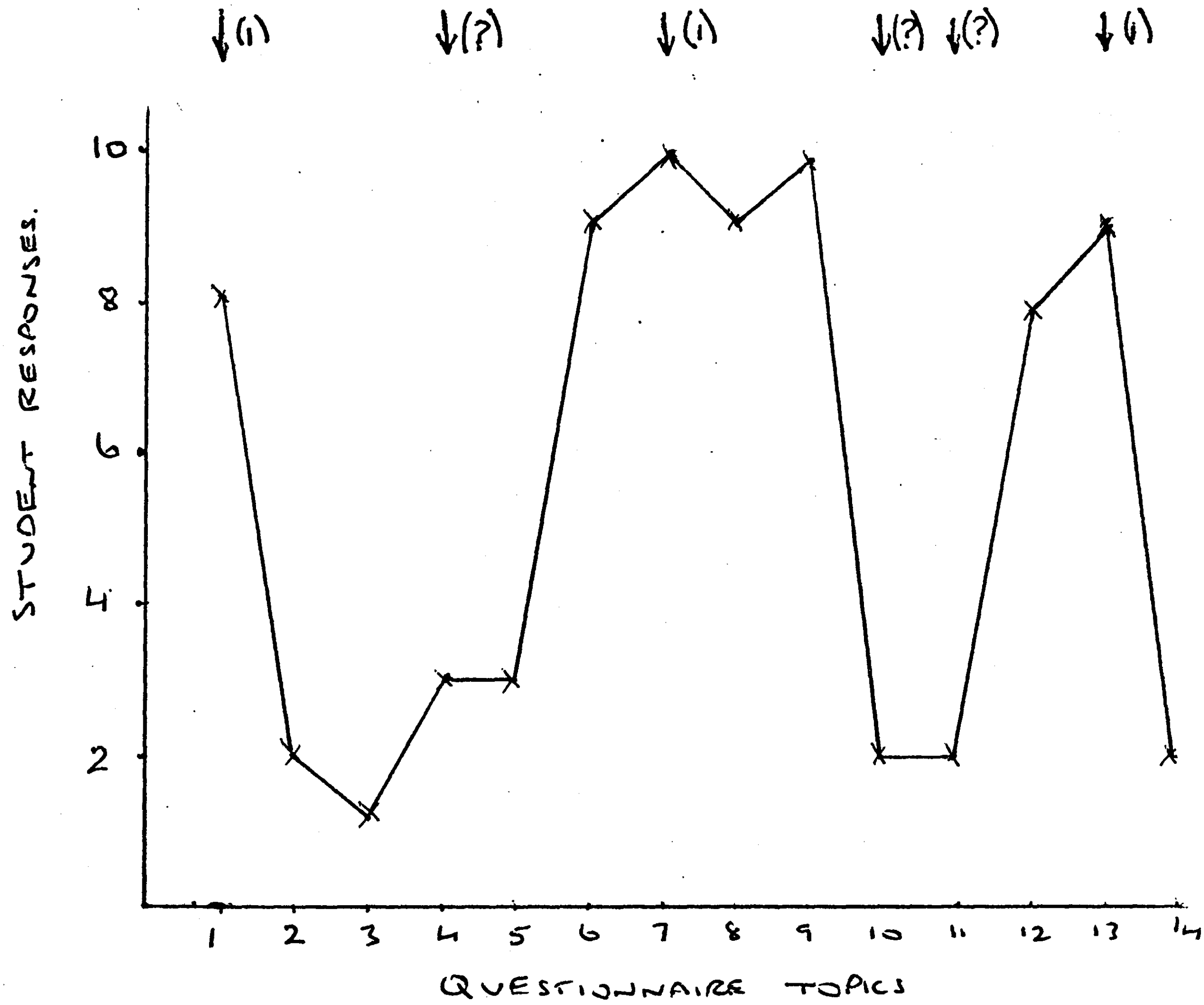
The student will be able to:-

(a) obtain ethyl acetate from ethanol, acetic acid and conc. H_2SO_4 in about 30-40% yield.
(b) describe the mechanisms of the reaction and the functions of conc. H_2SO_4 in the reaction.
(c) identify hazards involved in handling conc. H_2SO_4 mixtures and flammable materials, particularly during distillation procedures.
(d) to use a separating funnel correctly with appropriate precautions, release of pressure where volatile liquids or gas evolution are involved.
(e) to determine boiling points of organic materials on a micro-scale.

The objective attainment graph is shown in Figure 5.

The relevant and objective related questionnaire topics are clearly Question 1, Question 7 and Question 13, and in fact have been recognised by the students. It is suggested that students might well have had to consult other sources of help for background purposes. Similarly, since the work involved would be new to the majority of the students, there might have been some evidence of interest. However, both aspects (Question 4, Question 10, and Question 11) show a poor response. It would appear that they do not find the exercise or its reporting an imposition and again the understanding and knowledge aspects have had a favourable response.

Figure 5 Experiment 2 Preparation of ethyl acetate (11 students) (02)



EXPERIMENT 3. Oxidation of an alcohol

The lecturers' objectives in this experiment are as follows:-

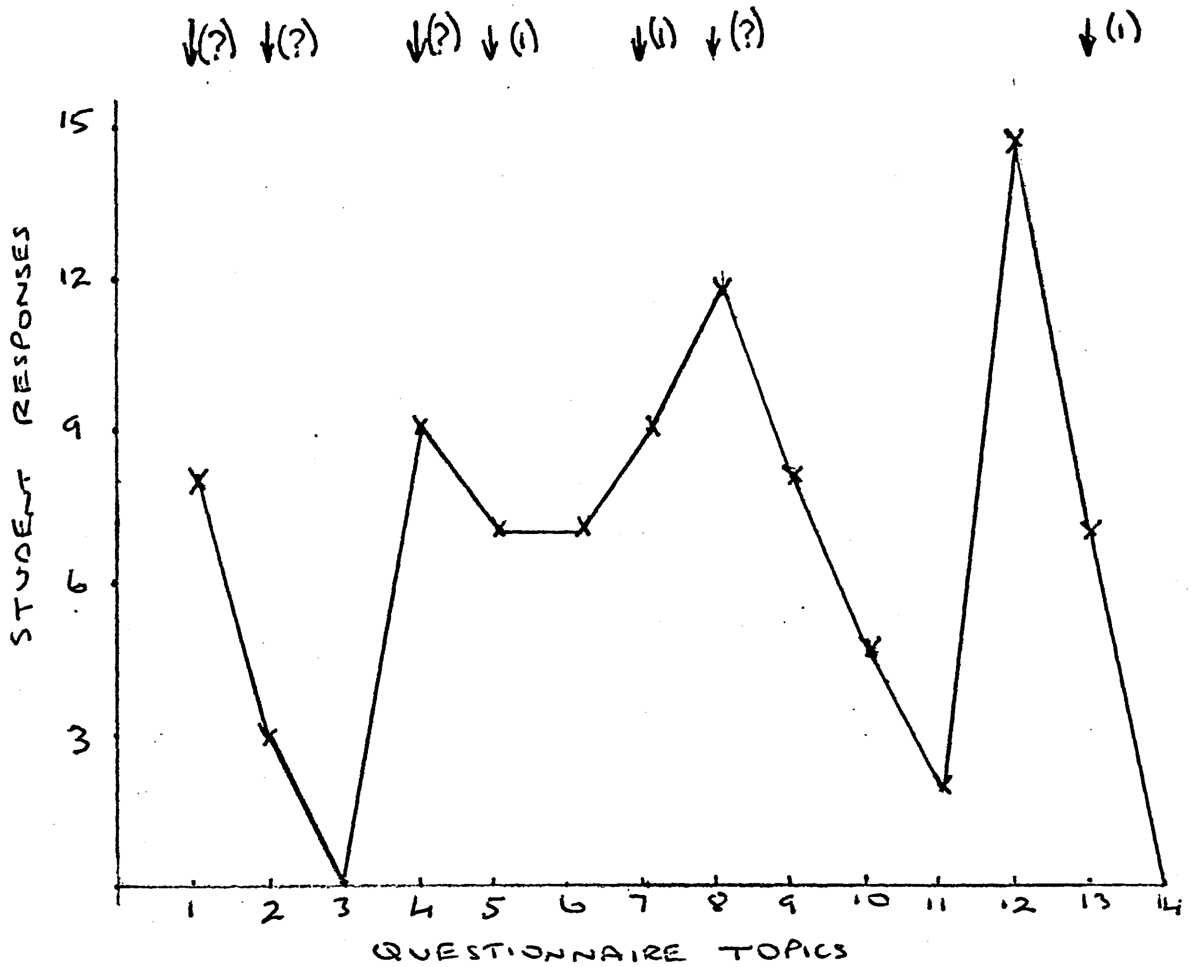
The student should be able -

(a) to recognise that a primary alcohol is oxidised in the first instance to an aldehyde and a secondary alcohol is oxidised to a ketone.
(b) to state, with reasons for their action, tests for distinguishing between aldehydes and ketones. [Schiffs Fehlings Tollens]
(c) to state the principles behind steam distillation.
(d) to describe the precautions required when dealing with conc. H_2SO_4/alcohol mixtures and with strong oxidising agents.
(e) be able to make use of the melting points of derivatives (in this case a dinitrophenyl hydrazone) in attempting to identify the product.

The objective attainment graph is shown in Figure 6.

From the above it would appear that the relevant objective related questionnaire topics are Question 5, Question 7 and Question 13. It is also suggested that (Question 1, Question 2), Question 4 and Question 8 would be relevant. The student responses are not particularly good in this case and are worrying in the case of the matter of safety. It would have been reasonable to expect a more positive response to matters of observation and measurement and to (Question 4) since consultation of lecture notes would seem relevant to the claimed benefit in understanding theory (Question 8). By the same token (Question 9) might have been more in line with (Question 8) with regard to knowledge and understanding of chemistry.

Figure 6 Experiment 3 Oxidation of an Alcohol/ Qualitative analysis of the Product (15 students) (02)



EXPERIMENT 4. Reaction between Fe^{2+}_{aq} and various oxidising agents.

The lecturers' objectives here were expressed as an overall objective which was "To give a practical background to lectures" and as specific objectives -

(a) to determine experimentally the actual reacting ratios (molar) of Fe^{2+} with various oxidants.
(b) to relate the experimentally determined reacting ratios to those predicted by theory (based on ion-electron equations) and thus to show that the theory is useful.
(c) to acquire a facility to carry out the calculations relevant to Redox theory.
(d) to acquire a facility to carry out volumetric analysis including end point recognition.

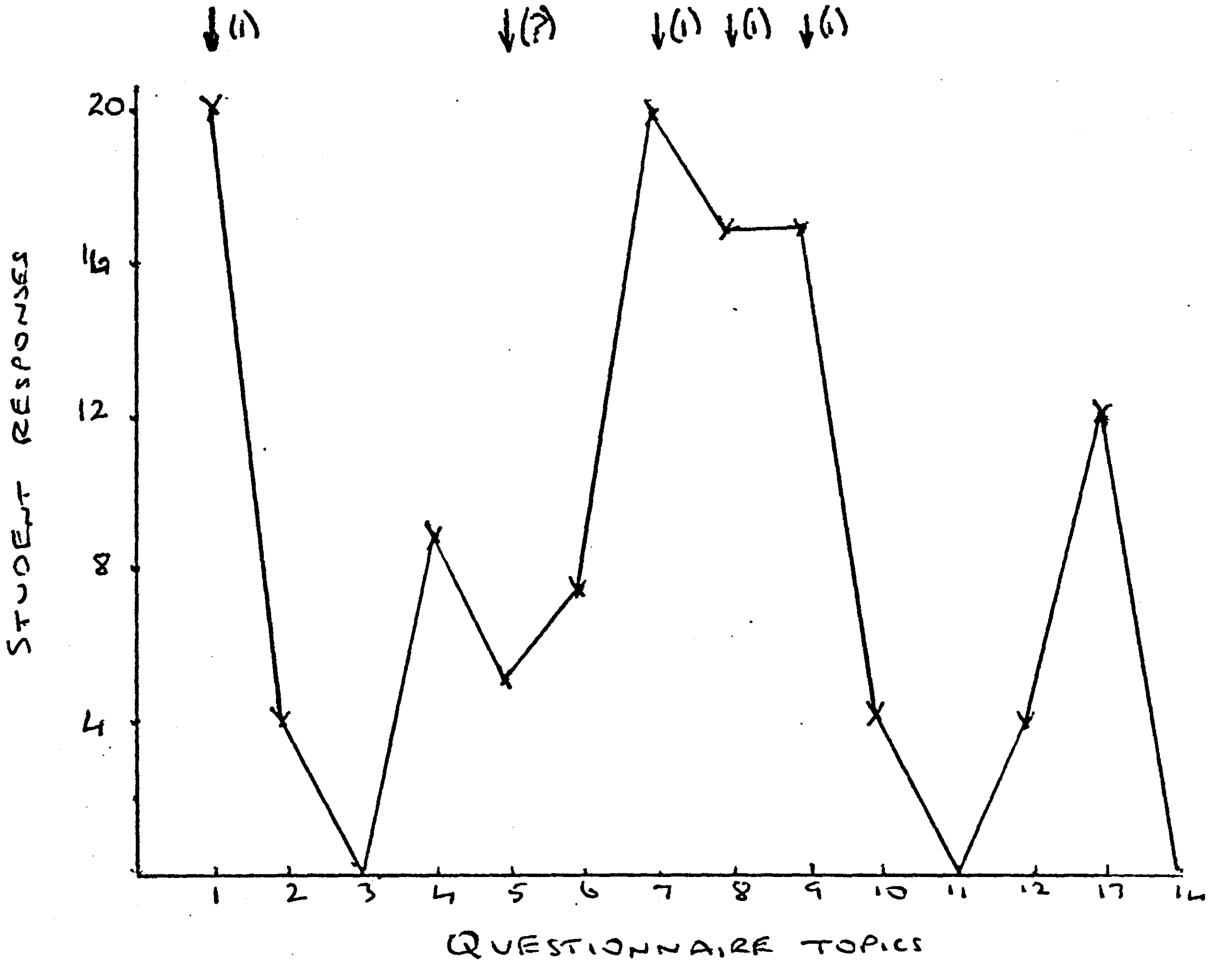
In addition, the relevance of the final report as a measure of the attainment of objectives was stressed.

The objective attainment graph is shown in Figure 7.

In this experiment the objective related questionnaire topics are (Question 1), (Question 7), (Question 8) and (Question 9), i.e. those emphasising observation and measurement, understanding and knowledge.

In this particular case there has been a positive response to these particular topics. Equally, in the light of the objectives as stated a more positive response to (Question 5) would have been expected in relation to overall purpose of the experiment and the fact that the instruction sheets were not highly detailed.

Figure 7 Experiment 4 Redox reactions. Reactions of Fe^{2+} with oxidising agents (20 students) (02)



EXPERIMENT 5 Volumetric Determination of Calcium

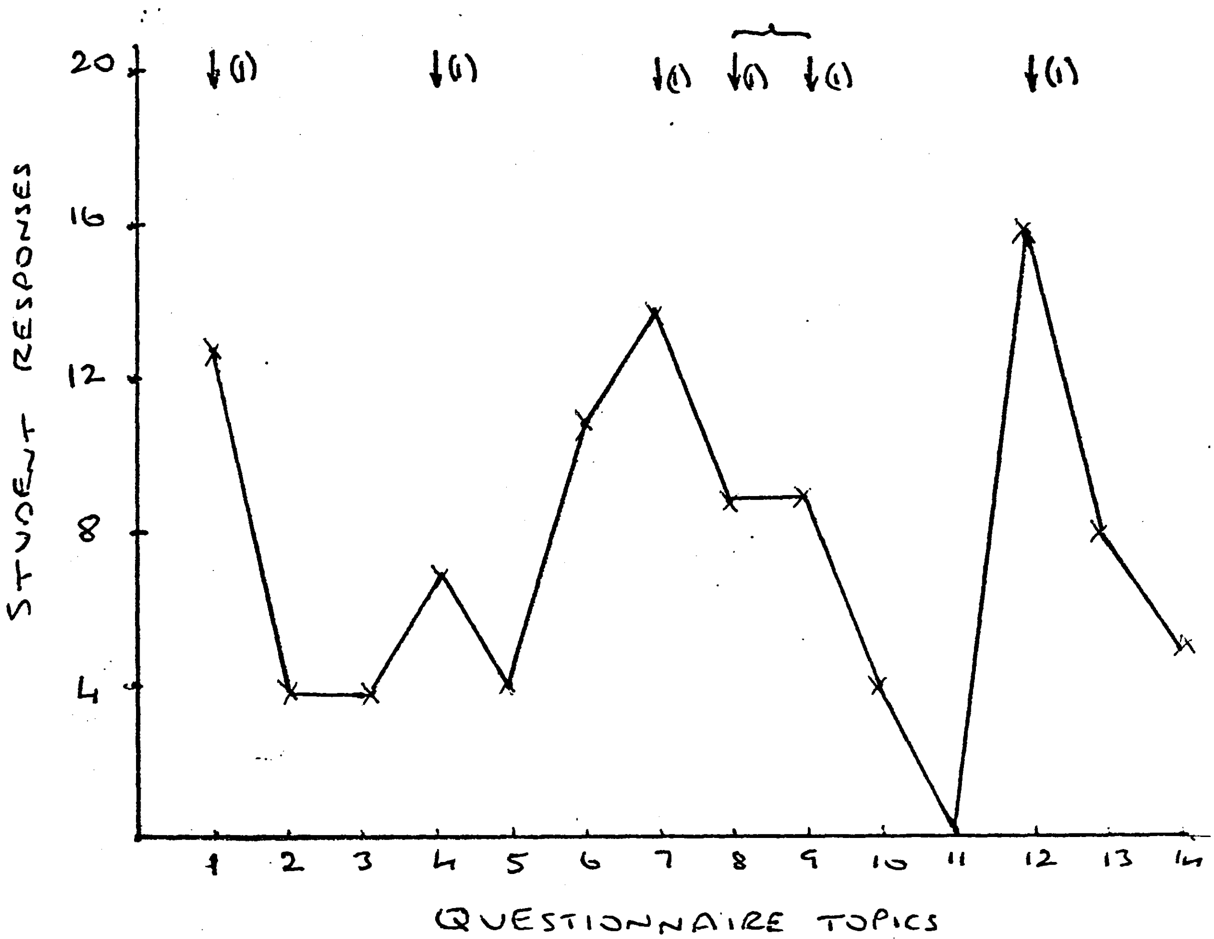
The overall lecturers' objective here is the appreciation of Redox theory and the specific objectives are -

(a) to use a "several step" reaction to determine calcium ions in solution.
(b) to process the several steps through a calculation of a more complex kind.
(c) to provide further chemical facts to the students' background.
(d) to provide further practice in analysis.
(e) to provide further practice in application of Redox theory.

The objective attainment graphs are shown in Figure 8.

The questionnaire related topics in this case are Question 1, Question 4, (Question 7), (Question 8 or Question 9) and (Question 12). No distinction has been made by the lecturer with regard to primary and secondary objectives. Success has been achieved with regard to three of the objectives, but those relating to a development of understanding of lecture material or a widening of knowledge and/or understanding have shown a poorer recognition by the students. It is also to be noted that no real need to consult lecture notes was felt by the students.

Figure 8 Experiment 5 Redox reactions. Determination of Calcium (16 students) (02)



EXPERIMENT 6. Determination of Copper in a Solution

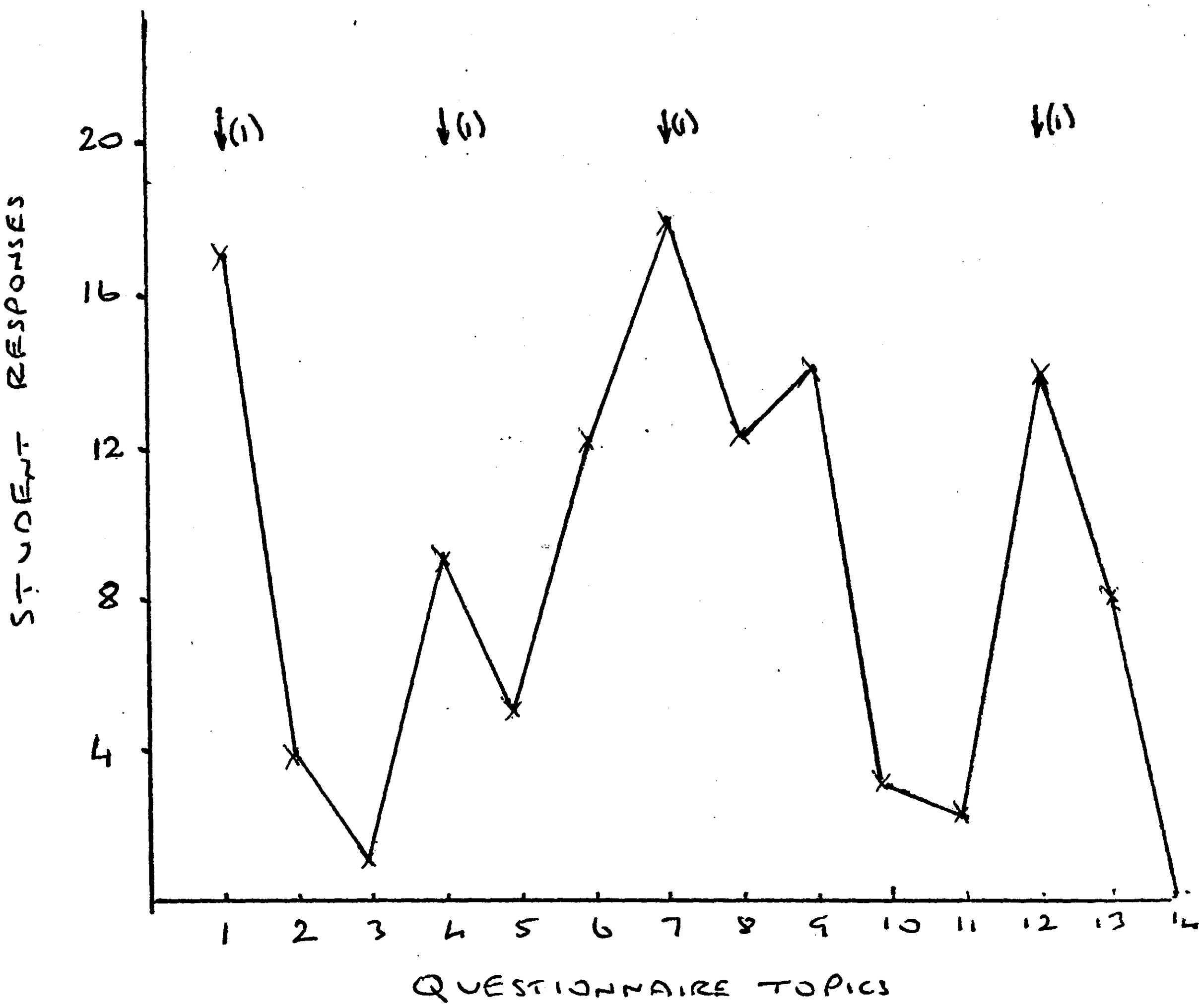
The lecturers' overall objective was the application of Redox theory in a more complex situation. The lecturers' specific objectives (unclassified) were -

(a) to standardise a solution of $Na_2S_2O_3$ by a given procedure using their acquired knowledge of Redox chemistry to carry out calculations.
(b) to determine the concentration of Cu^{2+} ions in solution by using a given procedure and relevant equations and their acquired knowledge of Redox chemistry.
(c) to acquire further practice in titrimetry.

The objective attainment graph is shown in Figure 9.

In this case it is a little difficult to select precisely the appropriate questionnaire response, but it is reasonable to propose (Question 1), (Question 4) (Question 7) and (Question 12). The cognitive objectives have been less obvious than would have been expected although the students have agreed on the relevance of thought before reporting. Again the psychomotor aspects have fared reasonably well and it is encouraging to find an interest or lack of boredom with regard to the experiment and its reporting and also in moderate terms with respect to the overall knowledge and understanding aspects.

Figure 9 Experiment 6 Estimation of Copper in Solution (18 students) (02)



EXPERIMENT 7 Heat of Solution

N.B. This experiment involved only a few students and observations must be tentative.

The lecturers' objectives were -

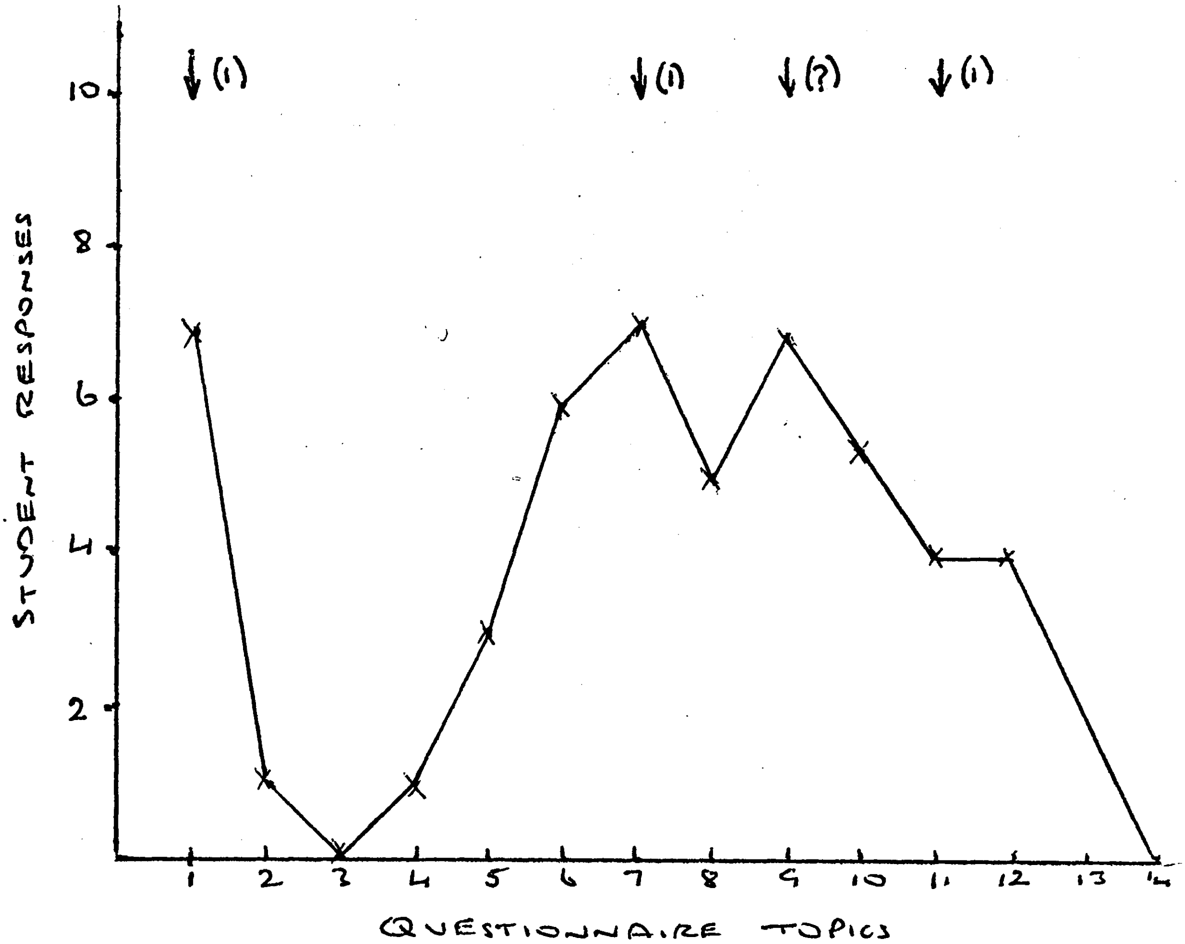
(a) the use of the Beckmann thermometer.
(b) the student should be able to carry out an experiment on calorimetry involving accurate weighings, accurate temperature measurements, accurate timings and volume measurements.
(c) the student should be able to use results in a calculation to determine the heat of solutions.

The objective attainment graph is shown in Figure 10.

In this the questionnaire related topics are (Question 1), (Question 7) and (Question 11). In addition, the novelty of the equipment to the student should have produced a positive response to (Question 9) although this was not an explicit objective of the experiment.

(Question 1), (Question 7) and (Question 9) have shown a more positive trend apparently than has (Question 11). Again boredom and an antipathy to report writing is not apparent.

Figure 10 Experiment 7 Heat of Solution
(7 students) (01)



EXPERIMENT 8. Conductivity and Concentration Relationships for Weak and Strong Acids

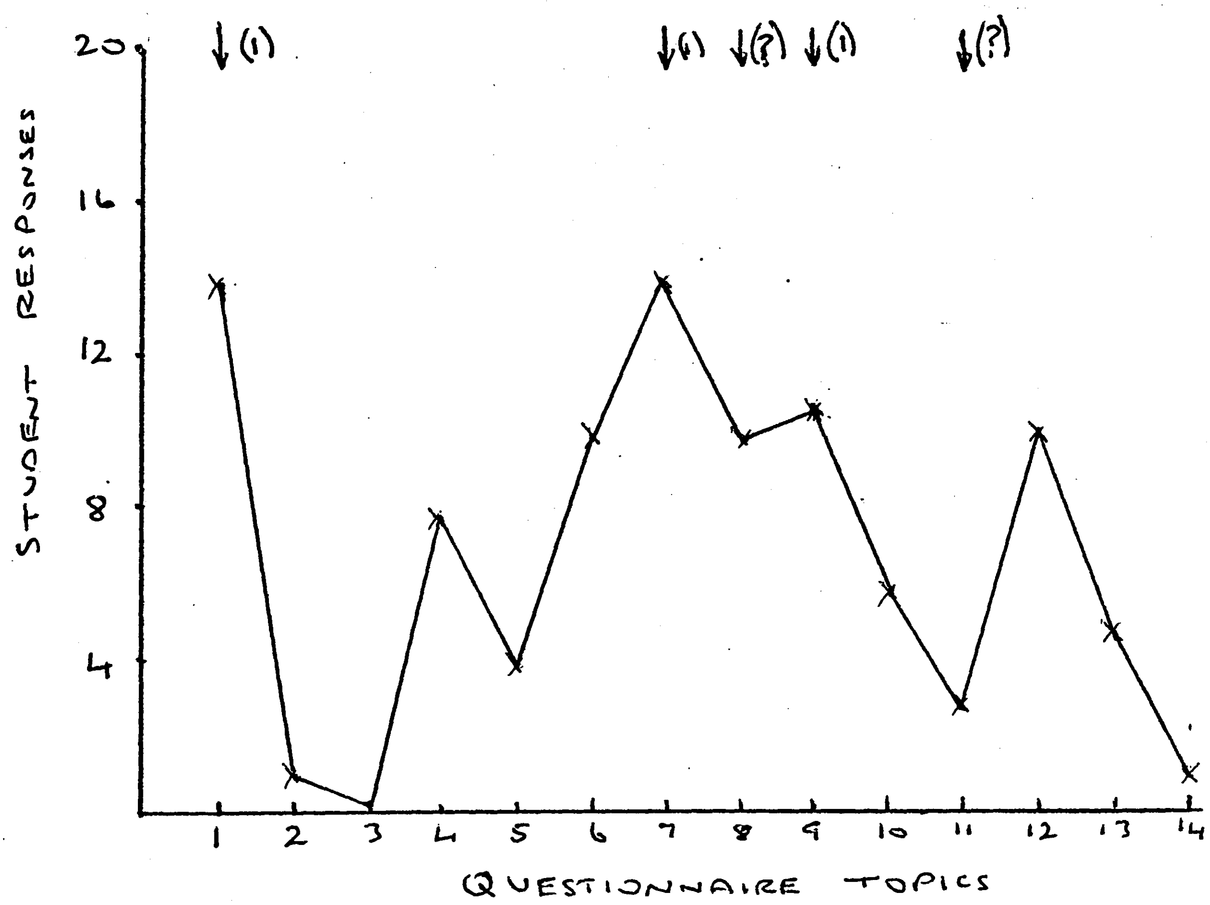
The lecturers' objectives (unclassified) were -

(a) the use of the conductivity bridge and the handling of the conductivity cell.
(b) the student should gain an understanding of the relationship between G, cell constant, K and Λ
(c) the student should be able to draw graphs of Λ against $\sqrt{c}$ for weak and strong electrolyte and make conclusions as regards sodium acetate and acetic acid.
(d) the student will require to use accurate volumetric work.

The objective attainment graph is shown in Figure 11.

In this case the questionnaire related topics are (Question 1), (Question 7), (Question 9) and probably (Question 11). ((Question 8) may be relevant depending on the degree of integration with lecture material.) Three of the objectives have been achieved but the response to (Question 11) is odd for the equipment and techniques were almost certainly new to the students. It may be that the students' perception has identified that part with which they were familiar. Yet again, interest appears to be present, the report is not an imposition and the added appreciation suggested by the response to (Question 9) suggests that they are getting something out of the exercise.

Figure 11 Experiment 8 Comparison of Λ / $\sqrt{c}$ / strong and weak electrolytes (14 students) (02)



EXPERIMENT 9 The Determination of the Molecular Weight of Urea by the method of the depression of freezing point.

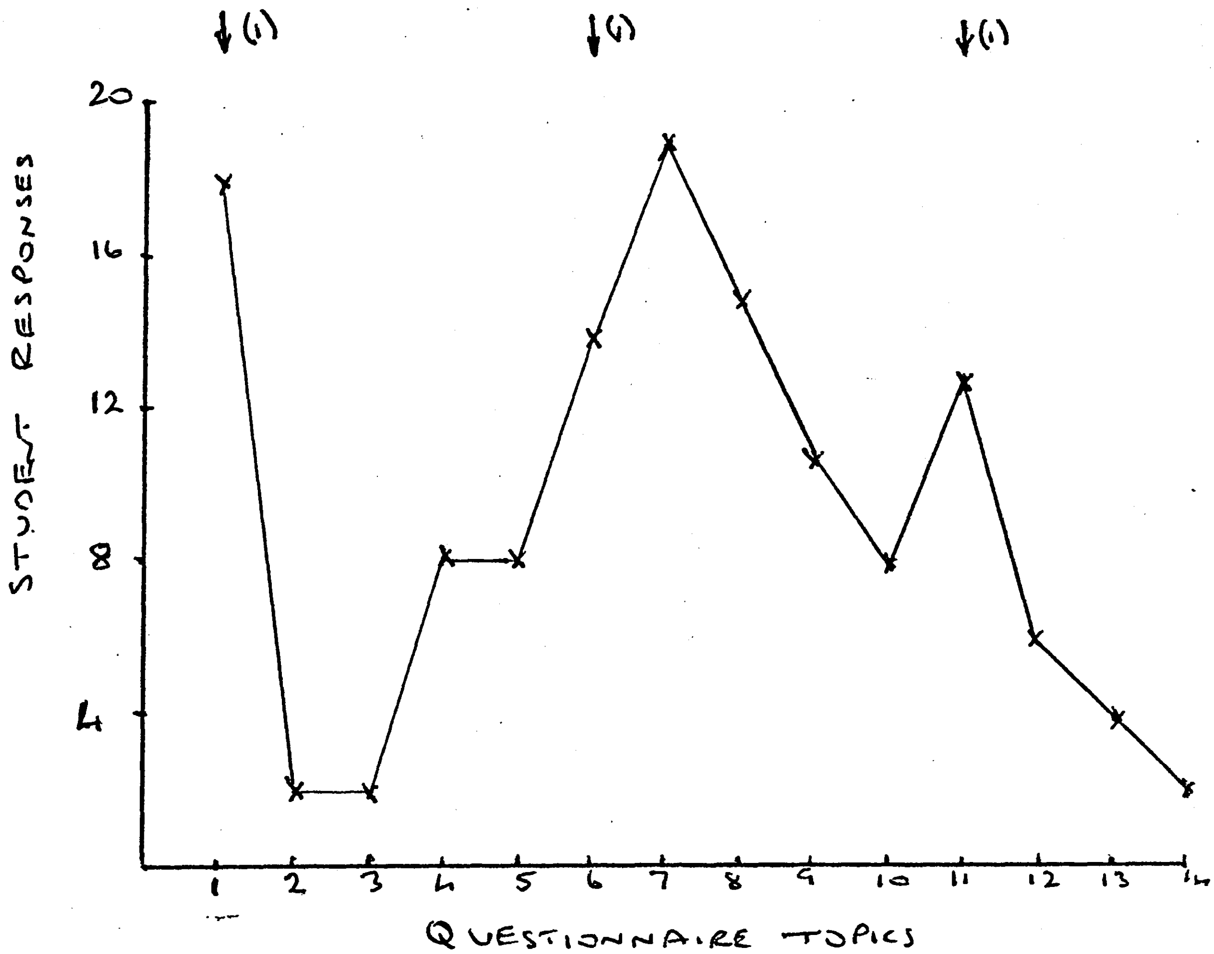
The lecturers' objectives (unclassified) were -

(a) the use of the Beckmann thermometer.
(b) the student should be able to make the necessary observations of temperature to obtain accurate results.
(c) the student should be able to substitute results into the depression of freezing point equation and calculate the molecular weight of urea.
(d) the student will have to weigh accurately.

The objective attainment graph is shown in Figure 12.

A limited set of objectives and a reasonable but not outstanding response to these. (Question 1), (Question 6) and (Question 11) appear to be the most relevant questionnaire topics. It is also to be noted that 15% of the students found the experiment to be helpful in understanding lecture material although this was not a specific objective.

Figure 12 Experiment 9 Determination of Molecular Weight by depression of freezing point (20 students) (02)



EXPERIMENT 10 Hydrolysis of Ethyl Acetate

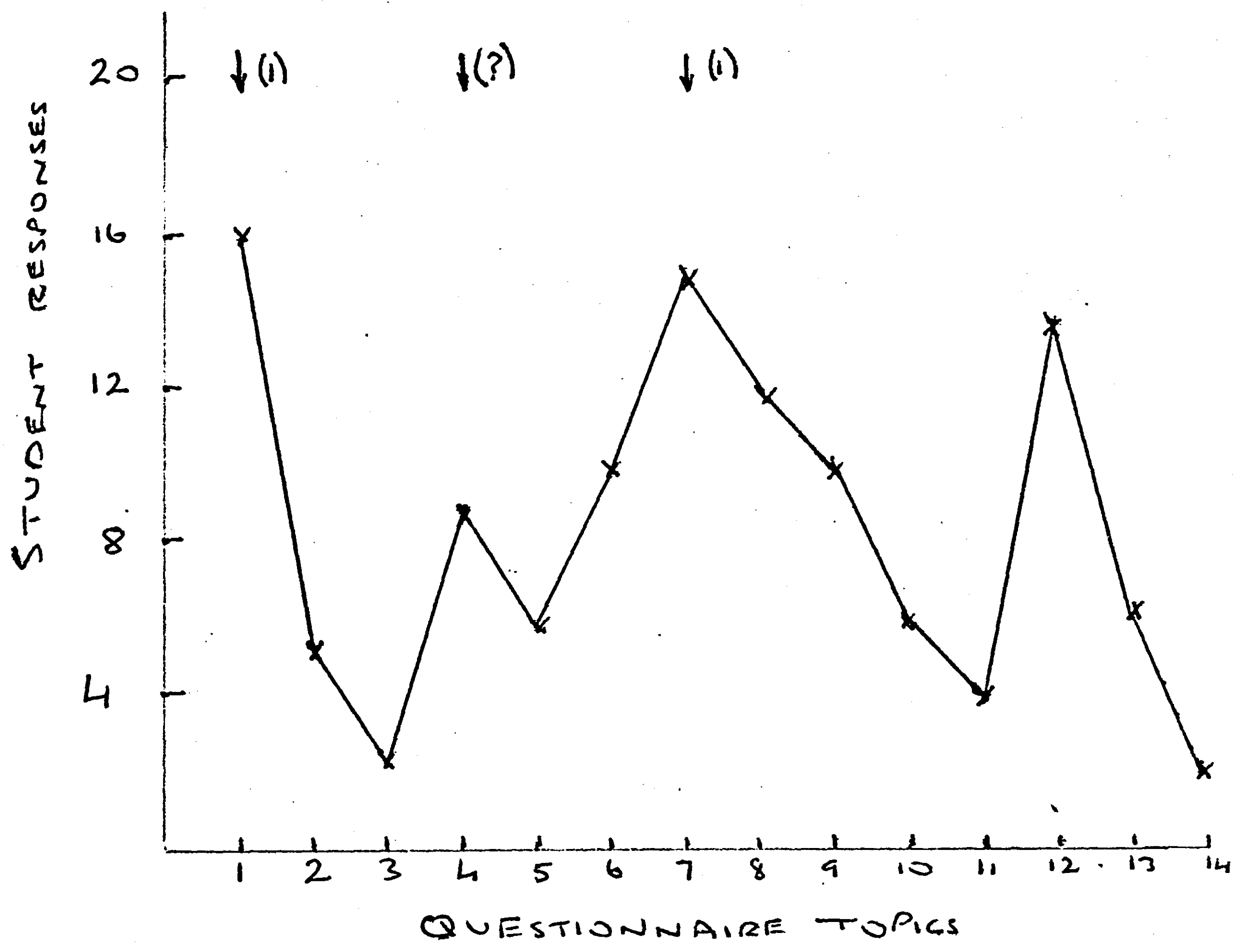
The lecturers' objectives (unclassified) were -

(a) from results obtained from experiment, students should be able to apply their theoretical knowledge to calculate the required equilibrium calculation.
(b) accurate volumetric work.

The objective attainment graph is shown in Figure 13.

The accent here is on applying knowledge and working accurately. Accordingly, the relevant related questionnaire topics are (Question 1) and (Question 7), both of which have shown a good response. It might have been reasonable to expect a more positive response to (Question 4) since in the light of the objectives consultation of lecture notes would have been a prerequisite for success.

Figure 13 Experiment 10 Hydrolysis of Ethyl Acetate
(Calculation of K_c)
(18 students) (02)



EXPERIMENT 11 Analysis of Anions and Cations using Semi-micro techniques

The interest in this particular experiment was that there were two different lecturers involved and each provided a set of objectives for their students, i.e. there were two groups of students involved.

Lecturer No. 1

Primary objectives:-

(a) appreciation of the significance of the operations commonly employed in qualitative analysis.
(b) illustration of how the reactions of individual component elements lead to analytical groupings and subsequent identification.
(c) introduction to the complete group analysis table.
(d) application of the solubility product principle.
(e) understanding that the quantitative analytical techniques are logical extensions of many of the procedures of qualitative analysis.
(f) introduction to semi-micro apparatus and operations.

Secondary objectives:-

(g) fostering safe working habits.
(h) working with economic quantities of material.

This is a reasonable set of objectives with the exception of (e) which seems inappropriate and beyond the capabilities of students at this stage in their education, i.e. 01 year. In addition (f) and (h) are really the same objectives.

Lecturer No. 2

This lecturer has less explicit and provided fewer objectives than Lecturer No. 1 although the broad aims are clearly the same. The author would suggest that, in terms of a description of the purpose of the exercise in relation to student learning, the first set of objectives /

objectives is more satisfying.

For the second lecturer the stated objectives are -

(a) to introduce students to the use of semi-micro apparatus and techniques.

(b) to illustrate some common reactions of ionic substances in aqueous solution.

(c) to indicate the type of observation which can be used for simple qualitative analysis.

The secondary objectives are -

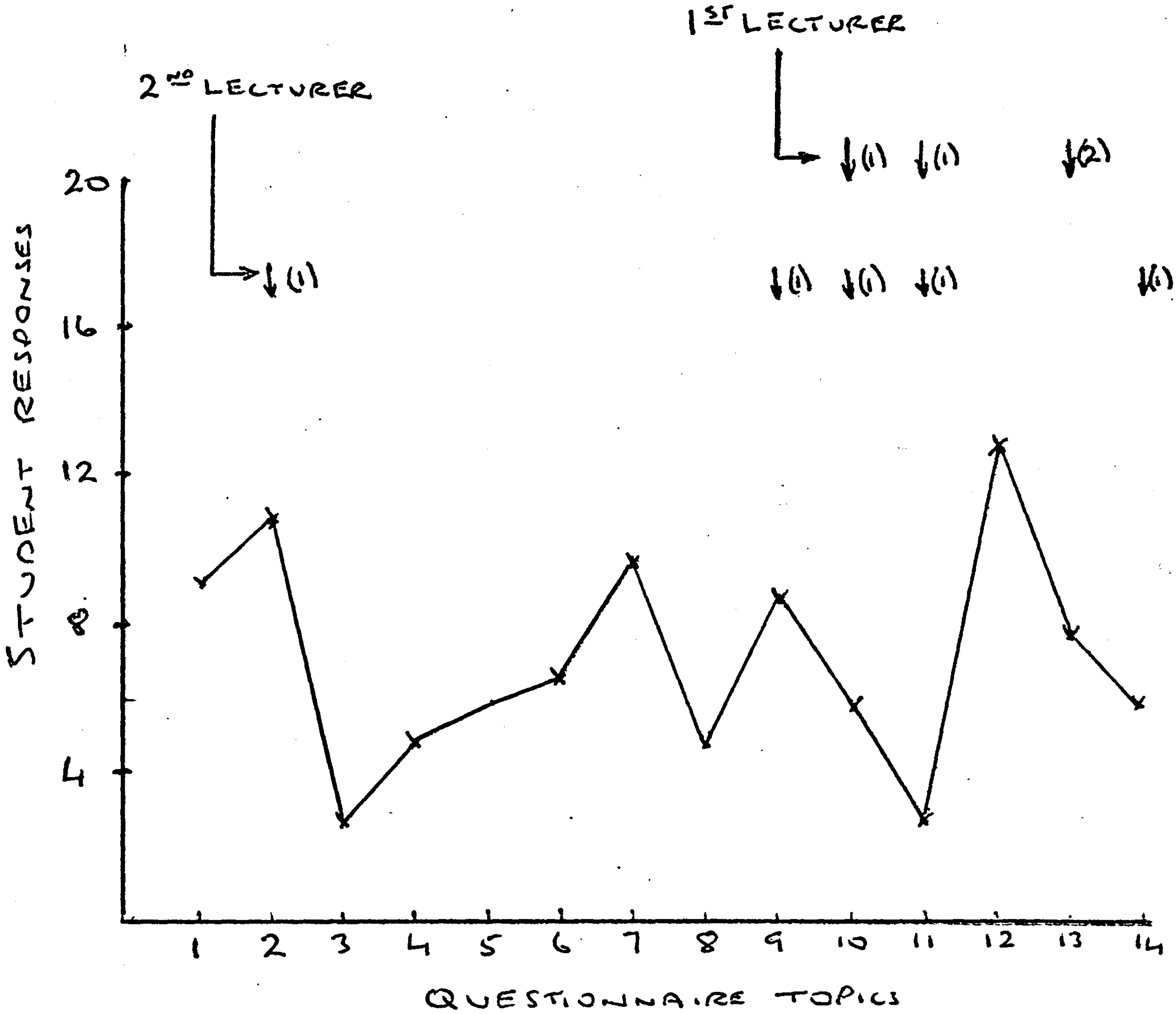
(d) to emphasise the importance of keeping careful laboratory notes if meaningful conclusions are to be drawn from a group of experiments.

In plotting the results the two groups of students have been combined and the two sets of objectives indicated separately.

The objective attainment graphs are shown in Figure 14.

The main points to note are that the response to (Question 2) is high but not as high as it might have been. The fact that the subject was an introduction to something essentially new to the students has not been recognised by them (Question 10) (Question 11). In addition by the nature of the exercise there are quite a few ideas, concepts and principles embodied in the work and yet the response to (Question 9) is not particularly good. Equally safety, if it is particularly relevant to qualitative analysis at this level, has impressed only half of the students while a higher than usual figure (6 out of 20) have found report writing to be an imposition. Overall the responses have been disappointing and this may reflect the comparative immaturity of the students, or could reflect on an inadequate presentation. (The author well remembers his reasonable efficiency at group separations in a 1st year Degree course. Understanding came in the 2nd year!)

Figure 14 Experiment 11 Qualitative Analysis (Separation of Anions/Cations) (16 students) (01)



EXPERIMENT 12   Preparation of n-butyl bromide

The lecturers' objective as stated was -

(a) to prepare an alkyl halide as an illustration of nucleophilic substitution reactions.

The secondary objectives as stated were -

(b) a knowledge of the fundamental structure of chemistry as a subject.
(c) a knowledge of important laboratory techniques.

In this particular case initially the objectives were far from clear and of little value for the investigation and could not be translated into the questionnaire topics.

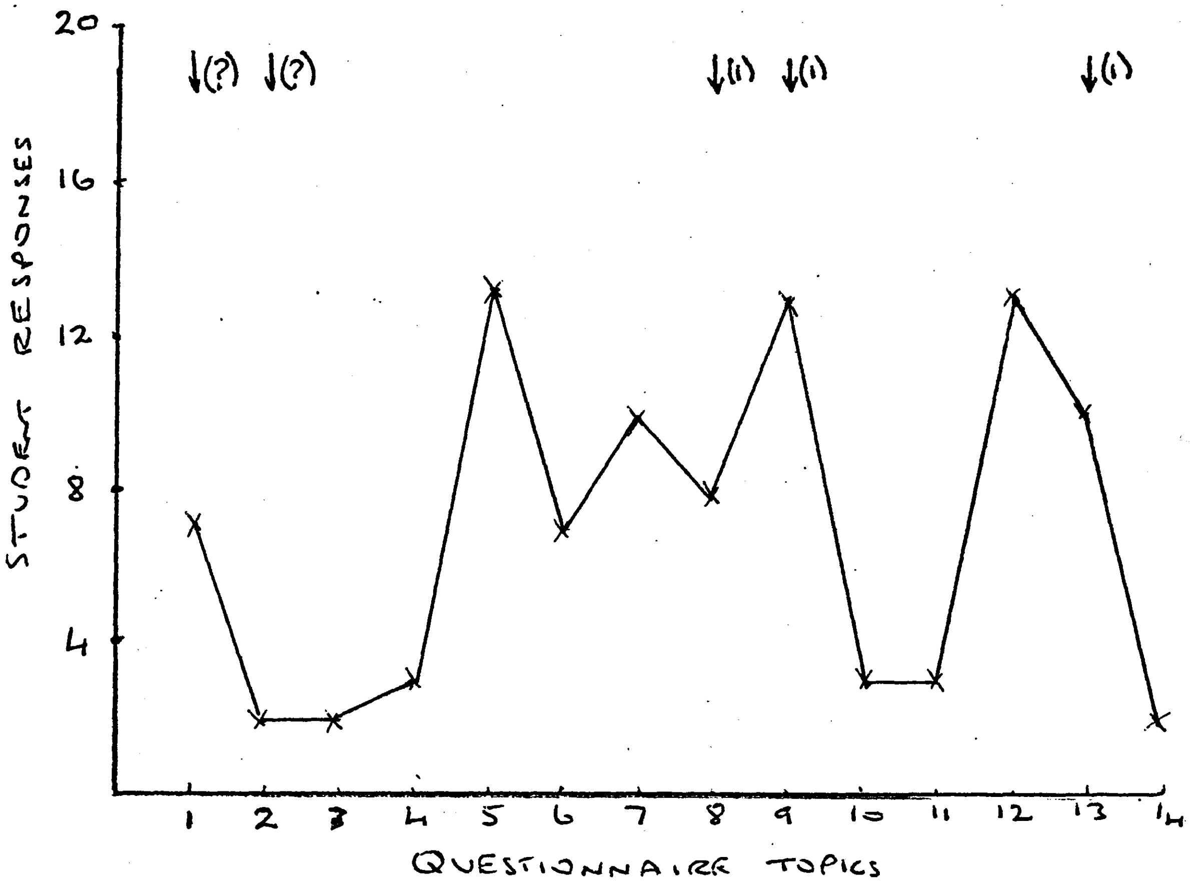
On further discussion it was agreed with the lecturer that more specifically the purposes of the experiment were to -

(i) apply a basic concept in the preparation of an organic compound.
(ii) safe working procedures.
(iii) to relate laboratory work to lecture material.
(iv) to introduce the idea of % yield
(v) to use simple procedures for checking purity, i.e. boiling point determination.

The objective attainment graph is shown in Figure 15.

The relevant related questionnaire topic or topics are (Question 8) and possibly (Question 9) and (Question 13) for the primary objectives since by implication, supported by the explicit secondary objective the experiment was designed to relate to lecture material. Only about half of the students were aware of this objective. Surprisingly (Question 1) and (Question 2) show a low score in a situation where observation at least would be relevant. An unusually high proportion of students found it necessary to consult lecture notes on /

Figure 15 Experiment 12 Preparation of n-butyl bromide (14 students) (02)



on the procedure rather than the purpose of the exercise. It is again encouraging to note a sense of an overall value in the experiment in the opinion of the students together with the acceptance of report writing without serious complaint.

Again since new ideas were being introduced a better response to Question 10 and Question 11 might have been looked for although the word 'technique' may have been off putting. The recognition of safety as a part of the exercise has been noted by 10% of the students and it may be a matter of concern that this is not higher in an experiment which requires a degree of care. (It is recognised of course that all chemical experiments require care for purposes of accuracy and/or safety. In some cases there must be a greater awareness of safety than in others.)

EXPERIMENT 13 The effect of changes of concentration and temperature on the rate of chemical reactions.

As in the case of Experiment 11, there were two sets of objectives available and from the same two lecturers as in Experiment 11. An interesting point is that the lecturer who had previously been quite specific was no longer so and stated the objectives as -

(a) demonstration of the Law of Mass Action.
(b) effect of temperature upon the rate of reaction.

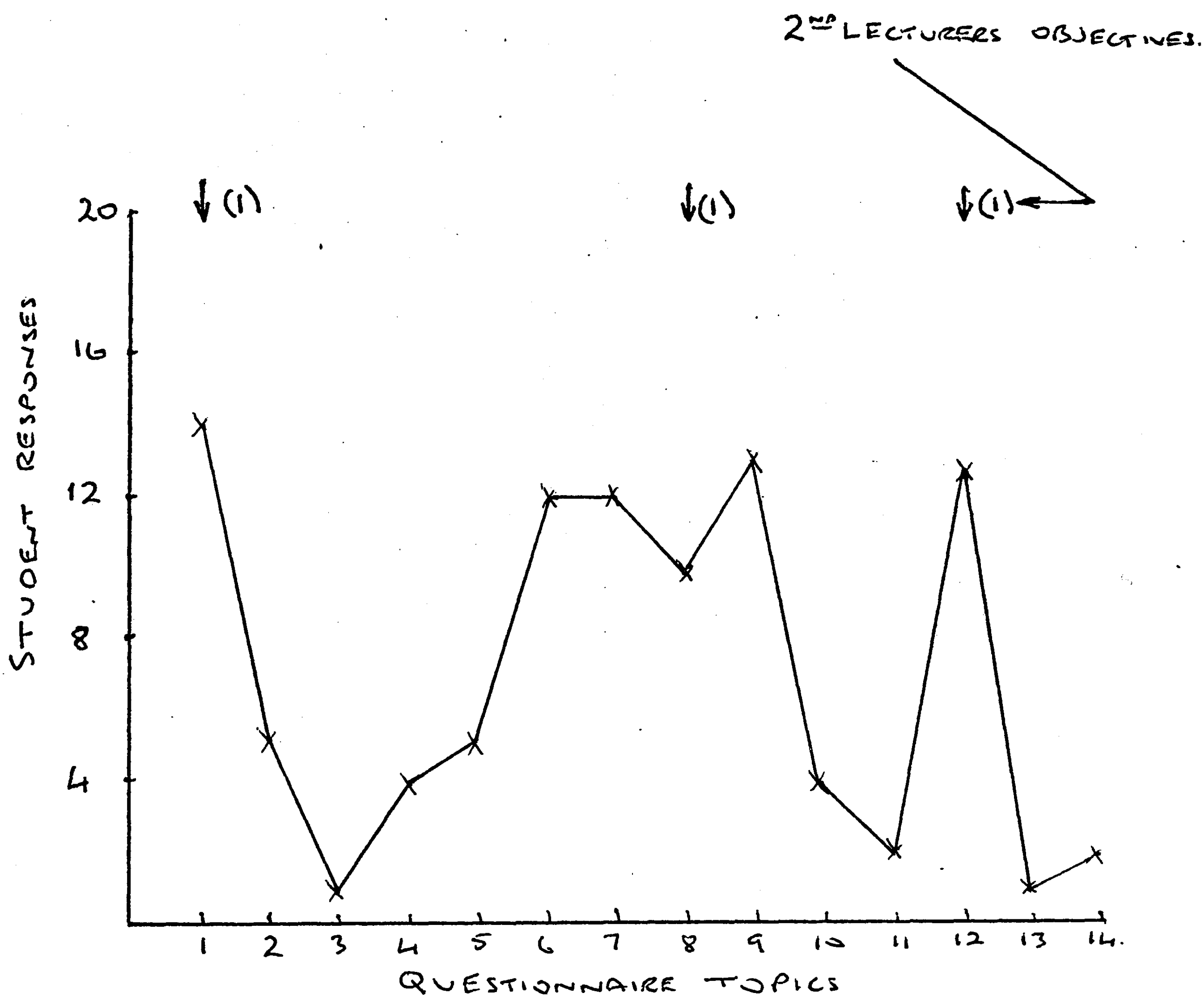
The other lecturer considered that the primary objectives were -

(a) to reinforce lecture material on the factors affecting rates of reaction.
(b) to introduce students to quantitative measurements in chemistry and the graphical presentation of experimental data.
(c) revision of volumetric techniques.

The objective attainment graphs are shown in Figures 16 and 16A.

The three reasonably stated but unclassified objectives are related to Question 8, Question 1 and Question 12, i.e. the emphasis is on quantitative work related and designed to support theory and with a practical revisionary element. All of these have been achieved by the students. Again there is a degree of interest and an appreciation of the overall educational purpose of the experiment (Question 9). Finally, it is to be noted that overall and despite the variable quality of the objectives the general pattern of response with two possible exceptions is broadly similar for the two groups.

Figure 16 Experiment 13 Effect of Concentration/ Temperature on reaction rate (15 students (01)



N.B. BECAUSE OF THE DIFFICULTY OF TRANSLATION THE 1ST LECTURERS OBJECTIVES HAVE BEEN OMITTED

Figure 16A . Experiment 13 Effect of Concentration/ Temperature on reaction rate

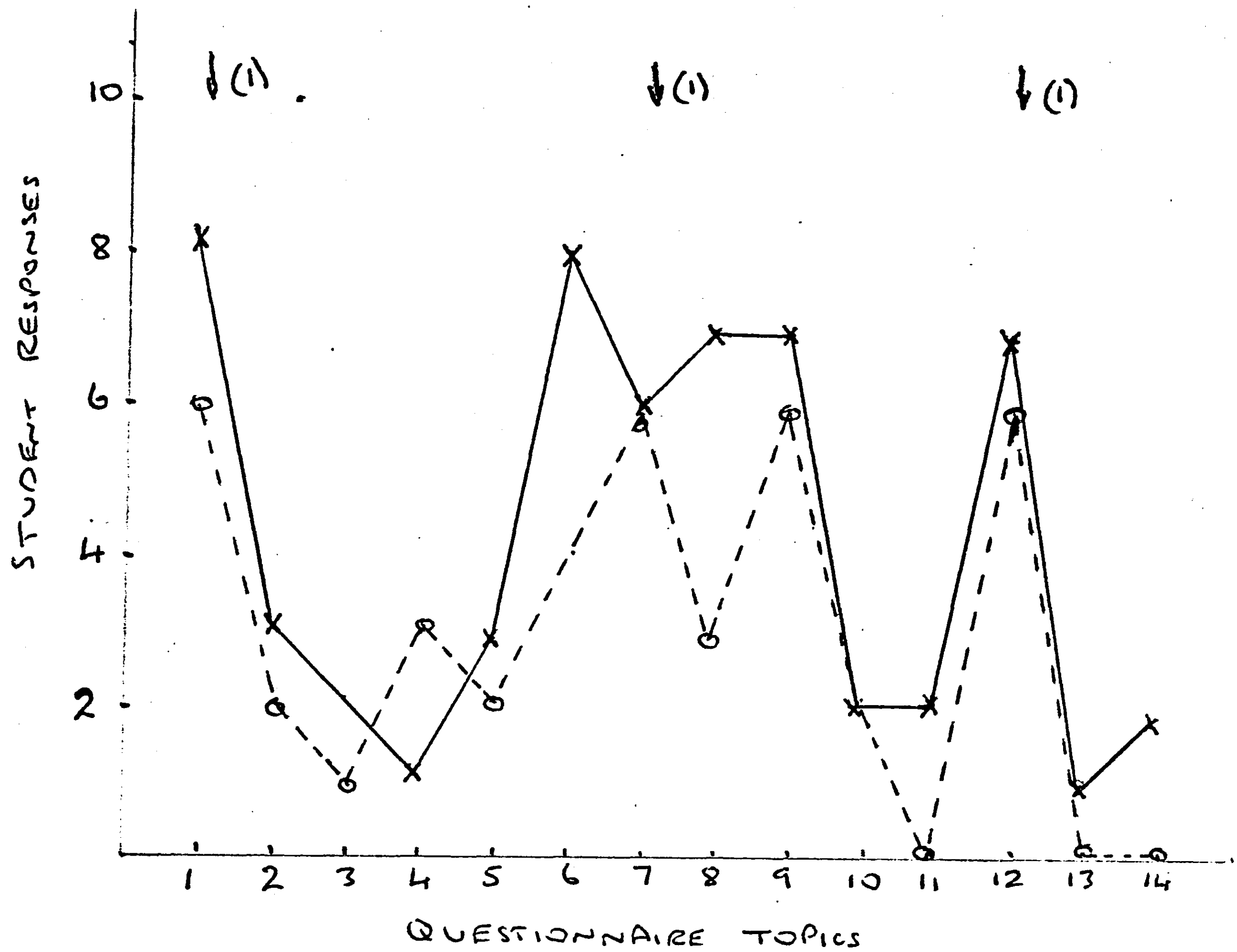


FIG 16 RE-DRAWN BY STUDENT GROUPS

x———x 9 STUDENTS

o - - - - o 6 STUDENTS

EXPERIMENT 14 Heat of Reaction ($CuSO_4/Zn/Fe$)

The lecturers' objectives for this experiment are not very helpful and were stated as -

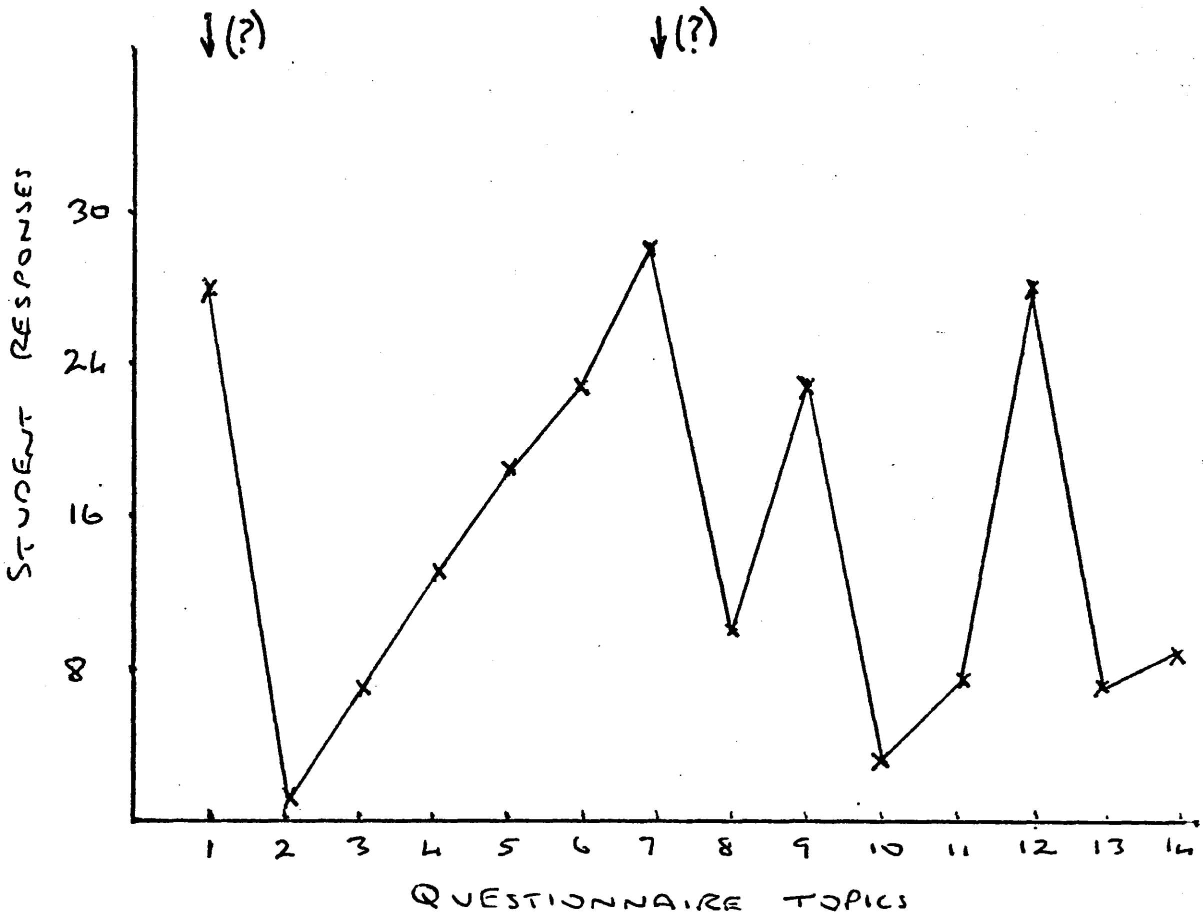
(a) to develop skill and dexterity in handling equipment and to work independently to achieve as an end product a result which will depend on individual results being collated.

(b) to show that a fairly sophisticated concept can be made fairly simple by introducing simple inexpensive equipment.

Secondary aims "as above".

From a perusal of the laboratory instruction sheet the accent is on measurement and interpretation and both have been achieved in (Question 1) and (Question 7). The students on the whole appeared to have gained something from the experiment; Question 3 (8 were bored!) and (Question 9) (23 students identifying the overall knowledge aspect of the experiment).

Figure 17 Experiment 14 Heat of Reaction
(33 students) (01)



EXPERIMENT 15 Identification of an Unknown Organic Compound

The lecturers' stated objectives for this experiment were as follows.

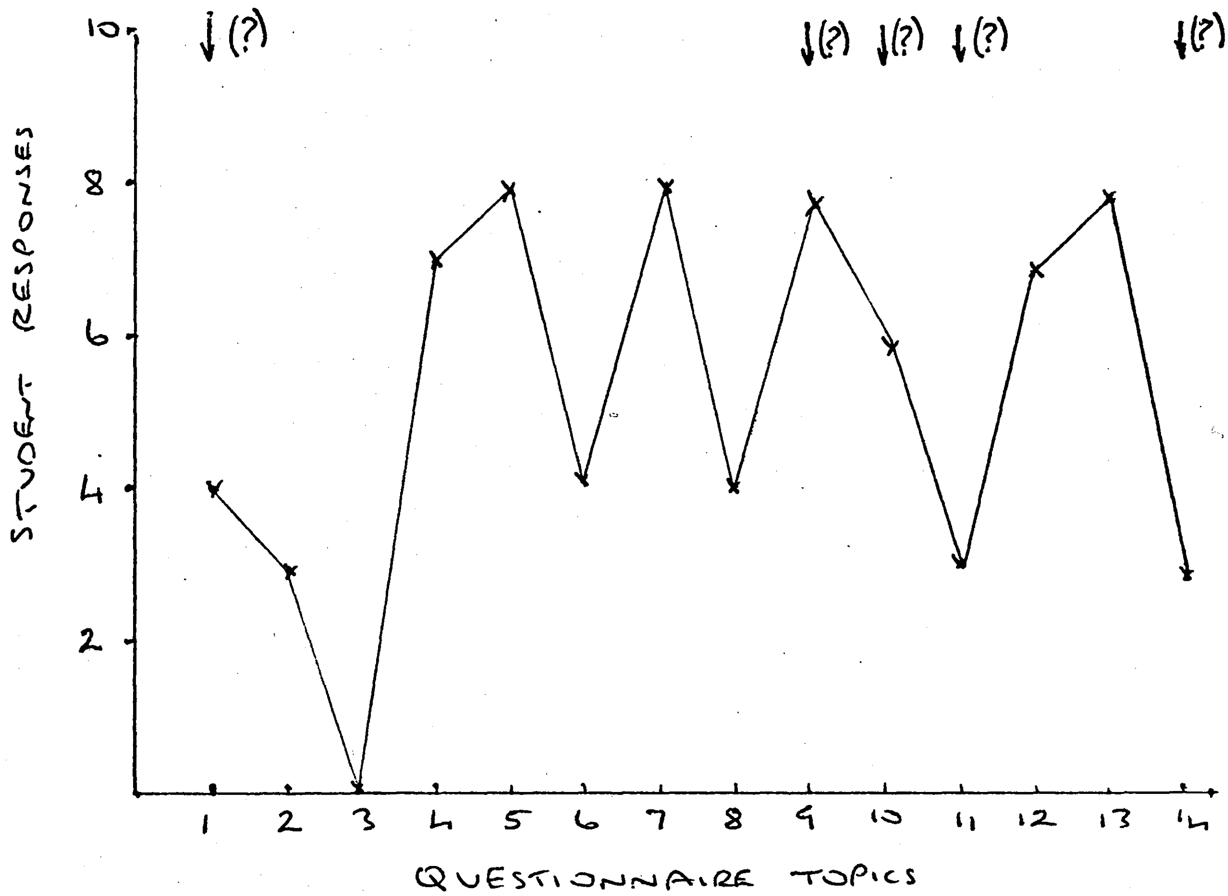
The primary objective was to provide an introduction to the procedures by which organic compounds are identified while the secondary objectives were -

(a) the ability to obtain, present and communicate information.
(b) an enthusiastic and inquisitive attitude to chemistry.
(c) the ability to observe accurately and objectively.
(d) a knowledge of the relevance of college laboratory work to their development as professional chemists.
(e) development of investigational skills.

These objectives are a heterogeneous mixture of aims rather than specific objectives and it is doubtful if some of them can be measured in the short term. The author, therefore, tentatively suggests that the questionnaire related topics are (Question 1), (Question 9), (Question 10), (Question 11) and (Question 14).

Since the emphasis is on observational skills rather than measurement the response to (Question 1) is surprising. There is an inconsistency between (Question 9), (Question 10), (Question 11) and (Question 3). None of the students found the experiment to be pointless or boring (Question 3) and 75% thought it had added to their overall chemical knowledge (Question 9). About half of the group claim to have become interested in an aspect which was clearly new to them (c.f. Question 3). It may mean however, that lack of boredom does not necessarily infer a great deal of interest. (Question 11) is certainly odd because they had to use techniques for the first time. It is very doubtful if three quarters of the class had had previous experience of the methods used unless, of course, equipment /

Figure 18 Experiment 15 Identification of an Organic Unknown (11 students) (02)



equipment is being interpreted as 'methods'. The objectives place more emphasis on report writing but 8% of the students have tended to find report writing as something of an imposition.

EXPERIMENT 16 Basic Techniques of Organic Chemistry Practical Work (Recrystallisation and Determination of Melting Points)

In this introductory experiment the lecturers' objectives were -

Primary objectives:

(a) to develop skill and dexterity in handling equipment such that technique improves to a standard high enough to produce a confidence and competence in the student leading up to subsequent (02) organic laboratory work.

Secondary objectives:

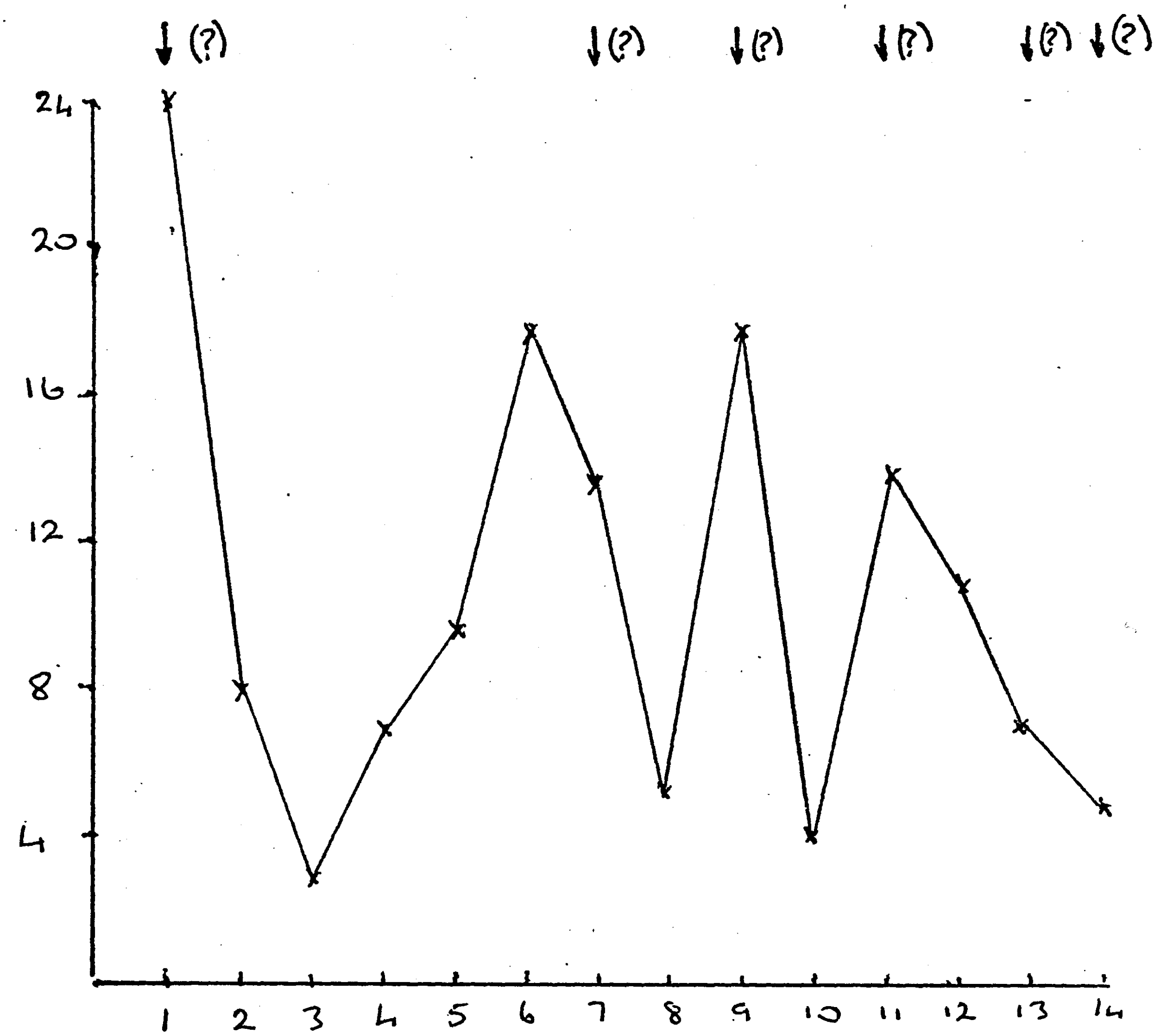
(b) develop a safety conscious attitude and to introduce safe working methods.
(c) obtain, pursue and communicate information.
(d) produce a concise and logical report.
(e) promote enthusiasm.
(f) instruct in accurate objective observations.
(g) encourage independence.

The objective attainment graph is shown in Figure 19.

The primary objective is an aim rather than an objective which can only be achieved, it is suggested, as the students experience a range of experiments. It is also difficult to see the sixth of the objectives as one which can be readily achieved within the context of the particular experiments involved. In addition, this is a teacher's intent and not a student experience!

However, that said, the questionnaire related topics would appear to be (Question 1), (Question 7 ?), (Question /

Figure 19 .Experiment 16 Basic Techniques of Organic Chemistry (24 students) (01)



(Question 9 ?), (Question 11), (Question 12) and (Question 14). In this case only (Question 1), i.e. the observational aspects shows an adequate response. The responses to (Question 11) are disappointing especially since the work was an introduction to practical organic chemistry while the students' acknowledgement of the safety aspects is totally unsatisfactory. One might expect the mature student to become blasé on safety but not the initiate!

EXPERIMENT 17 The Preparation of Ethyl Acetate

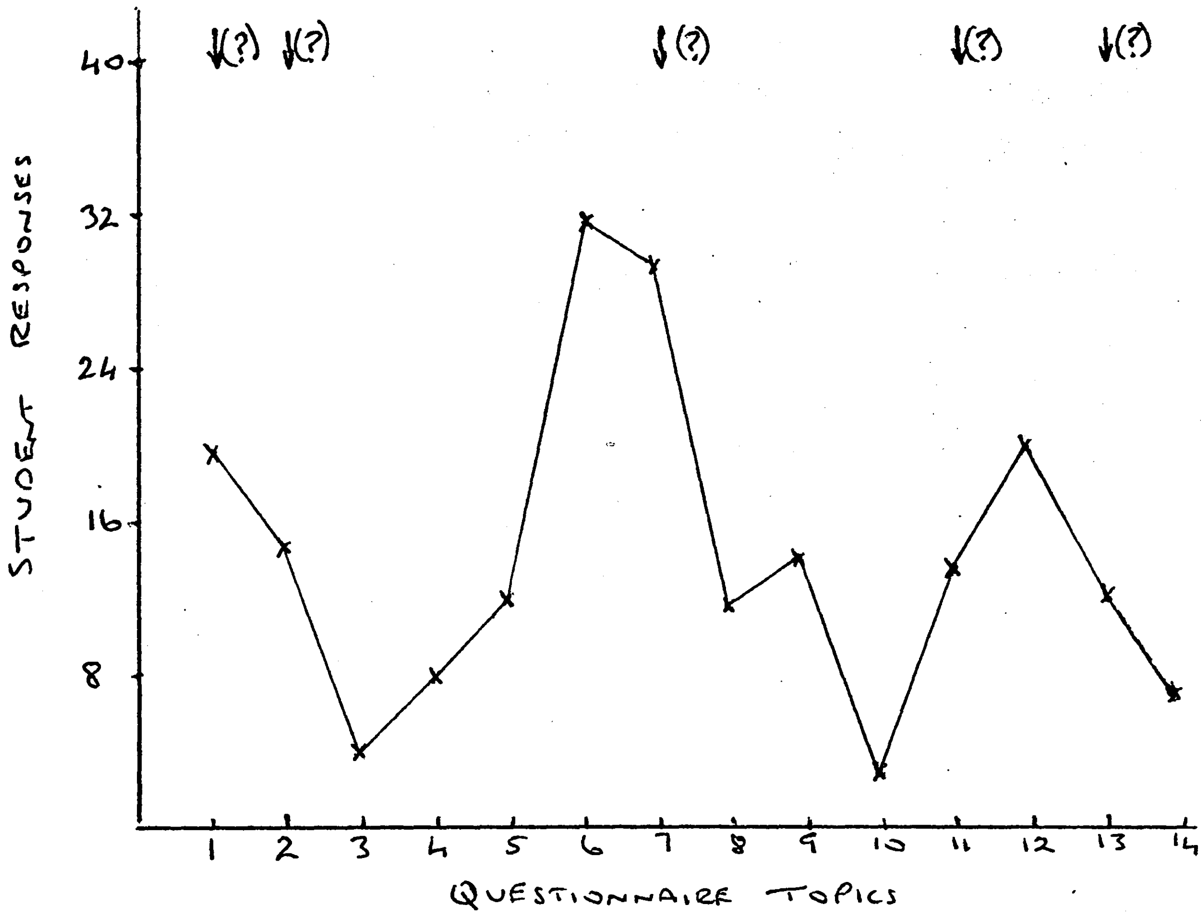
This is one experiment which can be compared on a college basis. In this particular case the 'objectives' are defined in terms of the SCOTEC learning objectives (c.f. Experiment 2). Accordingly, for the preparation of ethyl acetate the departmental objectives in this case are:-

(a) a knowledge of safety hazards and of safe working methods; the development of a safety-conscious attitude.
(b) the ability to obtain, pursue and communicate information.
(c) a knowledge of important laboratory techniques; the ability to use equipment and to interpret experimental results.
(d) the ability to work independently and as a member of a team.
(e) a knowledge of the relevance of college laboratory work.

As previously indicated these learning objectives were designed to be broadly based overall aims relating to the general philosophy of the total practical course and not designed for specific application to individual experiments. None the less, this college tends to use them as learning objectives.

However, in attempting to translate the objectives into questionnaire topics (Figure 20) it appears that the /

<u>Figure 20</u> Experiment 17 Preparation of Ethyl Acetate
(27 students) (01)



the relevant topics are (Question 1, Question 2), (Question 7), (Question 11), (Question 12), (Question 14). The observational/measurement aspects have not fared particularly well but on the other hand, the majority (80%) agree that interpretation of results was necessary before preparing a report. Unlike other students in other colleges the overall purpose (Question 9) of practical work has been rather devalued (about half of the class in favour) while again safety aspects are identified by only half of the students. A higher proportion than usual find the report preparation something of an imposition.

EXPERIMENT 18 Preparation and Standardisation of .02M potassium permanganate solution

This is considered to be a simple tutorial and an introduction to electron transfer reactions. Again the SCOTEC objectives are used and in particular those relating to -

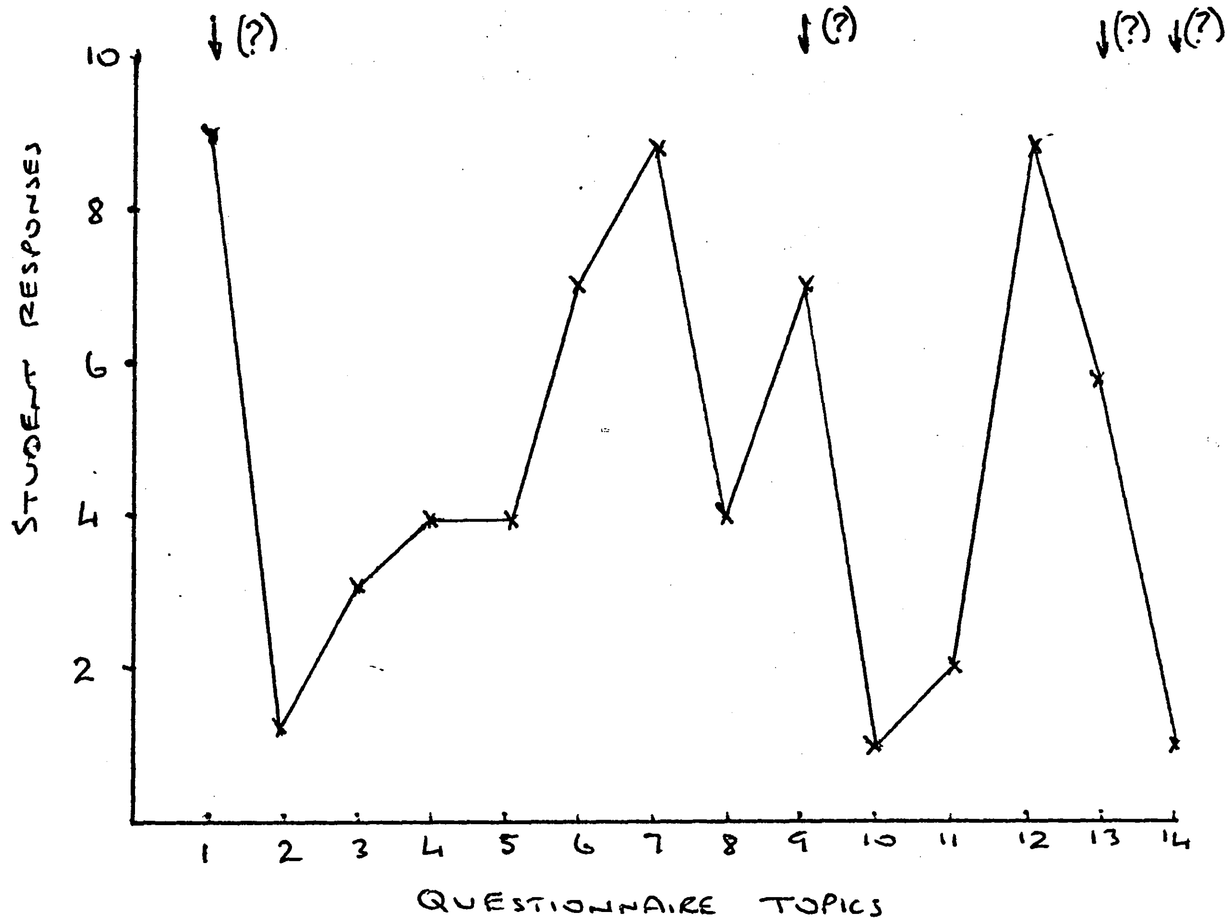
(a) safe working methods.
(b) obtaining, pursuing and communicating information.
(c) an enthusiastic, inquisitive attitude to chemistry.
(d) accurate and objective observation.
(e) the ability to work independently and as a member of a team.
(f) a knowledge of the relevance of college laboratory work.

Again, it is apparent that whatever the value of objectives, some of these are rather meaningless. What have the students to do to demonstrate their attainment of objectives (c), (e) and (f) ?

Interpretation of the objectives is shown in Figure 21.

Observational skills appear to be relevant allied with the ability to measure (Question 1). About one third /

Figure 21 Experiment 18 Standardisation of K MnO_4
(10 students) (01)



third found the exercise boring, (Question 3), and allied with this 7 out of the 10 considered the experiment relevant to their overall knowledge of chemistry (Question 9). Some success for the 'enthusiasm' objective? 40% of the students considered the experiment as helping in lecture material (Question 8). Again surprisingly the new technique aspect shows a poor response and for an O1 class this is odd. The author would not have thought that safety was in any special way significant in this experiment compared with, say, some organic experiments. None the less, it is mentioned as an objective and 60% of the students have identified safety as a learning experience.

EXPERIMENTS 19-21

Again in these experiments from a third college the objectives were relatively scant and lacked the precision of some of the previous experiments.

<u>EXPERIMENT 19</u> Heat of solution of sodium hydroxide

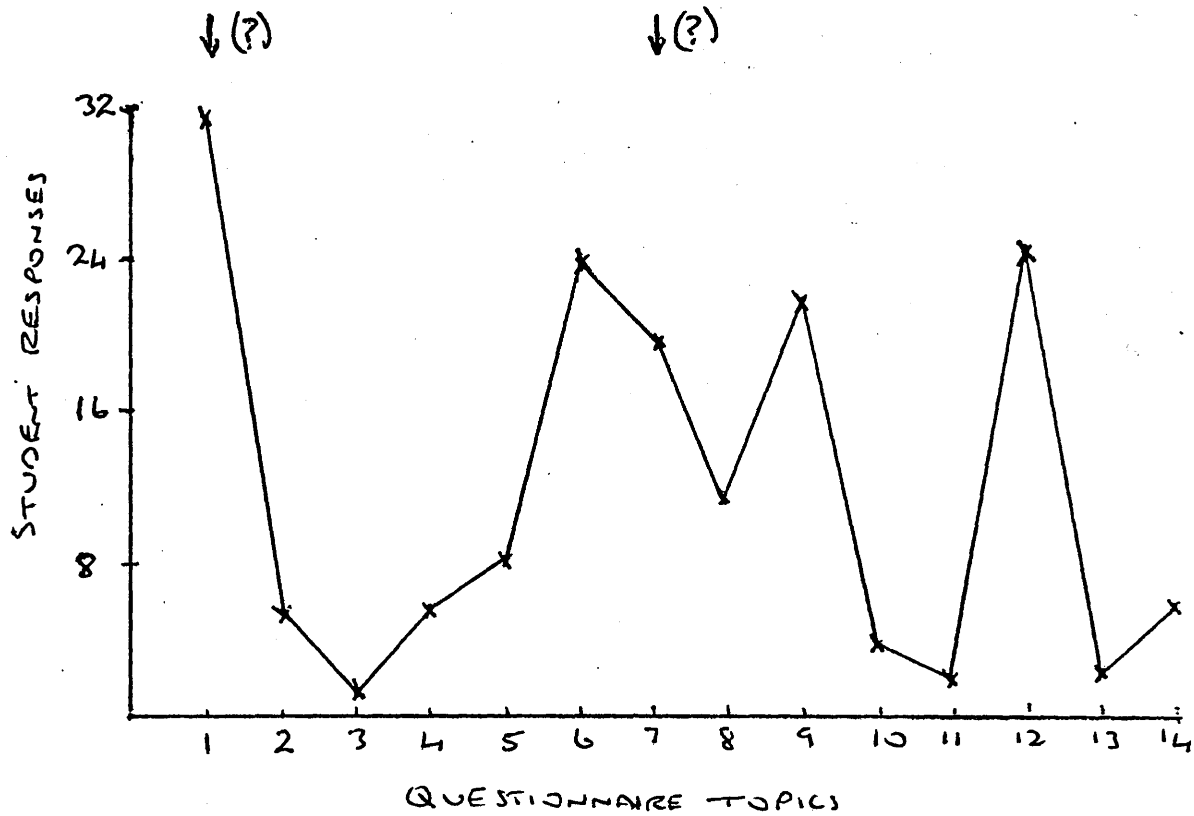
The lecturers' primary objectives were stated as being accurate and fast thermometer reading and manipulation of data to give thermodynamic data.

The secondary objectives related to the manipulation of Dewar flasks and fast addition of solutions.

The objective attainment graph is shown in Figure 22.

The students have agreed with the observational and measurement objectives (Question 1). They have not found the experiment boring and they have been told everything necessary for the experiment and the report. The relationship between the experiment and lecture material was apparent to only about 40% of the class. (Had the rest never heard of heat of solution or are they claiming that they never had a lecture relating /

Figure 22 Experiment 19 Heat of solution
(28 students) (01)



relating to the heat of solution of sodium hydroxide!) In spite of this latter response 22 out of 28 students considered the experiment relevant to their overall chemical knowledge (Question 9). The remainder of the topics were along the expected lines.

Two students commented that the experiment was "utter rubbish" and "a waste of time"!

EXPERIMENT 20 Heat of neutralisation - NaOH/HCl

The lecturers' primary objective was the accurate and rapid recording of temperature measurement. The secondary objectives were the accurate measurement of volume and the manipulation of data to give thermodynamic information.

The objective attainment graph is shown in Figure 23.

As usual the relevance of measurement has been noted by students (Question 1). With the objectives as stated it could hardly be any other way! The one other objective relates, to manipulation of data. If this means something more than filling up blanks in a formula then a response greater than that obtained might have been expected. The students felt equally strongly or indifferently to the relevance of the experiment in relation to theory and only 8 of the group of 14, unusually low for this topic, considered the experiment relevant to their overall knowledge of chemistry.

EXPERIMENT 21 The Cracking of Paraffin

The lecturers' objectives here are simple and possibly quite inadequate to potential learning. They are stated as -

Primary objectives: observing the result of thermal degradation of oils.

Secondary objectives: use of distillation type equipment.

The objective attainment graph is shown in Figure 24.

Figure 23 .Experiment 20 Heat of Neutralisation (NaOH/HCl) (14 students)(01)

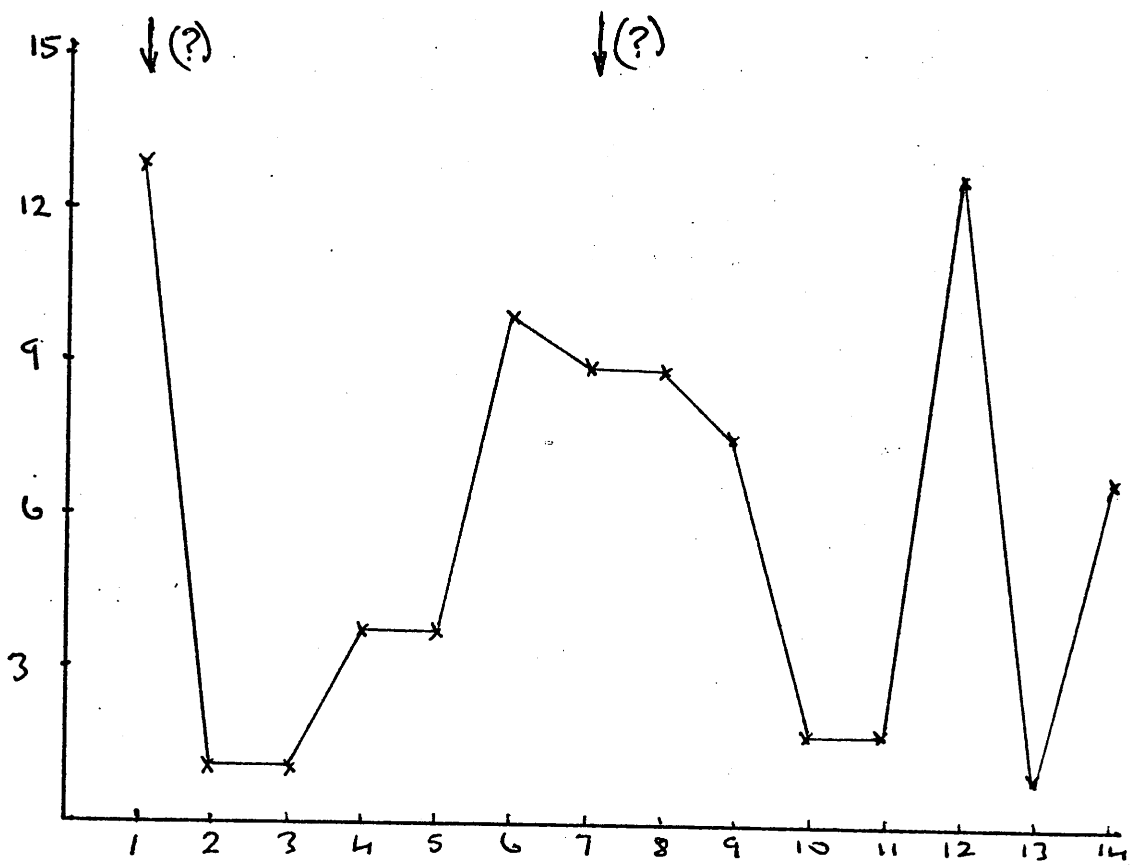
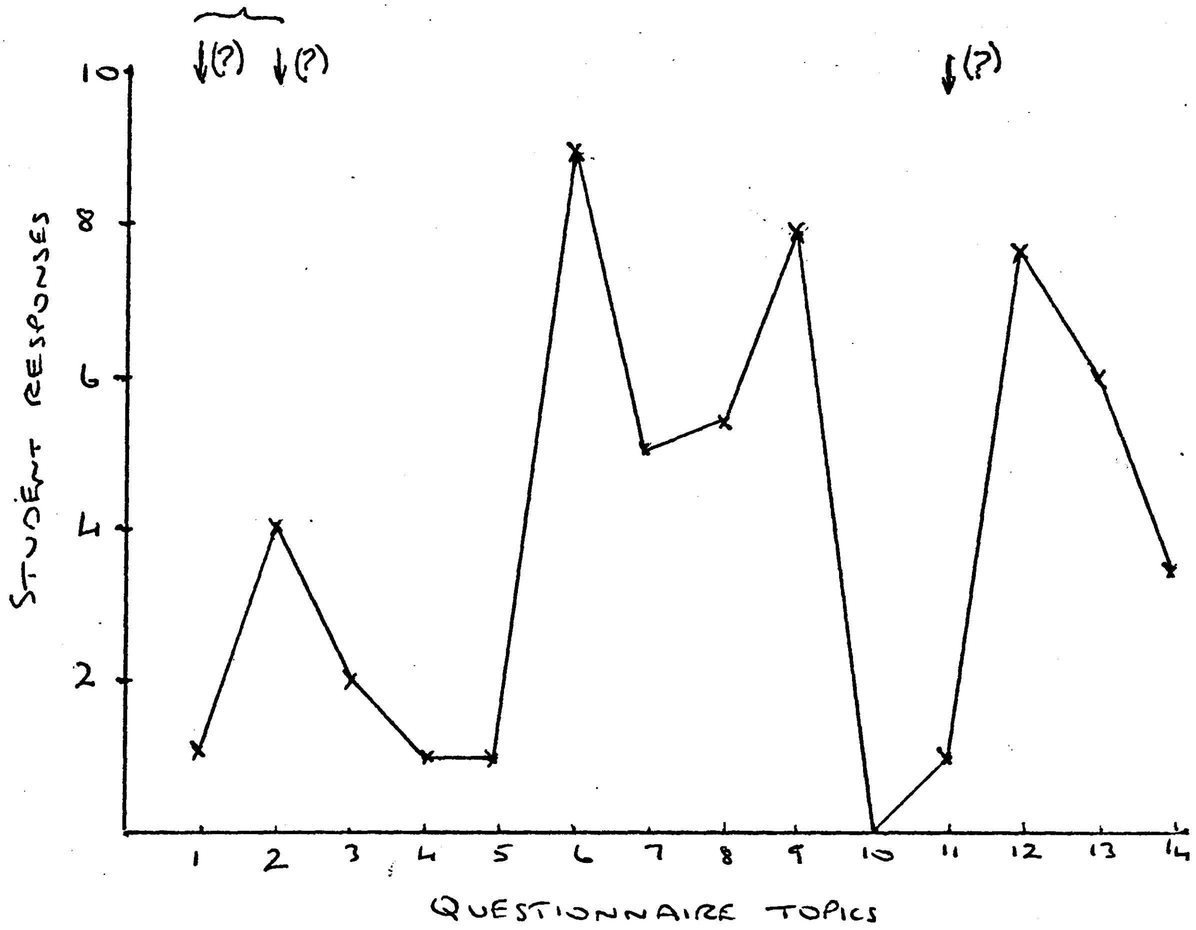


Figure 24 Experiment 21 Cracking of Paraffin
(13 students) (02)



The students in this case saw neither an observational or an observational/measurement purpose in the experiment. What is equally astounding is the response to Question 11! Apparently the students have vast experience in distillation of paraffin! (Because of the location of this college it is possible that 'cracking' on an industrial scale is well known to the students.)

The students were not apparently bored by the experiment but in general were not over-impressed in relation to any learning they achieved as judged by the general pattern of responses. It should be noted that surprisingly safety or safe working is not a relevant objective. The students, unfortunately, tend to agree with this! (Question 13)

There were several other experimental results of the above type available but it is considered that sufficient examples have been given to indicate the nature of the strengths and weaknesses in the practical situation vis-a-vis the role of objectives.

The general discussion of the results of this part of the investigation is considered in Chapter 8.

However, it has been noted that as previously indicated the 'objectives' show considerable variation in objectivity and specificity. They have been reported as stated by the lecturers, to demonstrate the problems of translating them to the language of the questionnaire. While it is not the author's desire to criticise the lecturers, the implication cannot be avoided.

6.5 Some Views on Behavioural Objectives

There are those in educational circles who are so attracted to behavioural objectives that their whole thinking about educational methods appears to be in something /

something of a strait jacket. Everything it seems within the area of technological education has to be expressed in behavioural objectives if it is to be worthwhile. The present author occupies a middle ground position valuing the role of behavioural objectives as an educational tool which is more relevant in its application in some areas of technological education than in others. It is the author's opinion that because there is an inability to describe an educational intent in behavioural terms this does not mean that the educational exercise is valueless. This is realistic.

Clearly there are areas of practical work where it is desirable that the student should demonstrate the attainment of basic skills without which his skill as a chemist might be in doubt. The term 'might' is used because to the O.N.C. chemist, for example, the attainment of experimental skills may not be a pre-requisite to his development and progress in industry. However, considering that, as has previously been indicated, the O.N.C. and the succeeding H.N.C. are concerned with chemical education for its own sake then a majority opinion would probably agree, at the present time, that practical skills were essential to that education if it is to be broadly based in a chemical sense.

There are areas like the development of interest, of enquiry, of enthusiasm which it would be hoped would be part of the make up of the developing professional chemist. These can be observed but not easily measured in an objective and reliable way. Behavioural objectives are irrelevant in such areas.

Johnstone[20] has pointed to the dangers of an over and mis-placed enthusiasm for objectives:- "Our noses can be pressed so hard against the bark that we cannot see the trees, let alone the forest".

Even /

Even Tyler[21], the father of the objective, has shown his concern for the way in which objectives can be misunderstood and hence mis-used.

The situation in practical work in the O.N.C. demonstrates the contrast between the possible relevance or irrelevance of behavioural objectives. It has been noted previously that the notes for guidance[3] are concerned with broad educational aims rather than with objectives although the need to identify the latter for individual experiments is also stressed.

Whatever the role, purpose or benefits of approaching practical work in chemistry on a behavioural objective basis, it has become apparent (see EXPERIMENTS 1-21) that the lecturers' ability to write objectives shows wide variation. In some cases it is open to question as to whether the stated objectives are capable of being assessed. It does seem reasonable to suggest that the lecturers should look to improving their expertise in this area at least to the point where the lecturer can tell the students the precise purposes of any one experiment.

If any general conclusion can be reached on this part of the investigation it is that while some educational success is being achieved by the student in the laboratory the overall pattern is like the objective writing, uneven. It is not being suggested that there is a relationship between these two aspects.

It has been hinted by Wood[22] that there is evidence to suggest that the transmission of cognitive objectives from lecturer to student via the experiment is more successful than are "attitude" objectives. Certainly it would appear easier to define a cognitive objective as compared with an attitudinal one and in addition the attainment of the former would be easier to measure within the framework of a given experiment or project. Attitudinal or affective objectives, the author /

author would suggest, are probably best considered as aims rather than objectives to be assessed, (and the measurement is not easy), on an on-going basis.

Within this investigation the majority of the objectives have been within the cognitive domain with two possible exceptions.

Referring to Table 9 (or 9R) questionnaire topic 9 is possibly affective in part although the cognitive words 'knowledge' and 'understanding' are included. This objective (or is it an aim?) was rarely, if ever, considered specifically by the lecturers although the latter might claim that because of its general nature it is implied being part of all experimental work. Could it be that the students who previously showed a favourable reaction to this topic are noting or appreciating that beyond the immediate purposes of an experiment there is in addition a broadening of general knowledge or 'feeling' for the subject. If so, and if this aim or objective is affective in part, at least then the students showed evidence of having appreciated this aspect.

Safety is often considered to be an attitude and the author would agree. Talking about safety is not enough, e.g. the safety campaigns and actuality of road accident statistics. If safety is, therefore, an attitude of mind then there is some evidence to indicate that in some cases this affective objective is not being adequately achieved. The author is of the opinion that on safety matters in the laboratory 100% is the only satisfactory objective attainment level. If 70% of a class are safety conscious the whole group may be at risk because of the 30%.

CHAPTER 7

OBJECTIVES AND ATTITUDES

CHAPTER 7

OBJECTIVES AND ATTITUDES

7.1 Introduction and Procedure

In the final stage of the investigation it was hoped to examine in more depth the influence of a knowledge of experimental objectives on the attitude and attainment of the students in the practical situation. The intention was to compare 01/02 students in situations where objectives had been given before or after any one or more in a series of experiments. For a variety of organisational reasons the proposals proved too ambitious and control of the situation was difficult. As a result the total number of experiments and objective situations covered was less than had been hoped for.

The total actually covered is summarised in Table 10 which shows for each of four colleges:-

(a) the student year, i.e. 01/02;
(b) the title of the experiment;
(c) whether objectives were supplied before or after the experiment;
(d) the particular college identified by A, B, C or D.

The type of objective format supplied to the students is shown in Tables 11 and 11A.

Table 10 /

Table 10

List of Experiments Investigated

College	Experimental Title	Year	Objectives Before	Objectives After
	1. Bromination of Cinnamic Acid	02		✓
	2. Reactions of alcohols, aldehydes and ketones	02	✓	
	3. Synthesis of t-butyl chloride	02	✓	
A	4. Thin layer chromatography	02	✓	
	5. Carbonate/bi-carbonate estimation	02	✓	
	6. Titration of Fe^{2+} with various oxidants	02	✓	
	7. Lassaigne test	01		✓
	8. Recrystallisation	01		✓
	9. Semi-micro qualitative analysis	01		✓
	1. Titrations involving arsenious oxide/pot. permanganate	02	✓	
	2. Determination of boiling points	02	✓	No Quests
B	3. Fractional distillation of mixtures	02	✓	returned
	4. Melting point determination	02	✓	
	5. Recrystallisation	02	✓	
	1. Carbonate/bi-carbonate estimation	02	✓	–
	2. Estimation of ortho-phosphoric acid	02	–	– No Quests
C	3. Estimation of calcium	02	✓	returned
	4. Partition coefficient	02		✓
	5. /			

Table 10 (cont'd)

College	Experimental Title	Year	Objectives Before	Objectives After
C (cont'd)	5. Steam distillation	02		✓
	6. Conductivity/Molar conductance	02		✓
	7. Neutralisation curves	02		✓
	8. Safety hazards	01		✓
	9. Balance	01		✓
	10. Volumetric analysis	01		✓
	11. Melting points	02		✓
	12. Mixed melting points	02		✓
	13. Boiling point	02		✓
	14. Recrystallisation	02		✓
	15. Hot filtration	02		✓
	16. Preparation of tri-bromo aniline	02		✓
D	1. Determination of chloride	02	✓	
	2. Techniques of organic chemistry	01	✓	
	3. Recrystallisation	01		

Table 11

Examples of objective format presented to the students

Experiment Objectives (B)

College : BELL   Student's Name :

Experiment Title
or Number : Volumetric determination of Calcium   Year : 02

Below is a list of the objectives for this particular experiment which you have just completed. Please indicate by ticking the appropriate column whether you considered that the objectives were or were not achieved.

Objectives	Objective achieved? YES	NO
1. You were able to use a "several step" reaction to determine calcium ions in solution.		
2. You added to your knowledge of chemical facts.		
3. You gained further experience in the application of redox theory.		
4. You gained confidence in your understanding of and your ability to use redox theory.		
5. You found the further practice in analysis useful in your development as a practical chemist.		
6. You found the experiment interesting.		
7. You considered the experiment to be important to your overall chemical education.		

Table 11A

Experiment Objectives (A)

College : BELL Student's Name :

Experiment Title
or Number : Standardisation of $Na_2S_2O_3$; Determination of Cu in solution.

Year : 02

Below is a list of the objectives for this particular experiment which you are about to start. At the end of the experiment please tick the appropriate column depending on whether or not you considered that the objectives were achieved.

Objectives	Objective achieved? YES	NO
1. You will be able to carry out a specified procedure for the standardisation of sod. thiosulphate to level of acceptance stated by the lecturer in charge.		
2. Construct ion-electron equations for each redox component.		
3. Construct a balanced equation from the above.		
4. Calculate the molarity of the thiosulphate.		
5. Use the thiosulphate in the redox titration of copper.		
6. Set up ion-electron equations for each redox constituent and hence a balanced equation for the reaction.		
7. Calculate the copper ion concentration in the solution.		
8. You will demonstrate the correct use of burettes and pipettes.		

Comments on the objectives

The administrative problems in this stage of the investigation have shown in the quality of the objectives.

In the case of college A the lecturing staff supplied the cognitive objectives and the author in most cases added one or two affective objectives.

In the case of college B there were real difficulties and the author had to add and expand on the scanty objectives supplied. This had to be done on the basis of assuming that there would be a similarity of approach and hence a similarity in objectives when any one experiment was carried out in different colleges.

In the case of college C the college supplied the objectives to the students without consulting the author. The move was well intentioned but against the variability in objective quality, consultation would have been preferred.

In the case of college D the objectives supplied by the college had to be amplified and amended to make them more specific.

Attitude test

In addition to the objectives each student was asked to complete an attitude test having been given a fictitiously completed example for guidance (Table 12).

The attitude test consisting of sets of 'opposites' was in content similar to previous questionnaires (see Table 9) because it was considered that the included topics covered the range of attributes generally associated with practical work.

Table 12 /

Table 12

Attitude Test. Format of test and guidance to students.

Attitudes to Practical Exercises

SPECIMEN COPY

College : Kilbelkirk Student's Name : J. Smith

Experiment Title
or Number : Test for Cations and Anions Year : 02

Qt. I found this experiment to be:-

1.	Interesting	X						Boring
2.	Important to my overall chemical education		X					Unimportant to my overall chemical education
3.	Clear in its purpose			X				Vague in its purpose
4.	Short				X			Prolonged
5.	Related to lecture material						X	Unrelated to lecture material
6.	Straightforward					X		Difficult
7.	Demanding in making me think		X					Undemanding in making me think
8.	Relevant to my development as an industrial chemist					X		Irrelevant to my development as an industrial chemist
9.	Helpful in teaching me practical skills new to me	X						Useless in teaching me practical skills new to me
10.	Helpful to my understanding of chemistry		X					Useless to my understanding of chemistry
11.	Useful to me in revising practical skills						X	Useless to me in revising practical skills

Comments /

Table 12 (cont'd)

Comments

From the position of the X's, it would appear that J. Smith has the following attitudes to this exercise:-

1. Very important.
2. Important but not very important to his overall education in chemistry.
3. The purpose was fairly clear rather than vague.
4. The experiment tended to be on the prolonged side.
5. There was no relationship with lecture material.
6. The overall exercise was difficult but not very difficult.
7. He had to give thought to what he was doing.
8. The experiment was irrelevant to his development as an industrial chemist.
9. The exercise in new practical skills was very useful.
10. He found that the practical work was helpful to his understanding of chemistry.
11. There was no benefit derived in revising practical skills.

7.2 Consideration of the objective linked Attitude Tests

In considering the attitude tests which were issued with the objective items it was decided to list the responses produced against each pair of 'opposites' and then to -

(a) look at the overall or average responses, and
(b) look for any positive bias one way or the other, i.e. left or right of middle, against any one pair of opposites. (Bias is difficult to assess meaningfully where small numbers are involved.)

The experiments as previously indicated are listed in Table 10 and if these duplicate experiments considered in the earlier stages of the investigation then this has happened by accident rather than design. However the /

the students, involved represent totally different groups.

7.3 Individual college performance

The data obtained is considered below on an individual college basis.

For each college the information supplied includes -

(a) the experimental objectives.
(b) a table which shows the extent to which the objectives were or were not attained by the students (explanatory notes are appended to the latter).
(c) comments on objective attainment.
(d) the attitude test results including -
 (i) the overall responses to individual pairs of 'opposites';
 (ii) the total column responses for attitude a, b, c, d, e or f;
 (iii) the column responses shown as a %age of the total responses;
 (v) an indication of an apparent bias shown as ____| or |____ where it was considered that a bias existed.

7.3.1. COLLEGE A

Experiment Objectives

Table 13

Experiment No.[t] A1   Bromination of Cinnamic Acid

Objectives

1. You were reminded and are now clear in your mind regarding the dangers in handling chlorinated hydrocarbons and bromine.
2. You were able to relate lecture material with this experiment.
3. You had to obtain a sample of dibromide in 40/50% yield after recrystallisation.
4. /

4. You had to use a purification process learned in a previous experiment.
5. You found the experiment interesting.
6. You thought the experiment was useful in the development of your chemical knowledge.

[t] Refers to equivalent number in Table 10

Table 14

Experiment No. A2 Reactions of alcohols, aldehydes and ketones

Objectives

1. You will be able to carry out oxidation of an alcohol.
2. You will know the dangers associated with the oxidation procedure and will know how to proceed safely.
3. You will be able to distinguish between a primary and a secondary alcohol using certain tests.
4. You will be able to see a relationship between this experiment and the lecture material.
5. You will be able to carry out a simple steam distillation process in order to isolate an aqueous solution of the oxidation products.
6. You will learn to recognise basic i.r. absorptions corresponding to -OH, C=O and -CHO and will know about the possibility of distinguishing between types of alcohol and aldehydes and ketones.

Table 15

Experiment No. A3 Synthesis of t-butyl chloride

Objectives

1. You will obtain t-butyl chloride in 70/80% yield.
2. You will add to your knowledge of safe working procedures in the laboratory.
3. /

3. You will know three possible causes for the loss of product.
4. You will know how to proceed such that you can minimise the loss of product.
5. You will be able to explain the use of anhydrous Na_2SO_4 for drying organic liquids.
6. You will be able to relate the work carried out in the laboratory exercise to lecture material.
7. You will be able to explain the formation of alkenes as by products.

Table 16

Experiment No. A4 Thin Layer Chromatography

Objectives

1. You will be able to run a thin layer chromatogram to the satisfaction of the lecturer in charge.
2. You will know and be able to state at least seven and not more than nine precautions which are necessary for successful running of T.L.C.
3. You will be able to state the principles underlying chromatographic separation.
4. You will learn and understand why chromatography is a useful procedure.
5. You will be able to state the most common detection methods for colourless compounds and when they might be used.
6. You will find the experiment interesting.

Table 17

Experiment No. A5 Titration of bicarbonate/carbonate mixtures

Objectives

1. You will be able to set down equations for the reactions HCl/Na_2CO_3 and $HCl/NaHCO_3$ and will be able to state the order in which they occur during the titration with acid.

2. You will be able to carry out a titration on a $Na_2CO_3/NaHCO_3$ mixture to the satisfaction of the lecturer in charge, i.e. to a stated accuracy.
3. You will be able to calculate the amount of $NaHCO_3$ and Na_2CO_3 in a mixture of the two.
4. You will be able to demonstrate your understanding of the background of molar calculations.
5. You will be required to demonstrate your knowledge of the use of approved procedures for using burettes and pipettes.
6. You will find the experiment useful and relevant to your chemical education.
7. You will find the experiment interesting.

Table 18

Experiment No. A6 Titration of Fe^{2+} with various oxidants

Objectives

1. You will be introduced to a new aspect of chemistry.
2. You will be able to calculate the experimental reacting ratios of Fe^{2+} ions with the three oxidants.
3. You will be able to set up ion-electron equations for each redox component.
4. You will be able to set up balanced equations for each redox reaction.
5. You will find the experiment interesting.
6. You will find the experiment useful in your chemical education.

Table 19

Experiment No. A7 Lassaigne Test

Objectives

1. You learned about and now know the hazards associated with sodium fusions and the precautions to be taken.

2. /

2. You learned how to carry out the procedure satisfactorily and safely.
3. You carried out a sodium fusion test on a known substance containing N, S and Cl.
4. You were able to carry out a sodium fusion on an unknown organic substance.
5. You learned when you would use a sodium fusion.
6. You became interested in this aspect of chemical analysis.
7. You found the experiment useful in relation to your chemical education.

Table 20

Experiment No. A8 Recrystallisation

Objectives

1. You were able to select the best solvent or solvent mixture from a given range for the particular solid provided.
2. You understood the reasons for your selection of a solvent.
3. You learned how to carry out purification by recrystallisation.
4. You knew why you had to carry out a melting point determination after recrystallisation.
5. You knew why and when recrystallisation might have to be repeated.
6. You learned about handling solvents carefully and why it was necessary to do so.

Table 21

Experiment No. A9 Semi-micro qualitative analysis

Objectives

1. You learned how to handle small amounts of substances.
2. You learned the importance of making accurate observations.
3. /

3. You learned how to separate solids from liquids by centrifuging.
4. You learned how to use and follow a qualitative analysis procedure.
5. You were able to carry out successfully the analysis of an unknown substance.
6. You found the experiment interesting.
7. You found the experiment useful to your chemical education.

Table 22 College A Objective Attainment

Expt. No.	Objective (OB/OA) *	No. of returns	No. of objectives for each expt.	No. of students attaining all objectives	Objectives which proved difficult for students (Refer to expt. objective)[t]
A1	OA	34	6	7	3, 5, 6
A2	OB	34	6	32	-
A3	OB	32	7	12	1
A4	OB	24	6	7	2
A5	OB	27	7	11	7, 3, 4, 6
A6	OB	22	6	10	1, 5
A7	OA	11	7	3	5, 6. 7
A8	OA	7	6	3	-
A9	OA	22	7	14	5, 6, 7

* OA, OB Objectives issued before (OB) or after the experiment (OA).
t Tables 13-21

The table and succeeding similar tables for other colleges attempt to summarise the extent to which students achieved or did not achieve the objectives for the experiment. It also attempts to indicate those objectives which appeared to give difficulty to the students.

Comments on Tables

Experiment A1 The difficult objectives include only one, i.e. % yield which was specific to the experiment. The others relate to general interest and widening of knowledge. About half of the class failed to achieve the expected yield and about the same number did not find the experiment interesting. There was no relationship between 'yield failure' and 'interest aspects'!

Experiment A2 The two students who failed to achieve all objectives could not relate the experiment to lecture material.

Experiment A3 The most difficult to achieve objective was in fact that relating to % yield. Twelve students failed to obtain the expected figure. Non achievement of other objectives was fairly evenly divided through 2 to 7 inclusive. 8 students, i.e. about 25% of the class, could not relate the laboratory to the lecture material.

Experiment A4 The second objective was clearly the one which most troubled the students. It may have been rather a formidable task to list 7/9 precautions relating to the successful running of T.L.C. Five students did not find the experiment interesting but otherwise there were no real problem objectives.

Experiment A5 In this case the fact that apparently less than half the class achieved all the objectives is not so serious since again it was the interest objective which came out rather poorly. One third of the class found the experiment to be other than interesting. Of the other objectives approximately 20% of the group failed to achieve the specific experimental objectives, 5 and 6 , and only three students failed on objective 3 relating to the calculation.

Experiment A6 Little comment necessary. Five students did consider the experiment to be a new aspect and six did not find it interesting. Otherwise all the objectives /

objectives were successfully achieved.

Experiment A7 The significant failed objective is apparently No. 5 relating to knowledge of when to use a sodium fusion procedure. Only a small group of students is involved but apparently half of them have missed out on an important objective. Objectives 6 and 7 again relate to attitudes and in each case three out of ten students are not impressed.

Experiment A8 With the small numbers involved comment is not really appropriate.

Experiment A9 Again the attitude objectives have not fared too successfully while about 20% of the student group failed to carry out the required qualitative analysis.

It is to be noted that in general the affective objective, namely interest, is not coming over to the students or rather they are rejecting interest. This appears to run counter to the previous observations (Chapter 6) where in general the students did not find the experiments boring or pointless. It was suggested then that lack of boredom may infer a presence of interest. This may be an over-simplification and it is possible that the attitude test is a more useful yard-stick since it allows shades of opinion on any educational topic relating to an experiment rather than a much more restrictive 'yes' or 'no' as required in the objective attainment approach. It is being suggested that the format of wording the questionnaire may strongly influence and bias the conclusions drawn from investigational data of the type presented in this thesis.

Table 12 R

Attitude Test. Format of test and guidance to students.

Attitudes to Practical Exercises

SPECIMEN COPY

College : Kilbelkirk Student's Name : J. Smith

Experiment Title
or Number : Test for Cations and Anions Year : 02

Qt. I found this experiment to be:-

1. Interesting	X						Boring
2. Important to my overall chemical education		X					Unimportant to my overall chemical education
3. Clear in its purpose			X				Vague in its purpose
4. Short				X			Prolonged
5. Related to lecture material						X	Unrelated to lecture material
6. Straightforward					X		Difficult
7. Demanding in making me think		X					Undemanding in making me think
8. Relevant to my development as an industrial chemist					X		Irrelevant to my development as an industrial chemist
9. Helpful in teaching me practical skills new to me	X						Useless in teaching me practical skills new to me
10. Helpful to my understanding of chemistry		X					Useless to my understanding of chemistry
11. Useful to me in revising practical skills						X	Useless to me in revising practical skills

Comments /

College A

These are reported below in Tables 23 - 31

Table 23

Experiment A1 Bromination of Cinnamic Acid (OA)

Responses

Qt.*	a	b	c	d	e	f	
1	2	10	9	7	5	-	
2	3	6	15	5	4	-	
3	8	16	5	3	1	-	
4	2	2	5	12	11	1	
5	9	11	7	2	2	1	
6	10	10	11	2	-	-	
7	1	2	13	8	8	1	
8	2	-	8	8	7	8	
9	1	5	9	3	9	5	
10	5	8	15	2	1	1	
11	10	7	11	1	1	2	
Column Totals :	53	77	108	53	49	19	(359)
% of totals overall:	15	21	30	15	14	5	
		66%			34%		

* Qt. = Questionnaire topic and Responses a - f refer to the topics and the six point choice for each topic in Table 12R (P120A). The latter is identical to Table 12 and has been repeated for convenience.

Table 24

Experiment A2 Reactions of alcohols, aldehydes and ketones (OB)

Qt.	a	b	c	d	e	f	
1	12	9	10	2	-	-	
2	7	16	11	-	-	-	
3	14	13	7	1	-	-	
4	2	2	6	13	8	4	
5	15	14	6	-	-	-	
6	13	14	7	1	-	-	
7	-	7	12	7	5	4	
8	2	5	14	2	8	4	
9	3	5	8	9	6	4	
10	6	16	13	-	-	-	
11	2	13	12	3	1	4	
Column Totals :	49	83	59	20	21	8	(240)
% of totals overall :	20	35	25	8	9	3	
	80%			20%			

Table 25

Experiment A3 Synthesis of t-butyl chloride (OB)

Qt.	a	b	c	d	e	f	
1	8	11	10	3	3	-	
2	4	12	10	7	2	-	
3	10	13	8	4	-	-	
4	4	8	18	4	-	-	
5	6	10	8	7	2	2	
6	7	14	11	3			
7	4	4	11	11	4	1	
8	-	4	13	4	7	7	
9	7	5	8	4	5	6	
10	5	12	14	3	-	1	
11	3	9	12	7	1	3	
Column Totals :	58	102	123	57	24	20	(384)
% of totals overall :	15	27	32	15	6	5	
	74%			26%			

Table 26

Experiment A4 Thin Layer Chromatography (OB)

Qt.	a	b	c	d	e	f	
1	4	9	5	4	2	-	
2	2	13	2	6	-	2	
3	7	9	4	3	-	1	
4	9	6	5	3	1	-	
5	-	1	3	5	5	9	
6	11	5	4	4			
7	-	-	5	9	4	5	
8	1	4	7	4	2	6	
9	8	9	6	-	-	1	
10	4	2	10	2	6	-	
11	3	-	7	4	3	7	
Column Totals :	49	58	58	44	23	30	(262)
% of totals overall :	19	22	22	17	9	11	
	63%			37%			

Table 27

Experiment A5 Carbonate/bi-carbonate estimation (OB)

Qt.	a	b	c	d	e	f	
1	3	8	8	4	2	-	
2	2	11	6	5	1	1	
3	9	10	4	1	-	1	
4	10	6	5	3	1	-	
5	2	2	3	4	5	9	
6	15	4	3	1	1	1	
7	8	6	3	4	3	1	
8	4	3	9	-	3	6	
9	3	3	-	6	8	6	
10	5	12	4	2	1	1	
11	5	8	7	1	-	4	
Column Totals :	66	73	52	31	25	30	(277)
% of totals overall :	25	26	19	11	9	11	
	70%			31%			

Table 28

Experiment A6 Titration of Fe^{2+} with various oxidants (OB)

Qt.	a	b	c	d	e	f	
1	1	9	4	4	3	-	
2	6	7	6	1	1	-	
3	8	10	3	-	-	-	
4	7	7	5	1	1	-	
5	12	6	-	2	1	-	
6	12	5	3	-	1	-	
7	-	10	4	4	-	3	
8	-	6	5	3	3	4	
9	-	1	3	4	4	9	
10	5	7	8	-	-	1	
11	4	4	4	4	2	3	
Column Totals :	55	72	45	22	16	20	(231)
% of totals overall :	24	31	20	10	7	8	
		75%			25%		

Table 29

Experiment A7 Lassaigne Test (OA)

Qt.	a	b	c	d	e	f	
1	3	7	1	-	-	-	
2	2	2	5	2			
3	3	5	3				
4	1	2	2	4	2		
5	1	-	2	-	2	6	
6	3	4	4	-	-	-	
7	1	4	4	1	-	-	
8	1	3	1	1	2.	3	
9	2	6	1	1	1	-	
10	1	5	2	2	-	1	
11	2	1	4	1	3	-	
Column Totals :	20	39	29	13	10	10	(122)
% of totals overall :	17	32	24	11	8	8	
		73%			27%		

Table 30

Experiment A8 Recrystallisation (OA)

Qt.	a	b	c	d	e	f
1	2	3	2	1	-	-
2	1	5	2	-	-	-
3	4	3	-	1	-	-
4	-	2	2	2	2	-
5	-	-	-	2	1	5
6	2	1	2	1	1	1
7	1	3	1	2	1	-
8	1	2	1	1	2	1
9	3	1	2	1	-	1
10	3	2	2	1	-	-
11	2	3	1	-	1	1
Column Totals :	19	25	15	12	8	9
% of totals overall :	21	28	17	14	9	11
	66%			34%		

Table 31

Experiment A9 Semi-micro qualitative analysis (OA)

Qt.	a	b	c	d	e	f
1	3	9	4	-	1	-
2	6	3	8	-	-	-
3	-	7	3	4	2	1
4	-	-	2	5	3	7
5	-	1	5	3	1	7
6	2	4	4	4	1	1
7	3	6	5	2	1	-
8	3	3	4	4	2	1
9	6	7	2	1	1	-
10	7	3	3	3	-	1
11	3	5	2	4	-	3
Column Totals :	33	45	42	30	12	20
% of totals overall :	18	25	23	16	6	11
	66%			34%		

Statistical Examination of the Results of the Attitude Test

A few of the results of the attitude test have been examined statistically.

For this purpose it has been assumed that for any one class of students carrying out any one experiment, then their responses to an attitude test would show a normal distribution with regard to their overall attitude and also with regard to their response to any one topic in the attitude test.

Table 25 Experiment A1
(a) Overall attitude

From the table –	a	b	c	d	e	f
Column totals :	53	77	108	53	49	19
Mean response (11 topics) :	5	7	10	5	5	2
Distribution of responses expected assuming normal distribution :	1	4	11	11	4	1

Chi-squared test:-

Response	O	E	$(O-E)^2$	$(O-E)^2/E$
a	5	1	16	16
b	7	4	9	2.25
c	10	11	1	0.09
d	5	11	36	3.27
e	5	4	1	0.25
f	2	1	1	1

$$\chi^2 = 22.06$$

There are three degrees of freedom.
From tables χ^2 (22.06) $>$ χ^2_{tables} (7.81) [P = 5%]
The hypothesis that the distribution is normal must be rejected as it is probably false.

Table 27
(a) Overall attitude
From /

From the table -	a	b	c	d	e	f
Column totals :	66	73	52	31	25	30
Mean response (11 topics) :	6	7	5	3	2	3
Distribution of responses expected assuming normal distribution :	1	4	8	8	4	1

Chi-squared test:-

Response	O	E	$(O-E)^2$	$(O-E)^2/E$
a	6	1	25	25
b	7	4	9	2.25
c	5	8	9	1.12
d	3	8	25	3.25
e	2	4	4	1.00
f	3	1	2	2.00

$$\chi^2 = 34.62$$

There are three degrees of freedom.
From tables χ^2 (34.62) $>$ χ^2 tables (7.81) [P = 5%]
Again the conclusion is that the assumption of a normal distribution is probably false.

Table 31

From the table -	a	b	c	d	e	f
Column totals :	33	45	42	30	12	20
Mean response (11 topics) :	3	4	4	3	1	2
Distribution of responses expected assuming normal distribution :	1	2	6	6	2	1

Chi-squared test:-

Response	O	E	(O-E)	$(O-E)^2$	$(O-E)^2/E$
a	3	1	2	4	4
b	4	2	2	4	2
c	4	6	-2	4	.75
d	3	6	-3	9	1.5
e	1	2	-1	1	0.5
f	2	1	1	1	1.0

Again for three degrees of freedom χ^2 (9.75) $>$ χ^2 tables (7.81) [P = 5%] although the difference suggests that the distribution of results is tending more to normal.

Comments on the Attitude Test analysis (College A)

In any set of experiments which was achieving the ultimate in terms of planning, presentation and educational value then referring to the attitude test every student would probably respond by filling in the first space on each line of the attitude topics. In such an ideal situation the students would have found the practical work interesting, educationally important, and short rather than unnecessarily prolongd. The practical exercises in addition would have been seen to be related to lecture material while demanding some thought on the part of the students. In addition the students would have developed former skills and learned new ones while they would in addition have derived some benefit in terms of their understanding of chemistry.

The ideal is not expected but it appears reasonable to consider how closely the ideal is approached. Accordingly the percentage of responses left and right of centre have been added together and compared as two groups. The results are shown in Table 32.

Table 32 /

Table 32

Summed responses % (a+b+c) and % (d+e+f) from Tables 23-31 (College A)

Experiment	% a+b+c	% d+e+f
A1	66	34
A2	77	33
A3	74	26
A4	72	28
A5	70	30
A6	75	25
A7	73	27
A8	66	34
A9	66	34

$\bar{X}$ = 71%

It appears reasonable to suggest that there are, allowing for the relatively small numbers of experiments involved, indications that success as measured by a positive bias in the attitude test is being achieved in the laboratory course, or at least in an element of that course, in College A.

With one exception the first three topics relating to interest, educational importance and clarity of purpose have all been received favourably by the students. Note especially the response to the question of interest and contrast this with the objective attainment situation (Table 22) with its 'yes' or 'no' alternatives.

The majority but not all the experiments have been seen as being linked to lecture material and this is not surprising in relation to overall laboratory/ lecture integration problems.

However, that the laboratory helps in the understanding of chemistry is accepted by the majority of the /

the students in all the experiments. This underlines the same point noted in the earlier stages of the investigation. Again, as was previously noted and again as is apparent in this case students in this academic course are not so convinced by the relevance of the laboratory work in relation to their industrial role.

There appears to be a consistency between the previous and the present stage of the investigation suggesting that the students have taken the questionnaire quite seriously and it would appear reasonable to conclude that their work in the laboratory is seen by them to have some relevance.

Unfortunately it is not possible to comment in a positive way with respect to the relevance of the timing of the presentation of objectives in relation to either objective attainment or student attitude to any one experiment. Within the 'A' college series there seems to be nothing to choose between the objective attainment of those students who knew the objectives before the experiment compared with that of the students who were told the objectives after the experiment. However, the total number of opposed situations was too small for definite conclusions to be made.

The author is of the opinion that it may be unrealistic to expect that all students will achieve all objectives set and while agreeing that objectives are the least the student can expect, would suggest that realism has to obtain. In any class the student ability varies, mishap can occur etc. and it would appear reasonable to expect that student performance will vary. Total failure to reach any of the objectives or all the class obtaining all the objectives might give cause for concern for different reasons. Was the exercise badly presented or set too high? Was the exercise so easy that success was unavoidable?

Against this background and noting the previous comments /

comments on 'interest' as an objective with little student appeal the overall performance of college A students appears to be reasonably satisfactory. At least there were those who were honest enough to admit that they did not achieve the expected yield in an organic preparation!

7.3.2 COLLEGE B

The data for this college follows the lay-out adopted for college A.

Experiment Objectives

Table 33

Experiment No. B1 Titrations involving arsenious oxide/ pot. permanganate

Objectives

1. You will increase your knowledge of safe working procedures in the laboratory.
2. You will be able to relate the practical exercise to lecture material.
3. You will learn how to use the equipment properly.
4. You will gain experience in titrations involving potassium permanganate.
5. You will be able to write down relevant ion-electron equations and hence balanced equations for the titrimetric operations.
6. You will find the experiment interesting.
7. You will find the experiment useful in your development as a professional chemist.

Table 34

Experiment No. B2 Determination of Boiling Point

Objectives

1. You will be able to determine boiling points by three methods.
2. You will then be able to evaluate each method.
3. You will learn how to use quickfit apparatus.
4. You will learn the importance of safety clothing in the laboratory.
5. You will learn what to do in the event of a fire.
6. You will find the experiment important in your developing your experimental skills.

Table 35

Experiment No. B3 Fractional Distillation of Mixtures

Objectives

1. You will improve your skills at assembling quickfit apparatus.
2. You will understand and be able to describe the simple theory of distillation.
3. You will be able to separate two liquids by distillation.
4. You will demonstrate your ability to work safely.
5. You will know why safe working methods are vital in distillation processes.
6. You will demonstrate that you can write a laboratory report to the satisfaction of the lecturer in charge.
7. You will find the experiment interesting.
8. You will consider that you have been introduced to an important aspect of chemistry.

Table 36 /

Table 36

Experiment No. B4   Determination of Melting Points

Objectives

1. You will be able to carry out melting point determinations to the satisfaction of the lecturer in charge.
2. You will learn to use three methods for determining melting points.
3. You will know the three factors on which the methods can be evaluated.
4. You will be able to evaluate the three methods.
5. You will know why melting point determination is useful in organic chemistry.
6. You will find the experiment useful in developing your knowledge of chemistry.

Table 37

Experiment No. B5   Recrystallisation

Objectives

1. You will learn the purposes of recrystallisation.
2. You will be able to carry out a recrystallisation process on a crude sample.
3. You will learn how to select an appropriate and suitable solvent for recrystallisation processes.
4. You will learn why and when charcoal may be employed in conjunction with recrystallisation.
5. You will develop your laboratory skills.
6. You will learn the importance of safe working procedures in the laboratory.
7. You will understand the principles underlying recrystallisation.
8. You will consider the experiment useful in developing your knowledge of chemistry.

Table 38 College B Objective Attainment

Expt. No.	Objectives (OB/OA)	No. of returns	No. of objectives for each expt.	No. of students attaining all objectives	Objectives which proved difficult for students [t]
B1	OB	15	7	1	1, 2, 3, 6, 7
B2	OB	13	6	-	4, 8
B3	OB	20	8	-	2
B4	OB	19	5	19	-
B5	OB	19	6	2	3, 4

[t] Refer to Tables 33-37

Comments on Tables

Experiment B1 In other situations and in other colleges, e.g. college A, it has been noted that the affective objective often fares badly as far as the students are concerned. This is again the case here but even ignoring these particular objectives the results are disappointing, only one student claiming to have achieved all objectives. Did ten students fail to recognise the dangers of arsenic compounds? If six students failed to relate lecture material to the laboratory why did nine do so? Eight students failed to learn how to use the equipment properly! Clearly there appears to be some cause for concern about this particular experiment, or about the way in which the students opted to handle the objective questionnaire!

Experiment B2 Again it was noted that half the class did not achieve the affective objective and nine out of thirteen did not learn anything about the use of the apparatus. Possibly they were already familiar with this or "Quickfit" was not used. On reflection this is rather a nebulous objective.

Experiment B3 The one problem objective here appears to have been surprisingly that relating to the theory of distillation. All students in the group claim that they do not understand and therefore cannot describe the simple theory of distillation. Does this mean that they have not been given any relevant theory or that they do not consider the theory to be simple? Again, all but one of the group do not consider that they have been introduced to an important aspect of chemistry. Are they doubting the 'novelty' (i.e. introduction aspect) or the importance aspect?

Experiment B4 and Experiment B5 No comment called for all the students attaining all the objectives in B4. Equally no student considered that B5 was useful in developing their knowledge of chemistry.

Table 39

Experiment B1 Titration involving permanganate/arsenious oxide (OB)

Qt.	a	b	c	d	e	f	
1	3	3	7	1	1	-	
2	2	3	3	5	1	1	
3	6	4	3	1	1		
4	1	4	7	1	1	1	
5	2	5	5	1	1	1	
6	9	3	3				
7	3	2	2	5	1	2	
8	3	-	3	4	4	1	
9	2	-	1	3	4	5	
10	1	4	4	1	4	1	
11	2	3	3	-	6	1	
Column Totals :	34	31	41	22	24	13	(165)
% of totals overall :	21	19	25	13	15	7	
	65%			35%			

Table 40

Experiment B2 Determination of Boiling Points (OB)

Qt.	a	b	c	d	e	f
1	1	5	4	-	1	2
2	-	6	5	1	-	1
3	2	4	3	3	-	1
4	-	-	2	3	1	7
5	-	1	-	-	2	10
6	8	2	1	1	-	1
7	-	1	5	1	-	6
8	7	-	3	1	1	1
9	3	1	5	1	1	2
10	1	1	2	1	1	7
11	-	-	4	3	-	6
Column totals :	22	21	31	15	7	44
% of totals overall :	16	15	22	11	5	31
	53%			47%		

Table 41

Experiment B4 Melting Point Determination (OB)

Qt.	a	b	c	d	e	f	
1	1	6	3	-	-	3	
2	1	5	3	3	-	1	
3	2	4	4	2	-	1	
4	-	-	1	2	4	6	
5	-	-	-	-	2	11	
6	7	2	2	-	-	1	
7	-	1	3	1	-	7	
8	5	4	1	1	-	1	
9	2	4	4	-	-	2	
10	-	1	1	-	2	8	
11	1	3	3	1	1	3	
Column totals :	19	30	25	10	9	44	(140)
% of totals overall :	14	22	18	7	6	32	
	54%			45%			

Table 42

Experiment B5 Recrystallisation (OB)

Qt.	a	b	c	d	e	f
1	3	4	7	1	-	1
2	3	5	4	2	1	1
3	7	4	3	2	-	1
4	1	4	5	-	4	3
5	1	5	2	4	1	4
6	3	3	5	3	1	2
7	2	4	4	2	3	2
8	4	2	5	2	1	3
9	4	5	5	1	-	2
10	-	5	5	2	1	4
11	3	6	4	1	1	2
Column Totals :	31	54	49	20	13	26
% of totals overall :	16	28	25	10	7	13
	69%			30%		

Again as in the case of college A the two sets of responses from the attitude test data have been abstracted below in Table 43.

Table 43

Summed responses % (a+b+c) and % (d+e+f) from Tables 35-38

Experiment	% a+b+c	% d+e+f
B1	65	35
B2	53	47
B3	-	- No data
B4	54	45
B5	69	30

$\overline{X} = 60.25$

The general attitude towards the laboratory work appears possibly to be set at a lower key in college B compared with college A although the number of experiments is lower in the case of B. The objective attainment has not been very impressive and in fact difficult to understand. However, it is again stressed that there were objective problems in this instance. In attitude the response is mixed and it is to be noted that while in all cases college A students considered on balance that each experiment was helpful towards understanding chemistry, this opinion was not so clearly expressed with college B.

Against the background of the amount of information etc. available, it would appear pointless to comment further on the attitude tests.

7.3.3 COLLEGE C

The previous lay-out is again followed below.

Experiment Objectives

Table 44 /

Table 44

Experiment No. C1 Project 1 : Estimation of Carbonate and Bicarbonate

A situation covering acid/alkali nuetralisation and the 2-stage reaction of an alkali metal carbonate with an acid.

Primary Objectives:-

Broadly - to consolidate on a practical basis the application of "neutralisation" to quantitative volumetric analysis.

Specifically - to emphasise the following features -

(a) primary standards, standardisation, standard solutions;

(b) choice and application of indicators;

(c) application of theory to calculation.

Secondary Objectives:-

(a) to introduce the apparatus and to develop skill and dexterity in the manipulation of the apparatus used in volumetric analysis.

(b) to encourage an appreciation of the need for accurate working and of the factors which can lead to inaccuracy in the result.

(c) to develop ability in the presentation of reports.

Table 45

Experiment No. C2 Project 2 : Estimation of Orthophosphoric Acid

A situation involving acid/alkali neutralisation and the stepwise dissociation of phosphoric acid.

The project is based on the same objectives as outlined for Project 1. These objectives are consolidated and extended to different situations in Project 2.

Table 46 /

Table 46

Experiment No. C3 Project 3 : Estimation of Calcium in a Sample

A situation involving redox reactions.

Primary Objectives:-

Broadly - to consolidate on a practical basis the theory of oxidation and reduction as applied to quantitative volumetric analysis and to introduce an aspect of precipitation as an additional feature.

Specifically - to emphasise the following features -

(a) potassium permanganate as an oxidising agent, arsenious oxide as a reducing agent, oxalate ion as a reducing agent;

(b) standardisation in the redox situation;

(c) experience of permanganate as its own indicator;

(d) application of redox theory to calculations.

Secondary Objectives:-

As for Projects 1 and 2. The exercise is intended to continue development of manipulative skills.

Table 47

Experiments No. C4 - C7

The following objectives would apply in general to physical chemistry projects:-

Primary Objectives:-

(a) consolidation of theory on fundamental concepts.

(b) demonstration of application of fundamental concepts to practical situations.

(c) to foster a knowledge of an important laboratory technique.

Secondary /

Secondary Objectives:-

(a) to test ability of student to use available equipment efficiently to obtain acceptable results.
(b) to test ability of student to present a concise and accurate report.
(c) to examine the ability of the student to work effectively as a member of a team in project work.

Table 48

Experiment No. C8 Safety Hazards

(a) Appreciation of the need for a safety conscious attitude at all times in the laboratory.
(b) Awareness of the safety hazards associated with basic equipment and operation in the laboratory.
(c) Awareness of the need to treat all chemicals as potentially hazardous.

Table 49

Experiment No. C9 Balance

(a) Ability to use the Stanton Unimetic CL 41 balance.
(b) Awareness of how the physical properties of chemicals can influence their weighing characteristics and techniques.

Table 50

Experiment No. C10 Volumetric Analysis

(a) Become familiar with the apparatus and terminology of volumetric analysis.
(b) Appreciation of the value of 'molarity' in expressing solution concentration and its use in stoichiometric calculations.
(c) Awareness of the importance of accurate experimental practice.
(d) /

(d) Ability to obtain and apply experimental results.

(e) Awareness that indicators are limited in their application.

Table 51

Experiment No. C11 Melting Points

(a) to introduce technique of determining a melting point accurately.

(b) to introduce the concept of -

(i) purity in organic compounds;

(ii) identification of organic compound.

Table 52

Experiment No. C12 Mixed Melting Point

(a) to explain theory behind Mixed Melting Points.

(b) to use technique to identify an unknown compound from a series of three compounds of similar melting points.

Table 53

Experiment No. C13 Boiling Point

(a) to introduce technique of determining a boiling point accurately.

(b) to give experience in the manipulation of "Quick-fit" glassware.

(c) to give student a knowledge of safe working procedure and safety hazards when dealing with volatile liquids.

Table 54

Experiment No. C14 Recrystallisation

(a) to enable student to select the most suitable solvent for recrystallisation.

(b) to give insight into theory behind recrystallisation.

(c) to give experience in recrystallising an organic material using most suitable filtration apparatus.

Table 55

Experiment No. C15 Hot Filtrations

(a) to give student experience in carrying out this technique.

Table 56

Experiment No. C16 Preparation of Tribromoaniline

(a) to test ability to prepare and purify an organic compound.

(b) to consolidate earlier experiments on recrystallisation, hot filtration and melting points.

(c) to introduce concepts of -

(i) percentage yield;

(ii) activated ring system.

(d) to develop "safe working" procedures (with bromine).

Table 57 College C Objective Attainment

Expt. No.	Objectives (OB/OA)	No. of returns	No. of objectives for each expt.	No. of students attaining all objectives	Objectives which proved difficult for students [t]
C1	OA	-			
C2	OA	-			
C3	OA	9	6	7	4, 1
C4	OA	7	6	4	1,2,4,6
C5	OA	7	6	5	4
C6	OA	6	6	2	1,2,3,5
C7	OA	7	6		All of them
C8	OA	16	3	8	2,3
C9	OA	14	2	11	2
C10	OA	15	6	8	2
C11	OA	6	2	6	-
C12	OA	7	2	7	-
C13	OA	7	3	5	3
C14	OA	6	3	3	2
C15	OA	-	-	-	-
C16	OA	7	4	7	-

[t] Refer to Tables 44-56

Comments on Table 57

This table refers to college C where, as can be seen from the returns, the latter are a little patchy and the numbers of students small.

Experiments C1, C2 and C3   These are concerned with inorganic chemistry at the O2 stage and the objectives as stated fall between aims and behavioural objectives. Objective attainment returns were received for C1 and C3 only and in relation to the numbers involved only C3 can be considered. The broad aims of the exercise and the application of redox theory to the calculation appeared to be the 'problem' area.

Experiments C4 - C7   These are all experiments in physical chemistry and the objectives a general set of rather vague aims. It is doubtful if such a generalised approach is meaningful and appears to be pointless. The results in terms of objective attainment are very mixed.

Experiment C4

The three students who failed on the objectives missed out on (2, 4, 6) (1, 2, 4 and 6) and (1 and 6) respectively. It is difficult to understand how the 'teamworking ability' can be assessed, (Objective No. 6) and the same can be said of (Objective No. 4) unless on the basis of close supervision which, of course, is possible with small class numbers. The other problems relate to the link between theory and practice although the instruction sheet did give some guidance on the theory.

Experiment C5 has enjoyed some degree of success in relation to objective attainment, but not so Experiment C6. Here the four 'failures' did not attain the objectives (1, 2, 5), (1 and 3), (1, 2 and 3) and 6 respectively. Again, the theory and practice link comes up (objectives 1 and 2) while in two of the cases the 'important laboratory technique' aspect has not impressed. The instruction sheet does not stress any such importance!

In the /

In the case of Experiment C7 the objective attainments are somewhat random with no students attaining complete success. The pattern of failed objective responses is in this case (1, 4, 5), (1, 2 6), (1 and 2), (6), (1, 2, 3, 4 and 5) and (3, 4 and 5). Little more need be said about this experiment which has been a total failure in relation to the 'objectives' of the exercise.

Experiments C8 - C10 Experiments C8-C10 are introductory experiments on basic aspects of practical work. It is to be noted that again, as has been previously observed, the safety aspect is not getting over to the student. Only half the class claims to have attained the three objectives in Experiment C8. In fairness to the students the author would suggest that the objectives are too ambitious for something which develops as new situations and new materials are encountered in the laboratory. However, the laboratory instruction sheet is fairly comprehensive in its coverage and should lead to the development of a reasonable set of knowledge facts regarding safety if not to the attainment of the prescribed objectives. It is suggested that objective modification would be helpful.

Experiment C9 is an introductory practical exercise on the use of the balance with only two objectives. More than two might reasonably have been expected by say the breakdown into the skill elements of "ability to use a Stanton Unimetic C141 balance" and by better definition of "awareness" in the second objective, "awareness of how physical properties of chemicals can influence their weighing characteristics and techniques". The three students who did not achieve both objectives failed on the second one. Overall, the experiment has been successful.

Volumetric analysis is introduced in Experiment C10 and only half the class has been completely successful in achieving six objectives. The molarity/ stoichiometric calculation was the most difficult objective /

objective to attain. This does not come as a surprise especially at the relatively junior 01 year. It is a problem which is liable to appear at later stages too!

<u>Experiments C11 - C14</u> These all involve the basic techniques of organic chemistry and again the objectives as stated are somewhere between aims and behavioural objectives. Experiments C11 and C12 can be considered as successful in relation to objective attainment. Really Experiment C13 has been almost as successful since only two students have failed on one objective but again it is the safety aspects. In the case of Experiment C14 the problem objective has been that relating to the link between the practical work and background theory.

<u>Experiment C15</u> No returns

<u>Experiment C16</u> Straightforward. There were four objectives and these were attained by all students. One point in passing to note is that the objectives tend to be less comprehensive than those for similar experiments in other colleges. This point will be considered subsequently.

Table 58

Experiment C1 Carbonate/Bicarbonate estimation (OB)

Qt.	a	b	c	d	e	f	
1	1	2	11	2	1	2	
2	-	6	7	4	2	-	
3	3	5	7	1	2	-	
4	-	4	1	5	5	4	
5	5	2	2	2	4	4	
6	3	9	4	-	1	2	
7	2	1	6	2	4	4	
8	3	2	4	2	3	5	
9	2	3	6	1	3	4	
10	-	3	8	2	5	1	
11	-	4	7	5	1	2	
Column totals :	19	40	63	26	31	28	(207)
% of total overall :	9	19	30	12	15	14	
		58%			41%		

Table 59

Experiment C2 Estimation of orthophosphoric acid (OA)

Qt.	a	b	c	d	e	f	
1	2	6	2	2	-	1	
2	-	1	6	3	3	-	
3	4	2	2	2	3	-	
4	-	-	3	5	3	1	
5	-	4	2	2	2	3	
6	2	4	2	4	1	-	
7	-	-	4	3	5	1	
8	-	1	3	2	3	4	
9	2	2	-	4	4	2	
10	1	2	4	3	2	1	
11	-	1	2	5	4	1	
Column Totals :	11	23	30	35	30	12	(141)
% total overall :	8	16	21	25	21	9	
		45%			55%		

Table 60

Experiment C4 Partition co-efficient (OA)

Qt.	a	b	c	d	e	f	
1	5	-	1	2	-	2	
2	-	2	1	3	1	3	
3	3	3	1	-	1	2	
4	1	2	4	2	1	-	
5	1	1	1	1	1	4	
6	4	3	1	-	-	1	
7	1	2	2	-	1	3	
8	1	-	2	1	3	4	
9	1	-	1	3	1	3	
10	1	2	2	2	-	3	
11	2	-	1	2	1	4	
Column totals :	17	15	17	16	10	29	(104)
% of total overall :	16	14	16	15	10	28	
	$\underbrace{\qquad}_{46\%}$			$\underbrace{\qquad}_{54\%}$			

Table 61

Experiment C5 Steam Distillation (OA)

Qt.	a	b	c	d	e	f	
1	5	1	1	-	-	-	
2	-	3	1	2	-	-	
3	3	3	1	-	1	-	
4	1	1	2	1	2	-	
5	1	2	1	1	1	1	
6	5	-	2	-	-	-	
7	-	3	2	-	2	-	
8	-	1	-	1	3	1	
9	3	2	-	1	-	1	
10	1	3	1	1	-	1	
11	2	4	-	-	1	-	
Column totals :	21	23	11	7	10	5	(77)
% of total overall :	27	30	14	9	13	7	
	$\underbrace{\qquad}_{71\%}$			$\underbrace{\qquad}_{29\%}$			

Table 62

Experiment C6 Conductivity/molar conductance

Qt.	a	b	c	d	e	f
1	1	-	2	-	2	3
2	-	1	1	1	2	3
3	-	3	1	-	4	-
4	4	1	3	-	-	-
5	1	-	1	-	1	5
6	2	2	1	1	2	-
7	1	3	1	-	3	-
8	-	-	1	2	2	3
9	2	1	1	1	1	2
10	-	2	2	-	-	4
11	1	-	-	1	2	4
Column totals :	16	11	16	6	15	24
% of total overall :	18	13	18	7	17	27
		49%			51%	

Table 63

Experiment C7 Neutralisation curves (OA)

Qt.	a	b	c	d	e	f	
1	1	-	1	1	1	2	
2	-	1	2	1	2	-	
3	2	-	2	-	2	-	
4	1	1	3	1	-	-	
5	-	-	-	-	-	6	
6	3	2	-	1	-	-	
7	1	-	1	-	2	2	
8	-	-	-	1	2	3	
9	-	-	1	1	1	3	
10	-	2	1	2	-	1	
11	-	-	-	1	-	5	
Column totals :	8	6	11	9	10	22	(66)
% of total overall :	18	18	22	14	11	17	
		58%			42%		

Table 64

Experiment C8 Safety Hazards (OA)

Qt.	a	b	c	d	e	f
1	1	2	1	2	-	1
2	2	-	1	2	1	-
3	6	-	-	-	-	1
4	-	3	4	-	-	-
5	-	1	1	1	2	2
6	4	3	-	-	-	-
7	-	1	1	1	-	4
8	2	2	3	-	-	-
9	-	-	3	1	-	3
10	1	-	-	2	3	1
11	-	2	-	-	1	4
Column totals :	16	14	14	9	7	16
% of total overall :	21	18	18	12	9	21
	57%			43%		

Table 65

Experiment C9 Balance (OA)

Qt.	a	b	c	d	e	f	
1	1	4	5	1	2	1	
2	3	3	5	2	-	1	
3	10	2	1	-	-	-	
4	5	6	1	2	-	-	
5	1	3	1	3	3	3	
6	9	2	2	-	-	-	
7	-	3	1	1	3	6	
8	5	3	5	-	-	1	
9	3	1	5	3	1	1	
10	-	1	3	5	1	4	
11	5	3	3	1	1	1	
Column totals :	42	31	32	17	11	18	(151)
% of total overall :	28	21	21	11	7	12	
	70%			30%			

Table 66

Experiment C10 Volumetric analysis (OA)

Qt.	a	b	c	d	e	f	
1	1	4	7	-	1	1	
2	3	5	5	1	-	-	
3	3	5	5	1	-	-	
4	-	1	4	4	-	4	
5	2	3	4	1	2	2	
6	6	2	3	3	-	-	
7	1	7	3	1	1	1	
8	6	2	4	2	-	-	
9	-	3	6	2	1	2	
10	1	7	3	1	-	2	
11	5	4	5	-	-	-	
Column totals :	28	43	46	16	5	12	(150)
% of total overall :	19	29	31	11	3	8	
	79%			21%			

Table 67

Experiment C11 Melting Points (OA)

Qt.	a	b	c	d	e	f	
1	-	4	-	2	1	-	
2	-	4	1	2	-	-	
3	5	1	1	-	-	-	
4	3	1	-	-	3	-	
5	-	-	1	1	1	4	
6	6	1	-	-	-	-	
7	-	-	-	3	1	3	
8	1	2	2	1	-	1	
9	1	2	2	1	1	-	
10	2	-	3	-	2	-	
11	-	2	2	-	-	3	
Column Totals :	18	17	12	10	10	11	(78)
% of total overall :	23	22	15	13	13	14	
	60%			40%			

Table 68

Experiment C12 Mixed Melting Points (OA)

Qt.	a	b	c	d	e	f	
1	2	2	1	1			
2	-	3	2	-	-	1	
3	5	1	-	-	-	-	
4	2	2	2				
5	-	-	1	2	-	3	
6	4	1	1	-	-	-	
7	1	-	2	1	1	1	
8	-	2	3	-	1	-	
9	1	1	2	-	1	1	
10	-	2	3	-	-	1	
11	-	2	3	-	-	1	
Column totals :	15	16	20	3	3	8	(65)
% of total overall :	23	25	31	5	5	11	
	79%			21%			

Table 69

Experiment C13 Boiling Point (OA)

Qt.	a	b	c	d	e	f	
1	2	-	2	2	-	1	
2	1	2	2	2	-	-	
3	6	1	-	-	-	-	
4	2	2	2	-	1	-	
5	1	2	1	1	1	1	
6	5	2	-	-	-	-	
7	-	1	1	1	2	2	
8	-	3	1	3			
9	1	2	3				
10	-	1	2	1	2	1	
11	-	2	1	1	2	1	
Column totals :	18	18	15	11	8	6	(76)
% of total overall :	24	24	20	14	10	8	
	68%			32%			

Table 70

Experiment C14 Recrystallisation

Qt.	a	b	c	d	e	f
1	2	3	1	-	-	-
2	-	3	2	1	-	-
3	5	1	-	-	-	-
4	-	2	2	1	1	-
5	-	-	1	-	1	4
6	3	2	-	1	-	-
7	-	2	2	1	1	-
8	-	1	1	2	1	1
9	2	1	3	-	-	-
10	1	2	2	-	1	-
11	-	2	3	-	-	1
Column totals :	13	19	17	6	5	6
% of total overall :	20	29	26	9	7	9
		75%			25%	

As before in the case of college A the two sets of responses from the attitude test have been abstracted below in Table 71.

Table 71

Summed responses % (a+b+c) and % (d+e+f) from Tables 58-70

Experiment	% a+b+c	% d+e+f
C1	58	42
C2	45	55
C3	-	-
C4	46	54
C5	71	29
C6	49	51
C7	58	42
C8	57	43
C9	70	30
C10 /		

Table 71 (cont'd)

Experiment	% a+b+c	% d+e+f
C10	79	21
C11	60	40
C12	79	21
C13	68	32
C14	75	25

$\bar{X} = 58$

Again it is noted that in comparison with college A the attitude response is less optimistic in the case of college C and here similar number of experiments are involved. The general pattern of response to the attitude test appears to suggest that the students in college C are getting less benefit from practical work than are those from college A. 'Appears to suggest' is used because clearly the numbers of students is relatively small. Because of this the process of emphasising 'bias' in the attitude test has been done very tentatively, and the author's observations on attitudes are equally tentative.

7.3.4 COLLEGE D

Experiment Objectives

Table 72

Experiment No. D1 Determination of chloride (OB)

Objectives

1. You will know why potassium chromate is used as an indicator in the volumetric determination of chloride in solution.
2. You will learn that accurate observation is essential for successful chemical experiments.
3. You will interpret your experimental results.
4. You will be able to work independently.
5. /

5. You will develop your ability to obtain and communicate information.
6. You will be able to carry out to the lecturer's satisfaction the volumetric and gravimetric determination of chloride.
7. You will find the experiment relevant to your chemical education.

Table 73

Experiment No. D2 Techniques of Organic Chemistry (OB)

Objectives

1. You will learn about the use and application of basic techniques in organic chemistry.
2. You will demonstrate that you are able to carry out these techniques.
3. You will learn about the dangers involved in using organic compounds.
4. You will learn about and be able to use safe working procedures.
5. You will be able to select an appropriate solvent for re-crystallisation processes.
6. You will understand the relevance of mixed melting points.

Table 74 College D Objective Attainment

Expt. No.	Objectives OB/OA	No. of returns	No. of objectives for each expt.	No. of students attaining all objectives	Objectives which proved difficult for students [t]
D1	OB	25	7	-	5, 7
D2	OB	15	6	-	3, 4, 5

[t] Refer to Tables 72 and 73

Table 75

Experiment D1 Determination of Chloride (OB)

Qt.	a	b	c	d	e	f	
1	7	5	6	1	2	-	
2	2	7	6	4	1	2	
3	12	8	2	-	-	-	
4	1	2	9	3	3	4	
5	3	3	3	7	4	2	
6	8	10	4	-	-	-	
7	3	5	3	1	6	4	
8	1	5	5	2	3	5	
9	2	5	2	3	6	4	
10	1	4	8	5	2	2	
11	4	11	2	-	3	1	
Column totals :	44	65	50	26	30	24	(239)
% of total overall :	18	27	21	11	13	10	
	66%			34%			

Table 76

Experiment D2 Techniques of Organic Chemistry (OB)

Qt.	a	b	c	d	e	f
1	6	5	7	2	4	2
2	4	10	7	3	1	1
3	9	7	5	2	2	1
4	2	1	8	5	2	8
5	3	2	4	4	5	8
6	13	8	3	1	1	-
7	2	3	4	7	4	5
8	4	5	5	3	3	6
9	8	6	7	1	1	3
10	2	8	8	5	3	1
11	5	7	3	3	3	4
Column totals :	58	62	61	39	29	39
% of total overall :	20	22	21	13	10	14
	63%			27%		

Comments on Tables 72 and 73

Experiment D1   In this experiment a volumetric and a gravimetric approach are used and judging by the responses the objectives have on the whole been successfully achieved. Four students failed to learn about the use of the particular compound/indicator used while six other students did not appreciate the relevance of the experiment in relation to communication skills. Again as has been noted before, the affective objective has not been unanimously accepted.

Experiment D2   This is an introductory experiment in the basic techniques of organic chemistry. The instruction sheet supplied indicates in bold type that there are fire hazards involved. Similarly a complete page is devoted to the choice of a suitable solvent for recrystallisation. On these matters, safety and solvent choice, the objective performance is very poor. Twelve students claim not to have learned about the dangers although only six claim that they did not learn about safe working procedures! Half the class apparently know nothing about the choice of solvent for re-crystallisation. Did they read the instruction sheet?

For what they are worth the summed responses from the attitude test are shown below in Table 77.

Table 77

Summed Responses %(a+b+c) and %(d+e+f) from Tables 75 and 76

Experiment	% a+b+c	% d+e+f
D1	66	34
D2	63	27

7.4 General Conclusions

While it was the original intention to look at the effect, if any, of prior knowledge of objectives on student /

student performance it has not been possible, for various reasons, to come to any positive conclusions. For example, the number of experiments in which objectives were supplied before or after each exercise is insufficient. Further, the quality of the objectives, and this is important in relation to any meaningful conclusions, is very variable between the colleges. That educational success and meaningfulness can be part of practical work is suggested by the results from college A and it appears that there is a case for closer co-operation between colleges to optimise laboratory work and the related learning experiences. The author is of the opinion that students will probably not vary from college to college.

CHAPTER 8

DISCUSSION AND CONCLUSIONS

CHAPTER 8

DISCUSSION AND CONCLUSIONS

This investigation has been concerned with the operation of practical work in the O.N.C. in chemistry and in particular with its educational value to the students.

The earlier chapters were concerned with the background to practical work and it would appear that there is room for improvement in one or more senses.

The importance attached to practical work in terms of a barrier to progress by the students clearly varies from college to college. Two extreme attitudes have been noted ranging from the "pass the students in practical work no matter their performance" attitude on the one hand to the other where access to a final written paper can be prevented because of performance in the laboratory. In addition the laboratory is an aspect which can be sacrificed time wise in order to find additional time for lecture/tutorial sessions. Without expanding further on details previously discussed, it does seem odd that, in a national course situation, these differences exist.

The fault, however, does not lie with the colleges but rather with a syllabus, theory and practical, which has been considered for some time to be too heavily loaded. Unfortunately, there appears to have been no concentrated attempt made by the lecturing staff, who are aware of the course problems, to come together and organise their reasonable objections. It would certainly appear that for the future and for any courses developed by SCOTEC more effort should be made to review the course structure at regular intervals and to make sure that the review involves all or at least a meaningful representation of the lecturing staff involved in teaching chemistry at the technician level. Too /

Too often it is felt that course structure and any reviews which do occur are left to the decisions of the very few.

More specifically with regard to practical work it appears that there is a case for an organised re-thinking of the purposes of practical work as part of the approach to the new courses. As previously indicated in the literature survey there is considerable disagreement about the particular and individual purposes of practical work in academic courses. It is possible that within the Scottish colleges of Further Education a similar disagreement will exist. It appears, however, to be worthwhile to attempt to define or re-define the purposes of the laboratory. The re-definition of the purposes may eventually be similar to those of SCOTEC which are supposed to be followed as guide lines and nothing more. A new statement of aims should possibly be hierarchical in composition. Whatever the presentation of aims a decision has to be taken on the details of course content. Should the practical scheme be even as detailed as it is just now? Having defined the purposes of laboratory work it might be possible to define the time required to meet these aims and then to provide a varied set of experiments which are to be carried out. Alternatively possibly all that is required is the broad aims, the total time available and then let the lecturing staff plan their laboratory work on a college or preferably an inter-college basis. This would allow for year by year variety not for its own sake but to meet the needs as the lecturer identified them. This would have the added benefit of encouraging the professionalism of the lecturers which the author knows is there to be used.

Similarly, it would appear that while the students do not appear to object to writing reports their real value is open to question and the cynic or the realist might suggest that the procedure is gone through to please the administration and not for any real benefit to the /

to the student. Exercises in report writing do not need a laboratory to justify them!

There may be a case for a new approach. What value does the administration gain from looking at a few reports? What is being assessed? The college? The lecturer? The student? What is the basis of the assessment? What is the point of the student writing up what should have happened rather than what actually happened? This situation has been noted in practice! Is there a place for an approach which uses a rough note book as the record of the experiment? It is appreciated that some may be so rough as to be unintelligible! However, a rough book might be a more meaningful experience and educationally more useful. Is the marking in terms of 'x' out of ten all that important when the lecturer should really be concerned with identifying the strengths and weaknesses of the student? The author suggests that this is an area worthy of further examination.

The matter of assessment has been raised. At the moment all colleges are required to some extent at least to follow the guide lines laid down for a basic set of experiments. Some colleges follow the guide lines at all times. The guide lines were sound enough in terms of their intent but they are involved and demanding and in some aspects are difficult to understand in relation to their operation in practice. Is there not a case for reverting to a global mark if there must be a mark? Again, it is suggested that this area would be worthy of further investigation.

It has been suggested above that thought should be given to operating the laboratory on a closed or open-ended basis. No matter which is chosen it would appear essential that for any one experiment within the system there is a case for making a clear statement of the objectives of the experiment. The students' comments /

comments on the pointlessness of the laboratory seem to suggest that the need exists.

The term 'objectives' has appeared frequently in the previous chapters and whatever their role it is very apparent that the objective approach is not used at the moment in any of the Scottish colleges of Further Education in the field of chemical education. It is also apparent that in many cases objective writing is not a skill which all lecturers have!

Is the ability to write objectives of any great significance in the operation of the chemical laboratory? The author would answer in the affirmative and it will be proposed shortly that there is evidence to suggest that clarity of purpose is relevant to the student performance particularly with reference to the broader benefits which the student may derive from his time in the laboratory.

It is not, however, suggested that the failure or inability to approach the laboratory on an objective basis indicates that the lecturer does not know what the laboratory is all about.

However, it is suggested that the ability to define objectives is indicative that the lecturer is quite clear about the specific teaching points which are relevant to any one experiment. After all behavioural objectives are not concerned with what the lecturer will do in any teaching situation. They form rather a definition of what is expected of the student and should indicate in part at least the points on which he will be 'assessed', whatever the 'assessment' procedure may be. It would seem reasonable to suggest that the student has every right to expect a statement of objectives as part of his laboratory remit. It is being suggested that the statement of objectives should form part of the project/experiment instructions.

Many of the comments made by the students in the earlier /

earlier general survey questionnaires suggest that more guidance should be given to them in relation to the overall philosophy of practical work. With such guidance the remarks on, e.g. 'boring titrations' might disappear.

If it is decided, rightly or wrongly, that a number of titrations have to be done then the students should be informed about the reason and the intent of such decisions. Otherwise the students are left to guess and to become bored.

Clearly this situation can be avoided or at least minimised if the whole purpose of the work in the laboratory is thought through, planned and presented to the student in the 01/02 years as a course plan or statement of intent with regard to the benefits they will or should derive.

The investigation has shown contrary to what might have been expected there are no real differences of opinion between the staff and the students in terms of the broad experiences which are gained by completing the practical work in 01 and 02 chemistry.

From what has been said earlier in this chapter it would appear that the teaching staff are not too satisfied with the general format and content of the O.N.C. It is interesting to note that an admittedly small group of professional chemists employed in the larger chemical organisations appear to be quite satisfied with the O.N.C. as it stands. This point of of view the author understands has also been noted by lecturers who visit industry in the East of Scotland as part of their teaching remit. It may very well be that provided a course of study is within certain broad lines, then industry, appreciative of the problems, will accept the courses. In other words, they have broad possibly ill-defined aims in their view of the purpose of education at the O.N.C. level.

Within /

Within the investigation there was more concern with objectives. These were of specific interest in the initial survey of the twenty experiments detailed in Chapter 7. One or two points can be noted which are of interest.

Overall the students do not find this series of experiments boring and, surprisingly, against the background of the lecturers' opinions, do not find the writing of a report to be an imposition. Can it be assumed that a 'lack of boredom' is equivalent to a 'presence of interest'? What is interest? Is it a sense of doing something? A sense of being involved? A change from a lecture? Could the answer lie in the fact that very frequently the students responded positively to the idea that the laboratory contributed to the students' overall knowledge and understanding of chemistry? It would not be fair to complain that this was never mentioned by the lecturers for it is certainly not an objective but an aim. However, as has been previously indicated, just because an educational experience cannot be described in behavioural terms this does not mean that the experience is useless. This appears to be a case in point.

While the linking of practical to theory as an illustration of the latter is considered by some as a virtue and a purpose in practical work it has become evident that this situation does not operate throughout the O.N.C. in chemistry. It is acknowledged that there are problems in the organisation of a laboratory for day release students working to a demanding and possibly over-demanding syllabus. Is the answer then to reduce the amount of ground to be covered and then to approach the laboratory work in a different way, as was suggested earlier in the chapter? The general trend in the answers to this particular topic is not surprising when the laboratory sheet format is considered. However, if integration of laboratory and theory is not uniformly possible /

possible then there is a case for the comprehensive recipe. There is also a case for re-thinking the role of the laboratory and its relationship with theory classes. While the comprehensive laboratory instruction sheet is clearly used it was noted that the majority of the students considered that 'interpretation' and 'thinking' was still a vital part of the laboratory situation. The word 'thinking' is capable of a variety of interpretations and the amount of thought must vary in relation to the types of experiment and its presentation to the student. This was very apparent from the laboratory instruction sheets and certainly the potential for generating thought, if that is considered desirable in an experiment, is probably greater in an organic preparation than say a relatively straightforward physical chemistry exercise.

Of the other aspects the most significant is that relating to safety. There are apparently situations where the safety appreciation objectives have failed to impress many of the students. This is a cause for concern both because of the significance to the student and in relation to the present legislative situation.

In the final stage of the investigation it was, unfortunately, not possible to pursue the planned intentions with regard to the role of objectives and their influence on student attitude. From the limited evidence available there is no indication that the timing of the presentation of the objectives has any real effect on objective attainment. However, the sample is small in terms of drawing conclusions.

One aspect however may be of significance. Looking at the performance of colleges A, B and C (D only contributed two sets of experimental results) it appears that overall the students are getting more benefit from the laboratory in college A as compared with the other two. The attitude test responses are more /

more clearly biased towards the favourable side and in addition the total summed percentage responses underline this observation. Strictly speaking only A and C should be compared on at least a number of experiments basis although not a sample size basis. As has been stated elsewhere the class size has been an ongoing problem in this investigation. Nevertheless, it is suggested that the evidence indicates a difference between college A students and college B.

One fact that may be relevant is that, throughout, the staff of college A has shown a greater consistency and ability in the statement of objectives. Is it possible that this ability is reflected in the day to day presentation and supervision in the laboratory? Do the students benefit because the lecturer in charge has clearly identified in his own mind the objective areas as distinct from the support areas in any one experiment? Clearly further investigation of the precise role of objectives would be worthwhile but in any case as has been previously stated the definition of objectives should be part of the overall presentation of the laboratory course and its individual experiments. This is the least the students can expect and ultimately it is the students that count. If college A is offering its students something more positive in the laboratory this further underlines the desirability of encouraging inter-college liaison and lecturer involvement in course planning and reviewing.

In attempting to draw conclusions the author is aware of the emphasis which has been given to the questionnaire approach throughout the investigation. Possibly it would have been beneficial to interview students although this technique has it problems and pitfalls as does the questionnaire approach. It would also have been beneficial to establish a series of investigations/experiments to monitor how far the students claims with regard to their laboratory experiences matched the reality of these experiences. If such a procedure had proved feasible it would have served to underline or otherwise the reliability of the questionnaire approach

However desirable these alternatives are, it has not proved possible to pursue them because of the organisational problems involved.

Conclusions

As a result of the investigation it is suggested that:-

1) There is a need to examine the overall philosophy of practical work in the O.N.C. (Or any succeeding course) in chemistry in relation to its educational purpose, its length and content, its presentation and its priority.
2) There is a need to encourage academic staff at all levels to become involved in course structure and, in future times, in course reviewing.
3) It is suggested that all academic staff involved in the O.N.C. (or succeeding course) practical work should seriously consider the role of objectives in giving guidance and purpose to the students who are involved.
4) There is evidence to suggest that accepting that it is impossible to satisfy all the students all the time, the students are deriving benefits by being involved in the laboratory. This situation should be developed and optimized.

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R E F E R E N C E S

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