A STUDY OF THE AIMS AND EFFECTS OF CHEMISTRY PRACTICAL WORK IN INDIAN SECONDARY SCHOOLS AT THE SENIOR CERTIFICATE LEVEL

by

PAUL ANTHONY HOBDEN

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ABSTRACT

This study is concerned with the aims and effects of chemistry practical work at the senior certificate level. In view of the time and the expenditure involved in organising practical work it was considered reasonable to enquire what the teachers hoped to achieve by means of practical work and attempt to ascertain if these aims had been achieved.

After a review of the relevant literature, two questionnaires were drawn up for the purpose of data collection. The first was sent to the teachers of senior certificate physical science to find out :

i) what practical work had been performed;
ii) the actual aims of performing this practical work;
iii) the practical skills at which their students were now competent.

The second questionnaire was administered to first year university students, before they had commenced their university chemistry practical programme, to find out :

i) the manner in which the teacher had organised the practical work;
ii) the degree to which the aims of the teachers had affected them;
iii) the skills at which they felt they were competent as a result of doing chemistry practical work.

The data from the two questionnaires were individually analysed and the results subsequently compared, both with each other and with previous studies in this field. Among the more significant results were :

i) there appeared to be a mis-match between the stated aims of teachers and the influence of these aims as perceived by the students.
ii) both the students and teachers agreed that the practical skills at which the students were competent were limited to only a proportion of the practical skills needed to carry out experiments effectively.

The implications of these findings for physical science teachers were considered. It is suggested inter alia that teachers should adopt strategies which would emphasise the objectives they hoped to achieve with special reference to developing process skills. If these strategies were followed then the teachers would be more successful in achieving aims which they considered very important when organising practical work.

PREFACE

The study described in this thesis was carried out in the Department of Education, University of Natal, Durban, from October 1981 to December 1984, under the supervision of Mr.M.Thurlow, Department of Education, and Professor M.Laing, Department of Chemistry, without whose guidance and valuable suggestions this study could not have been undertaken. Thanks are also due to the following individuals and institutions who have helped with the study in various ways:

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DECLARATION

The author wishes to states that the whole thesis, except for fully referenced extracts, is his own original work and has not been submitted in any form to another University.

P.A. HOBDEN

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

> Science teaching must take place in a laboratory; about that at least there is no controversy. Science simply belongs there as naturally as cooking belongs in a kitchen and gardening in a garden. Books of recipes or gardening manuals can be read anywhere, but the smells, taste, labour and atmosphere can only be evoked in those who already know the reality. It is the same with science, and so the teaching of it must involve real contact with those aspects of nature which are to be studied (Solomon 1980, p.13).

Teachers of physical science spend a significant proportion of their time demonstrating or organising chemistry practicals for their pupils. In view of the time and the expenditure involved it is reasonable to enquire what the teachers hope to achieve by means of practical work and attempt to ascertain if these aims have been achieved.

This study is primarily concerned with the aims of teachers and effects perceived by students of chemistry practical work at the senior certificate level in Indian secondary schools. Before these aims and effects are considered it is important that the role of practical activities in science education be considered.

1.2 THE ROLE OF PRACTICAL WORK

> Science instruction is expensive because of the need for materials and space, because of the low student-teacher ratio and because of the long instructional hours. And, if science teaching in general is expensive, then science laboratory instruction is one of the primary reasons. Yet, we insist on the continuation of the science laboratory experience because it is essential, but to whom? And, for what purpose? (Walker 1975, p.103).

What do we hope to achieve by teaching pupils Physical Science? It is only by searching for an answer to this question that the role of practical work will be seen to emerge in the correct perspective. A review of South African literature does not reveal many sources where the role of science education is discussed and motivated. The question necessarily arises whether Physical Science teachers have a clear conception of the ultimate aim of their teaching and the role of practical work within it.

Three significant sources of reference to the aims or role of science education in South Africa need to be mentioned. The first appears in each of the introductions to the Physical Science higher grade syllabi. For example the Department of Indian Affairs, Division of Education (DIE) lists nine general principles used as a guide for the drawing up of the syllabus. None of these principles refers directly to the need to carry out practical work. However, in the notes concerning the implementation of the syllabus, specific mention is made of practical work and the role it should play. A similar list, with the exception of the last paragraph in some cases, is to be found in the introduction to most of the Provincial syllabi e.g. Natal Education Department (1977).

> Physical Science is an experimental science. The syllabus gives ample scope for experimental work carried out by the pupils themselves.
>
> (i) to help pupils understand the fundamental role played by experiment and observation in establishing and extending the body of scientific knowledge;

(ii) to facilitate the learning and understanding of facts and principles;

(iii) to give pupils opportunites of making simple 'discoveries' on their own;

(iv) to provide experience of elementary measuring techniques, and acquaintance with some of the measuring instruments in common use;

(v) to give practice in the recording and treatment of observations, the drawing of appropriate conclusions and the presentation of results (in this connection, it is expected that pupils will gain some appreciation of what is meant by 'significant figures' in recording scientific observations, and of the importance of specifying limits of accuracy).

Aims (i) and (ii) can be achieved by treating experimental work by pupils as an integral part of the course, eg. by introducing fundamental principles or important extensions or applications of these by experiments carried out by the pupils themselves. Aim (iii) can also be achieved in this way, and by the provision of opportunities to carry out simple open-ended experiments (DIE 1977, p.1).

The second reference is that which occurs in the document 'A Science Education Policy for South Africa' which was produced as a result of a national meeting organised by the South African Association of Teachers of Physical Science (SAATPS) at which the basic role, purpose and overall structure of school science education was debated. Five aims were set out giving the basic purpose of science education in South Africa. The second aim specifically mentions practical work.

> The study of science as a human activity should lead to an understanding of the language and procedures of scienoe. The scientific methods of fact gathering, hypothesis, testing, evaluation and prediction should be presented as of value not only within the discipline itself but also in all spheres of life. Values such as 'humility before the facts' and the integrity this entails should also be emphasised. Appropriate laboratory work by the pupils must form an integral part of the course (SAATPS 1978, p.4).

The third reference appears in the first report of a comprehensive research programme on the instruction of Physical Science, Biology and Mathematics in secondary schools in South Africa by the Human Sciences Research Council (HSRC). The report isolates six 'meaningful' objectives for Physical Science teaching, one of which 'An Introduction to Scientific Methods' refers specifically to practical work. "By means of practical work in the laboratory the child is made aware of the objectivity, impartiality and honesty which scientists attempt to attain; is given the opportunity to make his own observations and logical conclusions and is brought under the impression of the strength of empirical investigation" (HSRC 1979, p.83). The report continues by giving a list of ten basic activities of scientific investigation to which pupils can be introduced, and concludes ".... the pupils' practical work should not only concentrate on heuristic and investigative experiences. A more realistic objective of practical work would be to allow pupils a wide spectrum of basic experiences" (p.88).

Although the overseas literature does not throw much more light on the role of the practical in science education, one report emanating from England which deserves attention is the policy statement 'Education through Science' issued by the Association for Science Education (ASE). Six aims of science education are listed, one of which refers to the laboratory. "The acquisition of a range of cognitive and psycho-motor skills and processes as a result of direct involvment in scientific activities and procedures in the laboratory and the field" (ASE 1981, p.10).

According to Kreitler and Kreitler (1974) any survey of the literature will reveal the following three general objectives for science practical work in some form or another:

i) the imparting of information;

ii) the training in basic processes;

iii) the building up of motivation or attitudes.

Each of the reports mentioned above, originating from subject associations, education departments and individual researchers, mention the need for practical work to be carried out. They also contain elements of the three general objectives given by Kreitler and Kreitler. It would appear that the quotation at the beginning of this chapter is valid; "Science teaching must take place in a laboratory, about that at least there is no controversy" (Solomon 1980, p.13).

However, one important omission in all these statements is a list of goals which are specific to science practical work. The role of the practical is intimately linked with the aims of science education but at no stage is the unique role of practical work spelled out. As indicated by Lunetta et al.(1981, p.23) it would appear that "we don't know enough to convincingly confirm or reject many hypotheses about the importance and/or effects of laboratory teaching". Perhaps this is the reason for the current rethinking of activity-centred science education. "Not only are students spending less time in the laboratory, but teachers are more often 'making do' with demonstrations or by distributing sample data from hypothetical experiments or field experiences as the basis for student work" (Gardener 1979, p.31).

With the advent of computer simulations of experiments the problem becomes even more alarming, especially when comments such as those of Moore and Thomas (1983, p.654) with respect to the use of the microcomputer in schools begin to gain acceptance. "Perhaps the time has come to reverse roles, to advise teachers to use simulations of experiments as common practice and to reserve the more expensive, more troublesome and more time consuming traditional laboratory for the few occasions when its use cannot be avoided."

To conclude, it must be mentioned that the Education Departments in South African, including the DIE, do not prescribe particular methods or approaches for practical work but merely general aims. Whilst the teacher has to conduct a certain number of compulsory practicals,e.g. DIE 1977, he is free to choose the method and manner in which they are conducted. However, as stated by Hofstein and Lunetta (1982, p.206), "there are vast differeces in learning strategy from one kind of laboratory activity to another that are bound to affect learning outcomes". Consequently, it is important that the various approaches to practical work be considered as these are the means by which the teachers attain their objectives.

1.3 APPROACHES TO PRACTICAL WORK

> A good teacher will see that a wise balance is held between individual practical work and demonstrations (The Science Masters Association 1942).

The teacher's approach to practical work will most likely be determined by the opinion that he holds of the role of practical work. One opinion holds that practical work is a teaching aid to enable theory to be understood and facts remembered i.e. a means to an end. A second opinion holds that practical work is a process, a discipline in its own right. Depending on the view held, practical activities will be organised so that they have a particular 'flavour'. Unfortunately teachers do not appear to vary their approach between the two. In a study for the 'Evaluation of Science Teaching Methods', a number of teaching styles were isolated in the teachers involved in the study, and it appeared that the teachers were consistent in their style. "The tendency is for the style to be consistent, no matter what form the activity takes. Didactic teachers teach practical work didactically. Teachers favouring investigatory methods of learning do so sometimes to the exclusion of anything else" (Eggleston et al. 1976, p.119).

According to Hofstein and Lunetta (1982) a number of different practical activities can be recognised as indicators of different teacher approaches. Some activities are organised deductively and pupils collect data to verify or illustrate a law or relationship that had been outlined in the class. Other activities precede formal introduction of a topic and involve pupils in obtaining data from which they will subsequently attempt to infer relationships or make generalisations. Some activities are highly structured and pupils follow instructions while others are much more open and involve pupils in the designing and planning of the experiment. Some activities are divorced from the theory almost as if they were tagged on as an afterthought, others are designed so that there is a constant interaction between the theory and the practical activities.

Attempts have been made to classify these practical activities and a number of schemes have been used. Kerr (1963) used seven categories of experimental work and Lynch (1976, p.86) used a very similar scheme in his enquiry.

1. Demonstrations that verify facts or principles already known to pupils.
2. Repetition of standard qualitative experiments (e.g. To show that...).
3. Repetition of standard quantitative experiments.
4. Fundamental classical experiments repeated to show crucial stages in the logical or historical development of a principle or topic.
5. Short term problem solving or discovery experiments designed to answer a question raised in the development of the course.
6. Long term investigational projects.
7. Practical work set primarily to develop skills in laboratory techniques.

Although this scheme covers most common categories of practical work carried out at school, it does restrict the demonstration to only one category. This has happened because the difference between the nature of the activities and the manner in which they can be carried out has been ignored. Consequently, its usefullness is restricted e.g. some teachers might plan a demonstration to illustrate a fundamental classical experiment. This does not fit in any of the above categories.

A completely different approach is adopted by Van Praagh (1983). He sees experiments as being divided into only three types:

1. Experiments which have a purely exploratory role.
2. Experiments in which the outcome is more or less known already.
3. Experiments used to test the correctness of theories.

> A school science course should find a place for all three types of experiment - the first, for the sake of its immediate appeal and the sense of satisfaction and even of wonder and excitement that the outcome of such an experiment can produce. The second type of experiment is more a part of the experience of any practising scientist and should be included in a school science course so that students can have personal experience of the activities of scientists. The third type is of the greatest importance in focussing the students' attention on the nature of facts and mental concepts and scientific theories. They should be given some opportunities to observe some facts that challenge us for an explanation, to formulate hypotheses and to test these by experiment. They should then formulate a theory and understand that a theory is just a hypothesis that has stood the test of experiment (Van Praagh 1983, p.635).

This classification focusses on the nature of the experiment but does not include other practical activities e.g. demonstrations. If for the word 'experiment' the words 'practical activity' were substituted this could provide a guide applicable to a broader range of practical activities. A more specific classification of the approaches or types of practical experience for school chemistry, which focusses on the nature of the practical activity, is suggested as follows:

1. Practical work designed to illustrate theoretical principles or show phenomena.
2. Practical work designed as a tightly structured activity to yield or verify known experimental results (linear path).
3. Practical work designed as a loosely structured activity for the purpose of investigation or problem solving (branched path).
4. Practical work, initiated by the teacher, as an open ended enquiry or problem solving activity (no set path).
5. Practical work which is initiated, designed and performed by the pupil to learn something new (self discovery).
6. Practical work designed solely to interest pupils in, or change their attitudes to science (to motivate).

A certain degree of overlap would occur between the above six types of practical work. On occasion a particular activity could be said to have elements of more than one 'type' present. Each practical can also be carried out in a number of different ways e.g. teacher demonstration and pupil experiment. Different objectives are achieved by planning practical work in one of the above ways. Consequently, a study of the activities planned by teachers, should give information about their aims or a study of the aims should indicate the nature of activities to be expected in the laboratory. These categories of practical activities are useful for both diagnostic and planning purposes.

1.4 SUMMARY

A study of selected published aims of science education shows without doubt that practical work is considered to have an essential role to play in science education. The precise nature of that role which practical work is expected to play is not spelled out but rather left to the interpretation of the teacher. Depending on the teachers' interpretation of this role, they will adopt particular approaches to achieve their aims. A number of different activities can be recognized as indicators of different teacher approaches. These activities have been variously classified but the most useful appears to be those classifications which concentrate on the nature of the activity rather than the method. Although there are a number of different approaches that can be identified, it has been found that teachers do not vary their approach from one practical activity to the next but rather restrict the majority of their practical work to a particular approach.

As guidance is not freely available in the syllabi or South African literature for the interpreting of the unique role of practical work, opportunities exist for teachers to misinterpret the role and attempt to achieve 'impossible' objectives by means of practical work. The following chapter of this study surveys the literature on the aims teachers have for practical work and the practical abilities they hope to develop in their pupils. When considered together, an indication of the role that teachers see for practical work emerges.

CHAPTER TWO

AIMS AND OBJECTIVES OF PRACTICAL WORK

2.1 INTRODUCTION

Although practical work has traditionally been regarded as an essential part of a physical science curriculum, questions are now being asked about the specific educational benefits a student should derive from being involved in practical work. The manner in which practical work can best be used is still considered an unanswered question. According to Buckley and Kempa (1971) the precise relationship of student laboratory activities to the goals of school science courses is not clearly understood. Consequently, the problem of producing a clear statement of objectives has not been found to be easily solved. Although there are many points of similarity, authors differ both on what they consider to be desirable practical objectives and the manner in which they should be formulated.

The exact nature of a practical objective is also open to question. Swain (1974, p.152) considers it to be "a statement of intended outcome in practical work after a suitable course has been taken". He suggests that the objectives should be stated in terms of behaviour whereas Thompson (1975, p.3), on the other hand, disagrees with this approach and states "the desirable aims of laboratory teaching are not necessarily stateable in behavioural terms". Two possible approaches can be identified for the construction of a list of practical objectives. The first involves the statement of aims from an intuitive point of view using the aims previously stated and used by teachers. Most of the studies into the opinions of teachers with respect to aims, have used this type of approach to the construction of a list of objectives.

An example of this intuitive approach is that used by Solomon (1980, p.139). She gives a few examples of what she calls 'real' objectives :

1) a feel for the right instrument or apparatus
2) a capacity to design and criticise experiments from the viewpoint of variables, controls and reduction of errors
3) a chance to appreciate skill and increasing accuracy
4) room for individual initiative and personal delight

These objectives are considered by her to be "practical not only in their method of attainment but also in their goal". Aims or objectives such as these are often criticised for not being detailed enough and are difficult to use for the purpose of assessment.

The second, or 'skills and abilities' approach, derives from attempts to improve the methods of assessment of practical work. It is thought that there is an important relationship between the purpose of practical work and its assessment at the secondary level as suggested by Thompson (1975, p.3); "practical examinations probably play an important part in steering the thinking of teachers". These objectives focus on the skills and abilities the pupils should have as a result of participating in practical work. They are often stated very precisely in behavioural terms.. The determination of the objective is approached from the practical situation and the experiment itself is analysed, extracting the skills and abilities necessary for each stage of the experiment. An example of this method of determining practical objectives is that used by Hellingman (1982). A list of these objectives is given in section 2.3, p.35.

A number of studies have been conducted using objectives determined by the 'intuitive' approach and some of their findings are mentioned in the next section. Little use has been made of the second approach in surveying the opinions of teachers or pupils concerning practical work. Most of the work published in this field has been in connection with assessment of practical skills. Consequently, the surveys and publications produced as a result of using these two different approaches, are considered separately in the following two sections.

2.2 THE INTUITIVE APPROACH

The first major study of aims or purposes of school practical work was carried out as a national survey in England by a team under the coordination of Kerr (1963). 701 science teachers (218 of whom were chemistry teachers), most following a secondary grammar school type curriculum, took part in the survey. In the section dealing with aims, teachers were asked to rank in order of importance the ten given aims of practical work, for various years of secondary school teaching. These ten aims were collected from a number of published reports on science teaching methods and reworded to remove any ambiguities. As part of the enquiry, the ten aims used were modified and reduced to six statements and given to first year students at universities and colleges. They were asked to indicate the degree to which they thought they had been influenced by these aims. The pooled rankings of the chemistry teachers for the ten aims of practical work are given in Table 2.1.

Kerr found that there was significant agreement among the different groups of teachers (chemistry, physics & biology) as to the values of practical work. He reported that the least agreement occurred amongst the teachers ranking chemistry aims in the last year of schooling (sixth form), compared to earlier years where there was good agreement. Kerr suggests that the sixth formers in the different sciences were doing similar practicals but for different reasons, whereas the junior forms were engaged in different activities in each science discipline, but with similar ends. A number of other interesting findings were also reported. Although the teachers were involved in the teaching of different sciences, (chemistry, physics & biology) they gave similar rankings to the ten aims. Considering some of the aims in isolation it was found that making phenomena more real and interesting (aim 10) was considered very important by teachers for the early years, but was given less importance in the sixth form. However, the students (who had completed sixth form the previous year) felt that this aim had been the most important.

Table 2.1 Rank order of importance of aims given by teachers for sixth form chemistry practical work (Kerr 1963)

Aim number	Aim description	Aim order
1	To encourage accurate observation and careful recording	1
2	To promote simple, common-sense scientific methods of thought	4
3	To develop manipulative skills	5
4	To give training in problem solving	7
5	To fit the requirements of practical examination regulations	8
6	To elucidate the theoretical work so as to aid comphrehension	2
7	To verify facts and principles already taught	6
8	To be an integral part of the process of finding facts by investigation and arriving at principles	3
9	To arouse and maintain interest in the subject	10
10	To make biological, chemical and physical phenomena more real through actual experience	9

adapted from Kerr (1963, p.27 Table 3)

The teachers ranked finding-out by investigation (aim 8) as third in importance but the pupils gave it a lower ranking (66% of the pupils felt they had been at most slightly affected by this aim). This suggested to Kerr that the schools were not making their pupils conscious of the nature of the 'finding-out' element in science. It was also found suprising that problem-solving (aim 4), although it is naturally linked with the process of finding facts by investigation (aim 8), was ranked of little importance by the teachers. Kerr interpreted this anomaly by saying the teachers must have considered problem solving in a strictly limited 'solving puzzles' manner and not as had been intended. A point of consensus for both the teachers and the pupils was that they agreed that practical work was an influence in making clear the theory (aim 6). However, it appeared that chemistry practical work was not considered as effective as practical work in physics, in elucidating the theoretical work. When it came to preparation for practical examinations this aim was ranked last but Kerr felt that the teachers had reacted as expected. "This preparation so obviously should not influence the practical work but we know it does" (Kerr 1963, p.30).

Part of the enquiry dealt with the types of practical work carried out by the teachers and when compared to the stated aims Kerr reported that when it came to the implementation of these aims there was found to be a lack of consistency between the stated values and the actual form of the practical work popular in schools at the time. Verification experiments were frequently used despite teachers saying they were of limited educational value. In the same way, although teachers regarded investigatory methods to be of considerable importance, there was little evidence that such methods were in use (Kerr 1963, p.54).

In the late fifties, as a result of a number of influences (e.g. child centred study advocated by Piaget, and Russian advances in technology) generous funds were made available both in England and the U.S.A. to inaugurate new science courses. The best known of these were the Nuffield Science Projects in England, the CHEMSTUDY and the Physical Science Study Curriculum (PSSC) in the USA.

The influence these curriculum innovations had on science teaching can be judged from the following comments by Solomon (1980, p.26).

> School text books were unanimously cast as the villains of the piece and were rejected as a respectable teaching implement. Experiment was promoted in their stead to pride of place in the teaching armoury either as inquiry into a problem posed by the teacher or even more boldly as an open-ended encounter between pupils and materials which was to generate problems, concepts and results.

As commented by Solomon, the emphasis of the curriculum innovations was to base the teaching in the laboratory, resulting in far more emphasis on problem solving and discovery learning. A further quotation, this time from the Nuffield Chemistry Handbook for teachers (Coulson 1967, p.2) indicates the type of practical work expected. "During practical work pupils should be given the opportunity to make observations that will excite and interest them, and should be encouraged to attempt explanations for what they have seen. Further experiments to test these suggestions should then be devised".

A few years after the implementation of the new curricula, a small scale study by West (1972) involving 31 chemistry teachers in England was undertaken to determine if any shift in teacher opinion could be identified following the Kerr report and the curriculum innovations such as the Nuffield programmes. It differed from the previous study by Kerr (1963), in that both grammar and comprehensive schools were included. However, the study was limited to teachers of fifth form chemistry. A questionnaire similar to that of Kerr was used. A significant measure of agreement was found amongst the different teachers regarding the importance of each aim. As recent curriculum development projects had emphasized discovery methods, aims such as developing scientific thought and finding facts, were expected to be given greater importance and this was found. Although 'encouraging observations' had declined considerably in importance, 'making phenomena more real and interesting' still showed marked differences in ranking for the different school levels.

Taking all the results into consideration, West reported that there appeared to be a general movement in the direction required by the curriculum innovations i.e. emphasis on discovery methods and developing scientific thought. However, the aim 'finding facts' still occupied a relatively low position in the order, with respect to the implementation of these objectives, when the frequency of different types of practical work used, were analysed. West concluded that "marked differences still appear between stated aims and actual practice" (p.157) i.e. aims stated by teachers might have changed but it was doubtful if changes in practice had occured since Kerr's study.

Ten years after the implementation of the curriculum reforms, a similar enquiry was carried out by Thompson (1975) but this time focussing on the sixth form. 655 teachers from a number of examination boards in Britain, representing both 'traditional' and the new Nuffield syllabi, participated. Of the teachers who participated, 220 were chemistry teachers. A list of aims was drawn up which, it was hoped, was sufficiently detailed to distinguish fairly small differences in the approach of teachers to practical work (see table 2.2). This was attempted as it was felt that Kerr's aims "indicated the prime areas but were sufficiently general to leave undrawn certain basic distinctions" (Thompson 1975, p.5). Consequently, distinctions which were previously not possible, could be made and, in his opinion, a better measure of the relative importance of the aims would be obtained. Some of the more interesting findings reported were :

i) Once again, considering all the sciences, the teachers of the three separate sciences involving quite different practical work had essentially the same ranking of aims.

ii) When the replies of the chemistry teachers were considered in isolation, the value of practical work for chemistry teachers seemed to be the carrying out of experiments (principally of a 'standard nature') for two main reasons. The first was the acquisition of skills and techniques which were related directly to the nature of practical work itself, almost practical work for its own sake (aims 1,5,10). The second reason seemed to be to develop certain attitudes to chemistry (aims 2,3,7).

Table 2.2 Rank order of importance of aims given by teachers for sixth form chemistry practical work (Thompson 1975)

Aim number	Aim description	Aim order
1	To encourage accurate observation and description	1
2	To promote a logical, reasoning method of thought	3
3	To develop a critical attitude	7
4	To make phenomena more real through experience	2
5	To become able to comprehend and carry out instructions	4
6	To practise seeing problems and seeking ways to solve them	12
7	To arouse and maintain interest	6
8	To develop certain disciplined attitudes	9
9	To develop self-reliance	11
10	To develop specific manipulative skills	4
11	To help remember facts and principles	8
12	To give experience in standard techniques	10
13	To prepare the student for practical examinations	16
14	For finding facts and arriving at new principles	14
15	To elucidate theoretical work as an aid to comphrehension	13
16	To develop an ability to communicate	15
17	As a creative activity	17
18	To verify facts and principles already taught	19
19	To develop an ability to co-operate	18
20	To indicate the industrial aspects of science	20

adapted from Thompson (1975, p.38 Table 6.0) iii)One result that Thompson felt was cause for interest was the perceived need for students to experience personal involvement (second in importance) with the content of the subject. As a result, the ranking indicated for verification of facts (nineteenth) was as expected but that for discovery learning (fourteenth) unexpectedly showed that it was also not considered important.

When compared with the aims of Kerr, it appeared that the function of chemistry practicals in supporting theoretical understanding of the subject had become much less important. Similarly aim 14 (finding facts and arriving at new principles) which is understood as the use of practical work for the purpose of 'guided discovery', had dropped dramatically from third position in Kerr's study to fourteenth position (eighth position if only the aims common to both studies are compared). This particular change, and others led Thompson to comment "teachers as a group have not been substantially affected by the new curricula in their conception of the role of sixth form practical work" (1975, p.42). This was most suprising due to the importance attached to 'discovery methods' in the new curricula over the previous decade and due to the trend indicated by West (1972).

A similar study by Beatty and Woolnough (1982) with 11-13 year olds in England showed that there was no evidence of a dramatic change in the reasons that teachers gave for doing practical work, despite all the curriculum innovations. However, a number of consistent changes in the rank orders suggested that "teachers might be viewing practical work more as an activity concerned with the development of those skills which are most specifically practical in nature and less as a method of enlarging knowledge or of understanding it" (p.28). This reinforced the findings reported by Thompson i.e. chemistry practical work was being done for its own sake.

The curriculum reform that occurred in England had a direct influence on many teachers' and curriculum planners' approaches to practical work in South Africa. The significant effect can be seen by examining the new syllabi which were introduced afterwards e.g. DIE 1972. However, it was not until 1976 that any research on a national scale was undertaken in this field . A large scale enquiry into science practical work was carried out with Lynch as co-ordinator (1976).

Approximately 600 schools and 2000 teachers throughout South Africa participated, 623 of whom were Physical Science teachers i.e. teaching physics and chemistry as one school subject. The nature, aims and purpose of practical work in schools was surveyed using a list of aims of laboratory teaching for teachers. This list of aims (see Table 2.3), was based on those aims compiled by Kerr with the addition of the aim 'to make teaching more stimulating and interesting'. Before comparisons can be made between this and other studies reported, it must be noted that in this enquiry teachers were asked to indicate the relative importance of each of the aims under ideal conditions, as opposed to actual aims in the earlier studies mentioned. A corresponding set of influences were used to assess the students' perception of these aims at the end of the senior certificate year. Pupils were also asked to give an estimate of the possible influence of practical work they experienced on their ways of thinking, their attitudes and modes of behaviour.

As the enquiry covered a very broad field, only the more significant findings in respect of the aims of practical work are outlined below.

i) Teachers' opinions of the aims of practical work showed few differences, whatever the level of the pupils, the teachers' qualifications or experience. The pupils' opinions were also homogeneous to a similar degree, showing little variation according to language medium, sex or type of school. This was different to previous studies such as Thompsons' where differences were found at different years of schooling i.e. 2nd vs 6th Form.

ii) Good correlation was also reported between the teachers' ideal aims and pupils' actual experiences. This implied that pupils appeared to be affected by practical work very much in the way that teachers had hoped.

Table 2.3 Rank order of importance for ideal aims for Physical Science practical work given by teachers and the perceived influence attributed by pupils (Lynch 1976)

Aim number	Aim description	Aim order (teachers)	Influence (pupils)
1	Encouraging accurate observation	2	3
2	Promoting the ability to think scientifically	4	4
3	Clarifying theoretical portions of the syllabus	3	2
4	Making the subject more real and interesting	1	1
5	Encouraging problem-solving and self discovery methods	5	8
6	Training pupils in basic laboratory techniques	7	7
7	Teaching pupils to organise their own laboratory experiments	9	6
8	Satisfying the minimum requirements of the syllabus (T) / Helping pupils to secure higher marks in matriculation (P)	10	9
9	Giving pupils an interest in experimentation	6	5
10	To make teaching more interesting and stimulating (T) / To encourage pupils to study science further after school(P)	8	10

adapted from Lynch (1976, p.46 Table 3.1)

iii) In all cases where the proposed ideal aim was identical to the possible influence, the response of pupils fell short of the ideal set by teachers. Lynch explains this by indicating that the teachers referred to ideal aims but conditions in the schools left much to be desired.

iv) The most important aims according to practising teachers were, 'to make the subject more real and interesting', 'to encourage accurate observations', 'to clarify theoretical portions of a subject' and 'to promote simple common sense scientific methods of enquiry'.

v) Teachers did not regard problem solving and self discovery methods as major reasons for making use of practical work, ranking this aim fifth in priority, while pupils ranked it even lower (eighth) as far as perceived influence was concerned. This indicated that in practice less emphasis was given to the use of practical work as a means of discovering principles and facts than was desired by the adherents to discovery type methods.

As part of the same enquiry, a number of individual reports were made focussing on particular population groups e.g. Colussi (1975) dealing with the four provincial departments of education concerned with 'white' schools. At the same time a detailed analysis was made of the opinions of Indian physical science and biology teachers and pupils by Naik (1979). 168 teachers from 64 schools under the Division of Indian Education were canvassed. However, only 17% of the sample (28 teachers) were teaching Physical Science (Std 8 to 10) and 59% of the 480 pupils intended to write the Physical Science Senior Certificate examination. The results for the teachers were very similar to those reported for the total sample by Lynch. Once again there was very good correlation between the rank orderings of the aims by the teachers at the two different levels (Stds 6 to 7 and Stds 8 to 10). However, when compared with the pupils' responses, some of the teacher aims differed significantly in ranking to the influences felt by the pupils e.g.

i) The teachers ranked promotion of ability to solve practical problems and to discover facts and principles by the pupils themselves (aim 5), as third while the pupils ranked the influence of this aim as ninth.

ii) Promoting the ability to think scientifically (aim 2) was ranked fifth by the teachers but only seventh by the pupils.

iii) Organising experiments (aim 7) was ranked ninth by teachers but second by pupils. This was explained by Naik as the need of pupils to be prepared to repeat particular practicals for the external moderation which was part of their senior certificate examination. This was not the situation in most other education departments and consequently was not revealed by analysis of the total sample.

Although satisfying the requirements of the syllabus / securing higher marks (aim 8) was ranked tenth by teachers and eighth by pupils, this aim still showed the greatest statistical difference in ranking for the two groups. This was seen as an indication that pupils' perception of acquiring better marks was a very dominant consideration on their part but the teachers were not prepared to consider, or perhaps to admit, that this was an important aim for themselves in an 'ideal' situation (see comments on Kerr study, p.14). Unfortunately, no information from other studies was available in respect of the 'actual aims' teachers had, making further comparisons impossible (see Section 7.4.2, p.142, for a comparison in respect of actual aims). Overall, the findings indicated that there existed a clear case of the ideal aims being different to the influence of the actual teacher aims as experienced by the pupils. The pupils were not being influenced in the manner desired.

Research studies have also been carried out in other countries especially when new curricula or syllabi were introduced. Ben-Zvi et al. (1977) undertook research in Israel to assess the reactions of high school chemistry students, chemistry teachers and university scientists to a new laboratory orientated school chemistry curriculum which had been followed for the previous three years. A list of 23 behavioural objectives related to laboratory work was compiled covering the areas mentioned by a number of sources such as Jeffrey (1967), Mathews (1969) and Boud (1973). Factor analysis of the list of objectives indicated that they fell into six areas or categories.

i) Investigative competence
ii) Bridge to theory
iii) Reporting and communication skills
iv) Ability to plan experiments
v) Manipulative skills
vi) Ability to interpret observations

Some of the more important findings reported after analysis of the responses of the three groups to the questionnaire were that :

i) No significant difference between the responses of the teachers and research scientists were found but significant differences were found for 11 out of the 23 objectives between the teacher group and the pupils (compare with findings of Lynch).

ii) Both groups agreed that making chemistry a concrete subject, forming a bridge between theory and experiment and teaching how to draw conclusions were important. Objectives similar to training students in writing reports and enabling closer contact between teachers and students, were rated as not important.

iii) The objectives rated higher by students fell into two groups a) teaching manipulative skills and scientific methods b) forming a bridge between theory and practice. On the other hand those rated higher by teachers inclined toward the affective domain e.g. creating interest in chemistry.

iv) Overall the students felt that 78% of the objectives (18 out of the 23) had been at least moderately attained. Surprisingly, one of those not considered as being attained was 'instilling confidence in chemistry'.

The results of this study were different in emphasis to previous studies mentioned, in that they were used to evaluate the new curriculum materials rather than just ascertaining if there was a mismatch between teachers aims and the influence reported by the pupil. Another study with similar intentions was that carried out by Boud (1973). A laboratory aims questionnaire was developed and used as a simple method of diagnosing areas for course improvement in a first year physics laboratory course. A recent use of these aims (see Table 2.4) was made at the 7th International Conference on Chemical Education (Montpellier 1983) where the responses of 22 participants in a workshop on 'Laboratory teaching of chemistry at university' were compared with the responses of a group of scientists questioned in an earlier study (Boud et al. 1980).

Table 2.4 Comparison of rank orders of importance attributed by workshop participants (Montpellier 1983) and scientists (Boud 1980) to chemistry laboratory objectives

Aim	Aim description	Aim order (workshop)	Aim order (Boud 1980)
1	To instil confidence in the subject	11	12
2	To teach basic practical skills	3	2
3	To familiarise students with important standard apparatus and measurement techniques	3	5
4	To illustrate material taught in the lectures	17	17
5	To teach the principles and attitudes of doing experimental work in this subject	11	7
6	To train students in observation	6	3
7	To train students in making deductions from measurements and interpretations of experimental data	1	1
8	To use experimental data to solve specific problems	9	6.
9	To train students in writing reports on experiments	6	9
10	To train students in keeping a day-to-day laboratory diary	21	19
11	To train students in simple aspects of experimental design	11	16
12	To provide closer contacts between staff and students	11	20
13	To stimulate and maintain students' interest in the subject	10	11
14	To teach some theoretical material not included in the lectures	20	22
15	To foster critical awareness (for example extraction of all information from data, avoiding systematic errors)	2	4
16	To develop skill in problem solving in the multi-solution situation	11	13
17	To simulate the conditions in research and development laboratories	19	21
18	To provide a stimulant to independent thinking	8	9
19	To show the use of practical work as a process of discovery	11	14
20	To familiarise students with the need to communicate technical concepts and solutions	17	15
21	To provide motivation to acquire special knowledge	21	18
22	To help bridge the gap beween theory and practice.	3	8

adapted from i) Boud et al. (1980, p.416)
ii) workshop notes (Montpellier 1983)

Comparisons of the results showed few significant differences between the two groups. Overall the responses indicated that the most important aims were thought to be those conventionally associated with the purposes of laboratory work i.e. to train students to be competent practical workers with emphasis on interpretation of data, possession of critical faculties, practical and observational skills. The participants and scientists (refer to Table 2.4 above) attached low priority to practical work as a process of discovery and to the development of 'problem solving skills in the multi-solution situation'.

These results once again reinforce previous findings that teachers and scientists consider the laboratory as essentially a place for the acquisition of practical skills and not a place for discovery learning. However, the views of pupils do not lead one to believe that this is what they are experiencing. Pupils tend to report influences related to making the subject more real and the theory more easily understood. The following section reviews the work carried out in assessing the practical skills which pupils should have obtained as a result of actually doing the practical work.

2.3 THE SKILLS AND ABILITIES APPROACH

Attempts to produce schemes for the evaluation of laboratory programmes and assessment of pupils' practical work have resulted in a number of publications focussing on the objectives of practical work. However, few quantitative studies of teachers' use of these aims have been attempted. Two formats have been used in attempts to produce realistic, useable sets of objectives. These focus on :

i) Skill categories - the skills pupils should have as a result of practical work or the skills required to actually do practical work

ii) Experiment stages - the stages the pupil must pass through for the successful completion of an experiment.

Both have produced objectives dealing almost exclusively with the pupil experiment, and make very little or no reference to demonstrations by the teacher. In this sense they do not refer to objectives for practical work but rather to the specific area of pupil experiments in the laboratory.

The first appearance of any detailed objectives, outlined in the form of skill categories, was in a report on science education in USA by Noll (1947) in which he outlined a number of skills as the basis of a successful study in science. Among others he divided the skills dealing with practical work into two categories :-

A. Instrumental Skills

i) perform fundamental operations with reasonable accuracy

ii) perform simple manipulatory activities with reasonable accuracy

iii) read graphs and tables in order to interpret them

iv) make accurate measurements and readings

B. Problem-solving Skills

i) ability to sense and define the problem

ii) test a hypothesis proposed by experiment and other means and reject the hypothesis on the basis of conclusions drawn.

In order to develop a guide for the construction of laboratory performance tests in Physics, this list was improved and extended by Kruglak (1951). He grouped twenty six specific objectives under six categories :

i) Instrumental skills
ii) Skills in the use of the controlled experiment
iii) Problem solving skills
iv) Miscellaneous skills
v) Functional understanding of principles
vi) Habits

This was the first attempt at a detailed statement of the objectives of practical work and it has been used as a point of departure by many other authors.

As a consequence of the curriculum innovations in England and the United States of America during the sixties, teachers had been encouraged to use practical work far more than before. Due to the importance now attached to this component of physics and chemistry, a careful re-evaluation of the practical work was needed, especially in the field of assessment. This led to a number of publications, one of the more significant being that by Jeffrey (1967). He postulated a set of outcomes which were hoped for as a consequence of the students' laboratory experiences. He called them 'Student Performance Objectives of the Individual Science Laboratory' (p.187). The following six outcomes or competencies were postulated :

i) Vocabulary competence
ii) Investigative competence
iii) Reporting competence
iv) Manipulative competence
v) Laboratory discipline
vi) Observational competence

Each competency was expanded with respect to the specific abilities expected of the student. For example, he postulated that investigative competence covered ten separate areas:-

i) knowledge of capabilities and limitations of laboratory equipment
ii) ability to design experiments to quantify characteristics
iii) ability to design experiments to identify substances
iv) ability to design experiments to separate substances

v) ability to order data
vi) ability to formulate a hypothesis
vii) ability to design an experiment to test a hypothesis
viii) ability to predict effects of actions
ix) ability to search the literature, and
x) ability to use standard handbooks

Following this, an investigation was carried out by teachers participating in the Nuffield trials and by those devising the course, to formulate objectives for Nuffield A-level practical work. As a result of this investigation, Mathews (1969) reported the following qualities which teachers could expect pupils to develop during a course of practical work:

i) Skill in observation
ii) Ability to interpret observation
iii) Skill in manipulation
iv) Ability to plan experiments
v) Attitudes to practical work

This was an important statement of practical objectives, especially as it was a direct consequence of the Nuffield innovations. This led to a number of reports, all based on these five general qualities, dealing with the assessment of practical work.

One of the first was that of Buckley and Kempa (1971) who carried out an enquiry to find out the percentage of teachers not involved in the Nuffield A-level chemistry trials who nevertheless found themselves in agreement with the set of objectives reported by Mathews. The motivation for this study was that a number of examining boards had suggested that future patterns of teacher-based assessment of practical abilities would be built around these objectives. Within four of these areas, sub-objectives were identified and teachers were asked to comment on their comprehensiveness. There was a high degree of acceptance of the suggested objectives by the sample of teachers (93% considered the list comprehensive). The fifth area, attitudes, was omitted from this study since in the authors' view it expressed a quality which was "more in the nature of a desirable by-product of students' involvement in practical work rather than a directly trainable practical ability" (p.36).

In a follow up study by the same authors (1972), student opinion about different assessment procedures was obtained, by means of a short questionnaire and individual interviews. Fifty students following a traditional A-level course were given statements describing the five assessment areas and asked what abilities should, in their view, be assessed. A fair degree of concordance between the students' views about abilities to be assessed and the views held by teachers and examiners was found. However, for two of the areas, ability to plan experiments and investigational routes (iv), and interest in and attitudes toward practical work (v), only 56% and 50% respectively of the students favoured inclusion, compared to responses of over 70% for the other three areas. No clear reason was given for this except that "some of the students felt somewhat unclear about exactly what areas (iv) and (v) meant operationally" (Buckley and Kempa 1972, p.159). This statement of skills and abilities, first proposed by Mathews, is still widely used today and forms the basis for the evaluation of pupil practicals in the DIE (see section 3.4, p.43).

More recent work has emphasised the stages the pupils must pass through to complete the actual experiment rather than the skills they should have developed. This was done in order to help in the production of a more specific assessment tool for experimental work. The first was a publication by Thomas (1972) who prepared the following list of specific behaviours for pupils to follow in a laboratory assignment:-

i) Understand and follow instructions
ii) Formulate method
iii) Organise work and work space
iv) Manipulate equipment and collect data
v) Record results accurately
vi) Present results
vii) Use statistical methods
viii) Discuss results and suggest follow up work
ix) Survey the literature

This list correlates closely to the typical steps some university tutors have used in guiding students in the preparation of laboratory reports.

In a review of practical objectives, Swain (1974, p.153) commented that any list put forward could be criticized. He suggested that what was needed was "a statement of practical objectives which could be adapted to meet individual requirements but at the same time the basic structure could be preserved". Using the experiment as a basis, he proposed a different method for categorising practical abilities which would achieve this aim. He identified three main stages or units of time within the experiment:-

i) the road to the experiment (e.g. purpose, planning)

ii) the experiment (e.g. manipulation, observation)

iii) the conclusions to the experiment (e.g. analysing)

Using practical objectives selected and modified from previous authors' lists, Swain then produced a detailed set of objectives, categorized according to these three units of time (see Table 2.5).

He did not include pupils' attitudes in the list, as agreeing with Buckley and Kempa (1971), he felt that many of the attitudes to be developed could be considered more as a by-product of practical work and "why at the moment they should be inserted solely into the practical area must remain a mystery" (Swain 1974, p.154). For those applicable to practical work, such as faith and reliance in observations, he indicates there might be a problem as to whether " we can at the present time give an objective assessment of such attitudes or are they only value judgements". He also comments that each ability could be broken down even further into sub-objectives but according to Holliday (1972), the list might then appear 'trivial' with such a large number of sub-objectives.

In an attempt to increase the reliability of teachers' assessments of practical abilities, Eglen and Kempa (1974) carried out a study concentrating on the assessment of manipulative skills in sixth form chemistry. They proposed that if the view was held that 'the objective of an introductory chemistry course lies first and foremost in the development of good manipulative skills and acceptable working habits in the laboratory' (p.262), then the acquired skills themselves need to be assessed.

Table 2.5 The three stages of the experiment and the abilities associated with each stage (Swain 1974)

I. THE ROAD TO THE EXPERIMENT

1. Ability to comphrehend the purpose of the experiment

2. Ability to plan an experiment
   i) Ability to analyze the practical problem into its component parts
   ii) Ability to devise/select a procedure/technique
   iii) Ability to recognise limitations and possible sources of error in (ii)
   iv) Ability to recognise the importance of controls and the use of pilot experiments

3. Ability to obtain a viable experimental set-up
   i) Ability to comphrehend written/verbal instructions
   ii) Ability to select and assemble apparatus to perform a standard/novel function
   iii) Ability to appreciate the need for care and for economy in time and materials

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II. THE EXPERIMENT

4. Ability to perform an experiment
   i) Manipulation
      (a) Ability to use familiar/unfamiliar apparatus/materials
      (b) Ability to implement familiar/unfamiliar procedures
   ii) Observation
      (a) Ability to make accurate qualitive observations
      (b) Ability to make accurate quantitative observations
   iii) Recording
      (a) Ability to record accurately the experimental data obtained

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III. THE CONCLUSIONS TO THE EXPERIMENT

5. Ability to analyse and interpret the experiment
   i) Ability to arrange/organise/classify data obtained in tabular/diagramatic/graphical form
   ii) Ability to interpret results and draw conclusions
   iii) Ability to assess the validity and reliability of the experimental procedures and results on the basis of the experiment
   iv) Ability to suggest improvements to the experiment
   v) Ability to make/reject a hypothesis from the data

6. Presentation of the experiment
   i) Ability to write a concise effective report
   ii) Ability to give a concise effective oral report

adapted from Swain (1974, p.156)

They produced a breakdown of the manipulative skills area into sub-categories and specified.for each, generalised performance criteria (see Table 2.6). Consequently, they produced a number of detailed sub-objectives for one of the abilities, which Swain had not considered advisable to produce. When it came to a particular practical it was suggested that certain components would be relevant to that practical and would thus be chosen. It was also felt that these generalised criteria might require further amplification in relation to particular practical tasks.

TABLE 2.6 A breakdown analysis of manipulative skills (Eglen and Kempa 1974)

1. Methodical working
   - Correct sequencing of tasks forming part of an overall operation
   - Effective and purposeful utilization of equipment
   - Efficient use of working time
   - Ability to develop an acceptable working procedure on the basis of limited instruction

2. Experimental technique
   - Correct handling of apparatus and chemicals
   - Safe execution of experimental procedure
   - Taking of precautions to ensure reliable observations and results

3. Manual dexterity
   - Swift and confident manner of execution of practical tasks
   - Successful completion of an operation or its constituent part-tasks

4. Orderliness
   - Tidiness of the working area
   - Good utilization of available bench space
   - Organisation in the placing of equipment used

adapted from Eglen and Kempa (1974, p.263 Table 1).

Table 2.7 Laboratory structure and task analysis inventory (Lunetta and Tamir 1979)

1.0 Planning and design
- 1.1 Formulates a question or defines a problem to be investigated
- 1.2 Predicts experimental result
- 1.3 Formulates hypothesis to be tested in this investigation
- 1.4 Designs observation or measurement procedure
- 1.5 Designs experiment

2.0 Performance
- 2.1a Carries out qualitative observation
- 2.1b Carries out quantative observation or measurement
- 2.2 Manipulates apparatus; develops technique
- 2.3 Records results, describes observation
- 2.4 Performs numeric calculation
- 2.5 Explains or makes decision about experimental technique
- 2.6 Works according to own design

3.0 Analysis and interpretation
- 3.1a Transforms result into standard form (other than graphs)
- 3.1b Graphs data
- 3.2a Determines qualitative relationship
- 3.2b Determines quantative relationship
- 3.3 Determines accuracy of experimental data
- 3.4 Defines and discusses limitations and/or assumptions that underlie the experiment
- 3.5 Formulates or proposes a generalisation or model
- 3.6 Explains a relationship
- 3.7 Formulates new questions or defines problem based upon result of investigation

4.0 Application
- 4.1 Predicts, based on results of this investigation
- 4.2 Formulates hypothesis based upon results of this investigation
- 4.3 Applies experimental technique to new problem or variable

adapted from Lunetta and Tamir (1979, p.22)

Lunetta and Tamir (1979), using a similar approach but covering the complete range of skills, published a list of 24 skills and behaviours as 'a laboratory structure and tasks analysis inventory' (see Table 2.7 above). These skills were grouped under four headings (as opposed to Swain who identified three phases) which represented phases of laboratory activity. In a later study it was stated that irrespective of the teacher's particular goals, the student behaviours will fall under these four phases (Lunetta, Hofstein and Giddings 1981). This inventory was produced, as it was felt that:

> Whatever one's goals, it is important to decide whether any given laboratory project or investigation will contribute to achieving them. One way to answer this question is to define each goal in terms of what we want the student to be able to do as a result of his or her laboratory experience .....we must be able to identify the specific problem-solving and inquiry skills that we are after (p.22).

One interesting finding reported after an analysis of numerous laboratory handbooks, using their task analysis inventory, was that pupils were still commonly working as technicians following explicit instructions and concentrating on the development of lower level skills. It appeared that pupils were seldom encouraged to engage in discussion of goals, strategies, results or implications i.e. higher level practical skills (see section 7.2, p.130).

One of the more recent attempts at producing an exhaustive list of practical objectives was that produced by CITO, the Dutch Institute for Educational Measurement (Hellingman 1982). The main features of the list of aims and objectives were :

i) The objectives are stated in terms of observable behaviour of pupils engaged in practical work.

ii) The list aims at as much completeness as is conceivable for any course of practical work.

iii) The list shows four levels of generality: i.e. it is divided into four broad classes which are three times subdivided. The third subdivision is specific to the different subjects, Physics and Chemistry.

An adapted list, showing only the first two levels of generality is given in Table 2.8. Commenting on the list, Hellingman states that "Its capacity for unambiguous screening of existing practical tests has been tried out in a number of cases. The outcome is that it fulfills this task better than previous lists did" (p.35). However, he also indicates that "there are things that probably cannot be reflected in a list of objectives and yet are taking place in an experiment...These are beyond the scope of an examination" (p.34).

Table 2.8 Abilities required for practical work in Chemistry (Hellingman 1982)

A. Preparation for an experiment
- A.1 Ability to put into words one or more experimentally viable problems, making use of sources of information
- A.2 Put forward one or more hypotheses regarding the problem(s)
- A.3 Formulate the purpose of an experiment
- A.4 Devise a work scheme

B. Performing the experiment
- B.1 Perform manipulations with apparatus/materials
- B.2 Make observations
- B.3 Make notes/records
- B.4 Repeat or supplement activities/observations, stating the reasons

C. Elaboration of the observations
- C.1 Work out/reconstruct measurement data
- C.2 Interpret data obtained

D. Account for activities and results
- D.1 Investigate reliability of values found / investigate validity of conclusions
- D.2 Offer explanations
- D.3 Offer suggestions for the continuation of the inquiry
- D.4 Report about the experiment

adapted from Hellingman (1982, p.39)

Although lists produced using this approach are primarily useful in assessment of practical work, they are limited in that they do not include any reference to affective domain objectives. Consequently, they are not particularly useful for the overall planning of practical activities. However, those areas of psycho-motor and cognitive skills covered, are done comprehensively. An advantage is that these classifications will only be revised and improved (with time and changes in curricula emphasis), and not undergo drastic revision as the 'intuitive' type skills lists might, as they are based on the structure of the experiment. Unless the nature of the experiment changes, the only significant changes to be expected are in the emphasis on particular objectives or skills.

2.4 SUMMARY

Lists of objectives constructed using the traditional or intuitive approach have been used in a number of studies of practical work. Evidence from these studies indicates that the teachers would appear to be carrying out practical work for its own sake i.e. acquiring experiment related skills, rather than as a means of supporting the theory. The pupils on the other hand report that they consider practicals as a means of making the subject easier to learn and more 'real'. It also appears that although the majority of teachers agree about the aims which they consider important, there does seem to be a difference between the aims stated and the actual practice. Notwithstanding the tremendous emphasis placed on discovery learning by the curriculum innovators, this approach does not seem to have gained much in importance when the actual practical activities organized by teachers are examined. However, it does seem to be an important aim with respect to ideal aims, as evidenced by the findings of the Naik study (1979) where teachers gave it a relatively important ranking.

Although teachers would appear to agree on the need to learn practical skills, very little work has been carried out to determine exactly what skills pupils possess as a direct consequence of practical work.

However, lists of skills associated with the different stages of experiments have been published. This skills approach has led to the development of comprehensive lists of skills that pupils should have as a result of, or in order to participate in, practical work. These lists have the advantage over the intuitive type lists, in that their basic structure is unlikely to change with time. As opinions of teachers change only the emphasis on particular objectives/skills will change. A disadvantage of these lists; with their emphasis on assessment, is the lack of objectives dealing with the affective domain. Consequently, they have not been used to survey teacher or pupil opinions on the purpose of practical work. They have been used more in the field of evaluating curricula and laboratory practical programmes.

As both approaches have some value in determining the purpose of practical work, it is found suprising that no studies have been carried out using a combination of both. Consequently, the present study has attempted to draw together both approaches and find out if there is a relationship between the opinions of teachers, determined using a traditional list of objectives, and the resulting skills and abilities of the pupils, determined using a 'skills and abilities' list. The following chapter outlines the aims, syllabus and assessment procedures for practical work in the department under which the teachers and pupils who participated in this study fell.

CHAPTER THREE

THE SITUATION IN INDIAN EDUCATION

3.1 INTRODUCTION

The opinions of teachers, concerning their objectives for practical work will be influenced by a variety of factors. In a number of enquiries, among others, Kerr (1963), Thompson (1975) and Lynch (1976), teachers were asked what the most serious problems or obstacles were in carrying out practical work. Three areas of common concern can be identified; the syllabus, the teaching conditions and the assessment of the practical work. As these 'factors' are considered to have an influence on teachers' aims and objectives for practical work, it is appropriate to consider these factors as they apply to Indian teachers employed by the Division of Indian Education (DIE).

3.2 THE SYLLABUS

The teachers follow a syllabus set down by the DIE and which meets all the requirements of the Joint Matriculation Board (JMB 1973, pp.147-154). The syllabus is very similar to the syllabi of other Education Departments but a difference exists in the case of practical work. A number of compulsory practicals are prescribed which are examined by means of continuous assessment and a control test. The mark gained by pupils forms part of their final senior certificate mark. The syllabus undergoes revision on a national basis approximately every ten years. The last syllabus was introduced in 1972/3 and a new one is to be introduced in 1985. Therefore, all comments made here are in respect of the 1972/3 syllabus. The syllabus for both Higher Grade (HG) and Standard Grade (SG) Physical Science for Standards 8, 9 and 10 starts with a general statement of objectives for the course. Although none of these objectives refers specifically to practical work, in the notes that follow (DIE 1977, p.5), attention is given to practical work (refer to Section 1.2, p.2).

It is suprising that some of the more common objectives mentioned in the literature, do not appear in this note on practical work. Those omitted are among others ;

(i) arousing the interest of pupils
(ii) making the subject applicable to real life situations
(iii) arousing or changing attitudes of pupils
(iv) problem-solving.

However, the following objectives are mentioned specifically :-

(i) to facilitate the learning of facts and principles
(ii) to give pupils opportunities for making simple discoveries
(iii) to give practice in recording and treatment of observations.
(iv) to acquire basic laboratory techniques

The objectives teachers adopt in practice, compared to these guidelines, are discussed in section 5.4 which deals with the opinions of teachers concerning the aims and purposes of practical work.

The department lays down a certain minimum of practical work that must be completed (Appendix C). These practicals are specified in the syllabus at the appropriate 'theory' section. In the chemistry section sixteen practicals are required to be done by the pupils themselves. Of these, nine are examinable in the practical control test. The aim of each practical is stated in the syllabus but the actual method is left up to the individual teacher. These practicals are outlined in the recommended textbooks, so teachers tend to use these methods or methods handed down to them by more experienced teachers or subject advisors. A guide to practical work was also compiled by the Physical Science subject committee and issued to all senior teachers. This guide outlines the procedure for the experiment and gives a short discussion for each of the examinable practicals (DIE 1981). Consequently, the manner in which a particular practical is carried out, is most probably very similar throughout DIE schools. (Extracts from the guide are reproduced in appendix E).

An analysis of the wording of the compulsory practical work in the syllabus indicates a bias toward what is called 'standard linear investigations' that is, investigations in which a series of pre-planned steps are followed . There are no branches for the pupil to follow on his own initiative. An examination of pupil practical notebooks collected from pupils on arrival at university indicates that the normal format of a practical consists of :-

(i) the aim given by the teacher from the syllabus
(ii) a list of instructions given by teacher
(iii) the results recorded by the pupil
(iv) a number of questions given by the teacher
(v) the conclusion, which in most cases appears to have been dictated by the teacher or copied from the text book.
(vi) assessment by the teacher .

Two examples of these practicals, taken from pupil notebooks, are reproduced in appendix F. It would appear from examination of practical notebooks and from conversations with teachers, that virtually no practical project work is carried out, nor are genuine investigations with open ended conclusions organized at the senior certificate level. One of the more important reasons for this could be that the aims of teachers do not require practical work of this nature to be planned i.e. this type of work does not achieve any of the desired objectives of practical work.

In his enquiry into practical work, Naik (1979), reported that the Indian teachers were primarily concerned with the preparations for developing skills for quantitative and qualitative experiments for the practical control tests conducted at the end of the matriculation year (Naik 1979, p.255). When asked to rank the various types of practical work used, the physical science teachers ranked repetition of standard quantitative experiments, repetition of standard qualitative experiments and the development of skills in laboratory techniques, first, second and third respectively. Short term problem-solving or discovery experiments, long term investigation projects and fundamental classical experiments were ranked last (p.141). It would appear that the types of practical and the approaches adopted by the teachers are limited. Consequently the effects, on the pupils, can be expected to be limited to those objectives attainable by this type of practical.

3.3 TEACHING CONDITIONS

Although the organization of practical work for their pupils is compulsory for the physical science teachers, the nature and extent of the work done will depend on a number of factors, one of the most important being the conditions under which the practical work must take place. The schools, which offer physical science to the senior certificate level, have at least one science laboratory. Most have two, one for general science and one for physical science. These laboratories normally have fixed benches with laboratory stools for pupils and a lecture bench and chalkboard for the teachers as it is often necessary to use these laboratories as classrooms. Attached to the laboratory is the chemical storeroom so that apparatus and chemicals are easily available. Each class is assigned to the laboratory for a specific time each week, in most cases for a double period. It is only in the schools with a number of laboratories that all the physical science teaching takes place in the laboratory. Each laboratory is equipped with a standard list of apparatus, glassware and chemicals supplied by the DIE.

It is the responsibility of the subject department head to apply for any chemicals, glassware and apparatus which he does not have, but which appear on the standard list. This equipment is adequate with respect to the chemistry experiments laid down, except in the case of the 'gas law' experiments where only three sets of apparatus are available per laboratory, and for organic practicals where a shortage of certain chemicals is apparent. If the school desires extra apparatus, it must raise the money itself. If consumable items are needed for particular demonstrations or experiments, e.g. antacid tablets, the teacher may obtain these items using a sum of money set aside by the department for such needs.

The problems experienced by teachers in Indian schools with respect to practical work were reported by Moodley (1972) and Naik (1979). In the study by Naik over forty per cent of the teachers felt that the syllabus was too long with the result that there was insufficient time available to do all the practical work they desired to do. Other time related problems experienced were 'lack of time between periods for preparation' and 'lack of laboratory assistants'. Twenty-three per cent of the teachers felt that there were few suitable text books for pupil experiments. Other problems which were given prominence by the teachers were the large size of classes, the limited number of laboratories available and the inflexibility of laboratory timetabling (Naik 1979, p.245).

At this stage some comment must be made concerning these problem areas reported by teachers and the organizing of practical work in schools. Although time problems might prevent a teacher from doing the 'ideal' amount of practical work, it does not prevent him from carrying out the practical work he does find time to do, in a manner which achieves the objectives he feels are important. However, one factor that could have a significant influence on him, is his experience and professional training. If he is unable to design a practical to achieve his desired objectives, he is then restricted to the methods presented in text books or obtained from other teachers. Consequently, there might be a significant difference between his desired objectives and actual objectives attained, for reasons beyond his control.

It must also be appreciated that conditions for teaching science practical work are unlikely ever to be ideal. Kerr (1963, p.97) referring to the comments of teachers on the conditions under which practicals are organized in England, stated that 'the three most serious obstacles to real experimental work are the lack of technicians, the full timetables of science teachers and the fact that laboratories are too frequently occupied by classes'. It appears that science practical work will always have its associated problems and teachers need to cope with these problems and still work out strategies to attain the objectives they consider to be important.

3.4 ASSESSMENT OF PRACTICAL WORK

The final Senior Certificate examination mark of physical science pupils has three components :

(i) the written physics paper (40%)

(ii) the written chemistry paper (40%)

(iii) the practical assessment mark (20%)

The significant percentage of the total mark assigned to the practical component (DIE 1979) ensures that assessment of practical work forms an integral part of the pupils' final school year. His practical work is internally assessed by the science teacher over the previous two years. This internal continuous assessment of practical work is moderated externally by a group of examiners who visit the school and administer practical 'control tests'. Pupils are warned of the date on which the external assessment will take place, (normally during September or October). The teachers in most schools will repeat the practicals in anticipation of the external moderation (sometimes this involves working with pupils out of school hours). This often takes the form of an internal control test during which all pupils are assessed. "...all the pupils are invariably tested. This procedure serves to give further guidance to teachers concerning the assessment and allocation of final marks for pupils. Secondly it serves as revision for the pupils who would undergo a practical control tests during September and October" (Naik 1979, p.187). In this inquiry by Naik into practical work, 40% of matriculation pupils reported that their teachers conducted practical tests several times annually (96% of the teachers preferred some form of assessment of practical work). It is therefore obvious that the senior certificate pupils are, or have the opportunity of becoming, exceptionally familiar with the prescribed experiments, and the questions associated with each experiment.

A number of pupils (approximately twenty-five per cent of all senior certificate pupils) are selected at random from the merit list supplied by the teacher and are required to repeat specified examinable experiments or parts thereof, and to answer questions on the experiment. Each pupil selected is expected to complete two experiments in two hours. Marks given by the examiner are compared with the teachers' internal assessment and adjustments are made accordingly. The examiner uses a mark scheme similar to that in appendix D. Depending on the experiment, different numbers of marks are allocated to the various skills or abilities but the total for a section is constant.

A. Laboratory skills and abilities : 60%

B. Scientific attitudes : 10%

C. Insight into, and understanding of, experiment : 30%

An example of a mark scheme for a specific experiment is reproduced in appendix D. Because of the nature of the assessment that is to take place, a lot of emphasis is likely to be placed by the pupils on the experiment working and on obtaining the right answers to the questions. Consequently, the pupils understanding of the role of the experiment in science is likely to be very limited (With this type of emphasis, can one expect a pupil to be satisfied with an experiment that produces an answer/result that is 'wrong'?).

It is interesting to compare the above comments on assessment with the following two extracts from previous research.

> Two main obstacles prevent full achievement of the possible rewards of learning science through practical work. They are first the conditions under which the pupils are taught and secondly the external practical examinations......Teachers favoured the retention of practical examinations. In their present form the examinations measured limited aspects of practical ability. They encourage undue attention to training in techniques of measuring things and getting the 'right answer' (Kerr 1963, p.97).
>
> There is an important relationship between the purpose of practical work and its assessment and at secondary level practical examinations probably play an important part in steering the thinking of teachers (Thompson 1975, p.3).

There is no doubt that practical assessment does have a profound influence on the nature and purpose of the practical work carried out by the teacher. This is taken into account when the aims stated by teachers are analysed.

3.5 SUMMARY

Three factors appear to have an influence on the manner in which practicals are carried out. Firstly, the syllabus provides for a number of examinable practicals to be performed. These appear to be organised in a few limited ways, although the objectives stated in the introduction to the syllabus would seem to provide many opportunities for a variety of approaches. Secondly, the teaching conditions are seen to be very similar to those in other education departments and similar problems are reported to those emanating from overseas. Thirdly, the assessment of practical work appears to focus the attention of both teachers and pupils on those aspects to be examined rather than on skills applicable to a wide range of activities.

Overall the situation in schools in the DIE appears to be encouraging. Practical work is an integral part of the syllabus and its importance is emphasised by the marks assigned to it out of the total final senior certificate examination marks. Laboratories are well equipped for the chemistry practicals to be performed. What actually happens in the schools is difficult to determine but the pupil and teacher responses to the questionnaires give a good indication. These responses are discussed in the later chapters. The following chapter indicates how the field of study was determined and the research methods implemented.

CHAPTER FOUR

RESEARCH PROCEDURES

4.1 DELIMITATION OF FIELD OF STUDY

> The danger is that too much practical work, without reference to theory already driven home, causes the pupil to perform experiments satisfactorily but to have little idea what it is all about : and having got results, then not having the faintest idea why he has them or what he should do with them (Kerr 1963, p.32).

4.1.1 Preliminary enquiry

From observations in the teaching situation it became obvious that the manner in which most practical work was organised at senior certificate level, did not result in many effective learning experiences for pupils. The emphasis seemed to be on the learning of a number of standard examinable experiments. On many occasions it appeared as if pupils were following the instructions for a practical with only superficial thought; were completing practicals without any idea of the purpose of the practical; were unable to write conclusions without reference to a text book or a teacher. However, when the external practical moderation approached, pupils would learn how to carry out 'experiments' by rote and achieve good marks but still have no real feel for the role of laboratory work in science.

The above mentioned state of affairs was considered to be the result of inadequate training of teachers in the preparation of learning experiences for the pupils in the laboratory. Alternatively the teachers might have been concerned only with the results of the practical moderation, an assesssment which influenced the pupils' final Senior

Certificate examination mark and as such, was considered a reflection of teaching ability by many teachers. At this stage a decision was made to focus attention on the training of science teachers in the preparation and organisation of laboratory work for pupils, with special emphasis to be given to the strategies for achieving the aims of practical work.

As a first stage in the preliminary study, a three month study tour of England and Scotland was undertaken, during which time science teachers and lecturers involved in post graduate teaching courses were interviewed. As the interviews progressed, it became obvious that no special emphasis was given to the purpose, aims and objectives of practical work during the post graduate teaching diploma courses. Here, the emphasis seemed to be on the completion of as many practicals as possible which might be used in the schools, so that the teacher would have at least experienced the practical before having to organise it when teaching. Many of these educators were not able to suggest well-defined reasons for actually carrying out practical work, or to justify its retention in school chemistry. However, all felt that practical work was an essential part of the science curriculum and should under no circumstances be omitted from the curriculum. The general feeling might be summed in the following comment by an experienced teacher tutor, " .... practical work has always been done and pupils who have not done practical work are in some way different" (from interview with J.Dowd, School of Education, Dundee 1982).

Although it was agreed that doing practical work did not necessarily result in higher examination results, there was some support for the idea that discovery learning, through practical work, had merit as a teaching method and resulted in the pupils having a deeper understanding of scientific phenomena. This was evidenced by the greater number of practical problem solving situations being given to teachers in training as a direct result of the Science Teacher Education Project (STEP 1975).

The second stage of the preliminary work concerned the teaching of science in South Africa. By means of informal discussions with teachers, a comparison was made between their ideas and those held in England and Scotland. From these discussions, it was inferred that many South African teachers of science expressed similar views to their colleagues in England and Scotland but were also unable to give well defined reasons for doing practical work.

One of the reasons advanced by teachers for not placing special emphasis on practical work was the lack of time, owing to the length of the prescribed syllabus. It would appear that the subject has become ever more complex with the syllabus over-burdened with so called essential topics. As a result, teachers have difficulty completing or covering the syllabus each year. "One of the most pressing difficulties facing the physical science teacher is the length of the syllabus" (HSRC 1982). This leads to many teachers neglecting practical work, where it is not examinable, as they consider it far too time-consuming for the rewards obtained. This attitude often arises because of experiences typified in the following comment from a teacher who participated in the Kerr inquiry : "I am often appalled by the small impact carefully considered laboratory lessons and demonstrations have had upon all but the best of my pupils" (Kerr 1963, p.33). Notwithstanding this comment, it is felt that if the teacher designs a practical, either a demonstration or pupil experiment, with particular aims in mind then the rewards for both teacher and pupil will be greater. However, the specific role that practical work plays in science education must be appreciated.

4.1.2 Field of study

As a result of these preliminary impressions obtained both overseas and locally, it was decided to change the emphasis of the proposed study from "the training of teachers in the techniques of practical work" to what now appeared the more fundamental problem of "the aims of teachers for organising practical work and the skills the pupils developed as a result ". If the aims of the teachers coincide with the influences experienced by the pupils, then teachers have the ability to organise practicals to attain particular aims. Further discussion and research would then have to concentrate on the educational relevance of the aims and objectives adopted. If the study showed that the pupils were not influenced in the manner planned for, then the problem could be considered as more serious. The focus of further study would then be both the manner in which practicals are carried out and the factors, such as teacher training and laboratory conditions, preventing the teacher from organising practical activities effectively.

A decision was made to place emphasis on the actual aims teachers adopted rather than their ideal aims. An argument that could be presented against this emphasis might follow these lines. "Surely it is more important to find out if the teachers' actual aims differ from their ideal aims and to determine what factors are causing the difference if it exists ?" However, it is contended that differences will always exist between the teachers' actual aims and their ideal aims. Even if, for instance, the teacher accepted all the syllabus content as being relevant and was prepared to carry out all experiments suggested, it is unlikely that conditions in the school would allow him to carry out the practicals in the manner he desired.

This is substantiated by a comparison of the obstacles to efficient practical work reported by Kerr (1963, pp.68-74), Thompson (1975, pp.24-25) and Lynch (1976, pp.134-152). This shows that similar problems were reported in each enquiry with only minor differences. The problems do not seem to have disappeared with time and they are shown to be similar in different education systems. For this reason, the above argument is rejected and it is felt that the focus of the present inquiry on the actual aims of teachers, will produce information of greater value. It is of prime importance to find out if the teachers are able to carry out practical work in such a way that the pupils are influenced in the manner desired by the teachers' aims. If this is not occurring, then the argument concerning ideal or actual aims is irrelevant as, whatever the aims, teachers would not seem to be capable of achieving them. New strategies would then have to be adopted that would enable teachers to achieve their aims.

Having further reduced the field of study to the actual aims of teachers, the next stage of the preliminary work concerned a thorough review of the literature. This review enabled the problems, previously researched in the field of practical work, to be surveyed and resulted in the identification of different approaches to the study of the aims of practical work (see Chapter 2). Using these studies as a basis, the next stage in the study, pertaining to the generation of hypotheses, was undertaken.

4.1.3 Generation of hypotheses

After careful consideration of the preliminary work carried out and an evaluation of the previous studies in similar fields, a decision was made to formulate hypotheses which would focus the study and allow the selection of a suitable research method. "As difficult as the process may be, it is necessary for the pupil to see the fundamental need of a hypothesis to guide sound research. Without it research is unfocussed...." (Goode and Hatt 1952, p.57). The specific hypotheses constructed were stated as follows:

A. There are significant differences in teachers' ranking of aims in order of importance for experiments and pupils' ranking of the associated influences of those aims.

B. There are significant differences in teachers' ranking of practical abilities at which pupils are competent and pupils' ranking of these same abilities for which they consider themselves competent.

C. There are significant differences in teachers' ranking of aims for demonstrations and their ranking of the same aims for experiments.

The research method selected was based on the need to test these hypotheses and it was felt that as a result of the analysis of the data gathered further relationships or lack of relationships would arise, allowing additional specific hypotheses to be constructed and tested. It was felt that the data collected should also be interpreted as a whole and in this manner an overall picture of the aims and abilities for practical work would emerge. If this was not done, then the specific hypotheses although initially guiding the study might divert the attention away from the more important whole.

4.1.4 Choice of sample

As a result of the decision to focus on 'aims of teachers' and 'influences felt by the pupils' it could be seen that two sample populations were required - teachers and pupils. Those teachers in the employ of the Division of Indian Education (DIE) were chosen as the teacher population. This choice was made for two important reasons. In an effort to reduce the number of extraneous factors that could influence the results of the enquiry, a homogeneous population was sought. This necessitated the choice of one particular education department, otherwise problems would have arisen due to differences such as departmental policy, syllabi, laboratory conditions and initial teacher training between the teachers in different departments. These differences could all have influenced the interpretation placed on the final results of the enquiry. The second reason for this choice was the fact that the writer was a science method lecturer in the Faculty of Education at the University of Durban-Westville (UD-W) and was thus familiar with the conditions in Indian schools and with the administrative methods of the DIE.

Having chosen the teacher population, the pupil population was restricted to those pupils taught by these teachers. This total population consisted of pupils entered for the Senior Certificate examination at the schools of those teachers mentioned above. To obtain a sample, it was intended that stratified random sampling techniques be used. This would have involved dividing the schools into groups based on geographic position (or other characteristics) and taking random samples of pupils from each group. However, to use pupils from particular schools would have meant that the pupils had to be approached while still at school. The nature of the enquiry meant that the information required could only be obtained from the pupils once they had completed their practical moderation examination (September or October). That particular time of year is very busy at schools, as the teachers and pupils are concentrating on finishing syllabi and revision work. The data collection would have been a distraction to both teachers and pupils. Consequently, the chance of fallacious results would have been significant.

The only viable alternative was to obtain a sample of the school population at a later stage. Of the few alternatives available, such as the UD-W, colleges and technikons, the university was chosen as it provided the greatest concentration of school-leavers at one institution. The Deans of the Faculties of Science and Arts were then approached to find out the number of students who had studied Physical Science (PS) at school and were expected to enrol. It was found that only a small percentage, about five percent of the expected first year students in the Faculty of Arts, were likely to have PS as a school subject. To ask these students to participate in a study (questionnaire) during one of the lecture periods would have resulted in considerable disruption and inconvenience to the large number of students not involved. Thus, the Dean requested that this be avoided, if at all possible. Consequently, the sample was restricted to those pupils who entered UD-W, in the year following their Senior Certificate examinations, to study Chemistry as one of their courses. (This sample is subsequently referred to as the 'students'.)

This sample was biased when compared to the total population of school leavers for two reasons. i) The majority of the students had above average examination results (see Table 6.1, p.107) because of the entrance requirements of the UD-W. ii) This sample also had the advantage that the students intended to take up chemistry or related studies at University and would have thus been motivated to achieve well in their Senior Certificate examinations. For this reason, their awareness of the subject and the related practical work was expected to be greater than that of students who did not intend studying chemistry further. As this sample was obtained to find out the influence of the teachers' aims, it was felt that the sample would be more perceptive of these aims and the resulting influences on them. Consequently, the comparisons were expected to yield better results than if a totally random sample of students had been chosen.

The following section outlines the research method, which was chosen after taking into consideration the guiding research hypotheses, the samples from whom data were to be obtained and the manner in which the data were to be used to best advantage.

4.2 QUESTIONNAIRE METHODOLOGY

> "I wish to stress that the method chosen from those available or offered should be the one (or more) best suited to the objectives and limitations set by the specific research problem" (Simon 1979, p.18).

4.2.1 Instrument for data collection

Descriptive research is "concerned with conditions that exist, practices that prevail, beliefs and attitudes that are held, processes that are on going and trends that are developing" (Lovell & Lawson 1970, p.31), whereas experimental research has the essential feature that "the investigator deliberately controls and manipulates the conditions which determine the events in which he is interested" (Cohen & Manion 1980, p.158). The aim of the proposed study restricted the choice of the basic research procedure in general, to a descriptive approach and in particular to a survey, rather than to an experimental procedure because the study was concerned with what teachers had done and what the students had experienced.

The survey, as opposed to other descriptive study designs like the case study and developmental study, was chosen as the specific descriptive procedure. Before this decision was made, the research procedures of similar enquiries were studied, especially with regard to the effectiveness of achieving the overall aims of each enquiry. As a result, it was considered that the survey method was the most appropriate and effective for the testing of the hypotheses described in Section 4.1.3 (p.50).

A number of instruments were available for the collection of data, namely interviews, questionnaires, attitude tests or combinations thereof. Three factors were taken into consideration before a decision was made : i) the aim of the enquiry; ii) the populations on which the enquiry focussed; iii) the resources available. The nature of the enquiry required the gathering of data at the end of the teaching year from a geographically scattered teacher population. The data from the pupil population had to be obtained after the practical moderation was complete and before new practical work was started at University. In each case, the data had to be collected over a very short time interval from a relatively large sample. Finally, taking into account the constraints of finance and resources, it was decided that the only viable instrument available would be the questionnaire. This decision was reinforced by reference to the studies previously mentioned (see Chapter 2) where effective data collection were also carried out by the use of questionnaires.

It was anticipated that interviews of a selected sample of students would be conducted to verify the data obtained in the questionnaires. Unfortunately this was not feasible for the following reasons:

i) Students were involved in a programme of practical work which was likely to influence their perceptions of school practical work;

ii) Students had a very full timetable making it difficult to arrange interviews at convenient times.

4.2.2 Design of questionnaire

It would appear that the questionnaire is accepted as a convenient method of collecting data in a study of this nature. This view is confirmed by the large amount of social research which is carried out using this technique of data collection. It is estimated that this technique is used in more than fifty percent of all research studies in education (Good 1963, p.271). However, it is by no means a perfect technique and is liable to produce fallacious results for a number of reasons. The chances of this occurring can be greatly reduced by the careful design of the questionnaire. The techniques adopted in this enquiry to minimise fallacious results are outlined in the following paragraphs. These techniques were divided into two main groups:

i) Those which attempted to maximise the proportion of questionnaires returned (relevant to teacher postal questionnaire) and;

ii) Those which attempted to ensure that the questions were understood and truthfully answered.

A number of strategies were adopted to ensure that the proportion of questionnaires returned was sufficiently high to make the sample truly representative of the whole group of teachers.

i) The covering letter which accompanied the questionnaire (Appendix B) stated who was doing the enquiry, indicated the goals of the enquiry and also guaranteed the anonymity of the respondent. A copy of the letter granting permission to carry out the enquiry was also attached as required by the Division of Indian Education (Appendix B).

ii) The appearance of the questionnaire was made as attractive as possible. It was clearly printed, using only one side of the paper, with a humorous cover to attract attention. "The appearance of the questionnaire is vitally important. It must look easy and attractive. A compressed layout is uninviting; a larger questionnaire with plenty of space for questions and answers is more encouraging to respondents" (Cohen & Manion 1980, p.85).

iii) The length of the questionnaire was limited to six single pages. Most of the questions required only a tick or cross as response, thus making it possible to answer in less than ten minutes. "The researcher should always bear in mind that the completion of a questionnaire is a favour asked of persons, and hence it should be so constructed that the required data is obtained with the minimum of the respondent's time" (Behr 1983, p.152).

iv) The questionnaire was supplied with an addressed and stamped envelope to make the return as simple as possible for the teacher.

As far as the student sample was concerned, no such strategies needed to be adopted once the co-operation of the students was given. As the questionnaire was to be administered and collected at the same practical session, the return was expected to be close to 100%. However, to ensure that all the questions were understood and truthfully answered for both questionnaires, a number of strategies were employed:

i) To encourage truthfulness, the importance of the enquiry was emphasised and the anonymity of replies assured.

ii) To prevent the teachers or students making responses expected of them, the questions were worded in a completely non-leading manner and a number of 'repeat' questions were asked to check the reliability of answers.

iii) To avoid serial effects i.e. showing preference for items at the beginning or end of a list, the items in the lists of aims and abilities were presented in a purely random order.
iv) To ensure that the questions were understood, the wording of the questions was carefully studied by a number of colleagues and all ambiguities found were removed.
v) To ensure that the response procedure was understood, detailed instructions were given with each section of the questionnaires and emphasis placed on the fact that the enquiry was with reference only to chemistry practical work.

The overall design of each questionnaire was carefully considered and particular attention was also paid to the following points: length of questions, usefulness of each question, order of questions, intended meaning of questions and possible alternative responses. An attempt was also made to make the questionnaire for teachers more personal and open-ended, in that space was provided for comments to be made, or for explanations of responses to be given. "Designing a questionnaire needs considerable thought. The nature, form and order of the questions are very important if meaningful results are to be obtained" (Behr 1983, p.151). Further to this, a pre-test was administered for both questionnaires (see Section 4.3). The adoption of the above strategies ensured, as far as possible, that the responses to the questionnaires were truthful and thus analysis would not produce fallacious results. Used in this manner, the questionnaire was considered a most suitable research tool for the purposes of this enquiry.

Two questionnaires were used in the enquiry, (see Appendix A), one for the senior certificate physical science teachers (teacher questionnaire) and the other for the first year university chemistry students (student questionnaire). The questionnaires were prepared to obtain information about the experiments and demonstrations carried out, the organisation of practical work, the aims of the practical work and the practical abilities developed during the final year of senior certificate study.

4.2.3 Teacher questionnaire

The teacher questionnaire was divided into three sections. Section A dealt with the general particulars about the teacher, e.g. experience and qualifications. This section was included so that the teachers who responded could be analysed by sub-groups e.g. opinions of those teachers who had taught for more than 5 years or teachers who had post-graduate teaching diplomas. Section B was designed to obtain information regarding the actual experiments and demonstrations carried out by the teachers. Two lists of practicals were given and the respondents were required to indicate how each practical had been carried out, i.e. by the pupils themselves, individually or in groups (pupil experiment) or by the teacher (demonstration). The first list consisted of typical chemistry demonstrations that the teacher might attempt, during the senior certificate year, to illustrate chemical concepts and phenomena included in the syllabus. The instructions for each demonstration were available in the text books in use at that time (Brink & Jones 1979, Pienaar & Walters 1976). Instructions for all but three of these demonstrations appeared in both text books. Consequently, there was only a remote chance that a teacher was not aware of a demonstration listed.

The second list consisted of seventeen practicals prescribed as compulsory by DIE in the Physical Science syllabus (1977). All had to be carried out by the pupils and not as teacher demonstrations. However, only ten of these practicals were examinable. These practicals were chosen for inclusion in the questionnaire as it was felt that a comparison of examinable and non-examinable but compulsory practicals carried out, would elicit information about the teachers' approach to practical work and the influence of the senior certificate assessment on their choice of practicals.

Section C was constructed to obtain information about the actual aims of teachers for practical work and about pupils' practical skills and abilities. The list of aims was drawn up after consulting previous research carried out in this field (see Chapter 2). It was decided that the aims presented by Thompson (1975) were the most clearly and unambiguously stated, for the purpose of this enquiry. However, Thompson had used a list of twenty aims, many of which it was felt were aims of education in general, rather than chemistry practical work in particular. Examples of these were: 'To develop self-reliance' and 'To develop an ability to communicate'. For this reason they were omitted from the final list . Other aims were omitted in an attempt to reduce the length of the list while still retaining comphrehensiveness. After careful consideration, only eleven of the twenty aims were chosen as being comphrehensive and representative of the most important aims, in the South African context, of chemistry practical work (see Table 4.1). The aims used fell into four overlapping categories:

i) to teach manipulative skills;
ii) to provide motivation and interest;
ii) to illustrate aspects of scientific methods and;
iv) to consolidate theory and teach concepts.

Each of these aims, which included elements from the cognitive, affective and psychomotor domains, is expanded upon later in this chapter.

Table 4.1 List of aims constructed for use in teacher questionnaire

1. To encourage accurate observation and description.
2. To arouse and maintain interest in chemistry.
3. To make chemical phenomena more real through actual experience.
4. To develop specific manipulative skills, e.g. handling of chemicals.
5. To prepare the pupils for the practical examination or moderation.
6. To clarify theoretical parts of the chemistry syllabus.
7. To promote a logical reasoning method of thought.
8. To let pupils discover facts and arrive at new principles.
9. To verify facts and principles already taught.
10. To give pupils practice at seeing problems and seeking ways to solve them.
11. To help pupils remember facts and principles.
12. ....

Provision was made for further or alternative aims to be expressed by the teacher, by the addition of a space for a twelfth aim. Attention was drawn to this provision by a comment which appeared directly below the list of aims :- "If you have any other aims which you considered important when performing practicals please add them to the above list".

The teachers were asked to indicate the importance they had allocated to each aim. Two responses were requested, one for experiments carried out by pupils and one for demonstrations conducted by the teacher. This was required as it was hypothesised that teachers had different aims for these two categories of practical work. This had not been made apparent in any of the other studies undertaken up to this time. In these studies (see Chapter 2) the aims had been viewed under a general heading of 'practical work' or 'laboratory work' which could be taken to include both demonstrations and pupil experiments.

The teachers were asked to indicate the actual importance attached to each aim. This differed in emphasis from the previous enquiry carried out in South Africa by Naik: "It is very important that this section reflects your considered opinion about the ideal purpose served by practical work quite apart from existing conditions in your school or what you are actually able to do with your pupils now" (Naik 1979, p.323). However, it was similar to the approach adopted by Kerr (1963, p.103): "Please refer to your ACTUAL work in sections iv, v, and vi not what you think should be aimed at".

Provision was then made for comments by the leaving of a number of blank lines prefaced with the following remark :- "If you have any comments to make concerning the questions please do so (e.g. difference between your actual aims and ideal aims)". Besides giving respondents an opportunity to comment this was also included to once again reinforce the idea that the actual importance was desired, not the ideal importance.

The third part of this section was concerned with the practical abilities that the pupils were expected to have developed as a result of the practical work done (see Table 4.2). The list of practical abilities was adapted from the list proposed by Swain (1974) as it was considered to be the most suitable for the purposes of the study.

Table 4.2 List of practical abilities used in teacher questionnaire.

1. Ability to understand the aim of an experiment.
2. Ability to devise or select a procedure or technique.
3. Ability to recognise limitations and possible sources of error in procedure.
4. Ability to follow and understand written and verbal instructions.
5. Ability to select and assemble apparatus to perform a particular experiment.
6. Ability to determine whether the apparatus is functioning correctly.
7. Ability to use familiar apparatus and materials.
8. Ability to make accurate observations.
9. Ability to record accurately the experimental data.
10. Ability to arrange/organise the data in tabular/graphical form.
11. Ability to interpret results and draw conclusions.
12. Ability to understand the purpose of the experiment.
13. Ability to write a concise effective report.
14. Ability to use the results to make predictions for new situations.

These abilities were chosen because they covered the three principal stages of the experiment.

I. The road to the experiment – which includes abilities such as: understanding the purpose, selecting a procedure and recognising limitations in the procedure. The first six abilities fell into this stage.

II. The experiment - which includes abilities associated with the performing of the experiment such as: using the apparatus, making the observations and recording the data. The next three abilities (Nos. 7, 8 and 9) fell into this stage.

III. The conclusions to the experiment - which covers abilities associated with the analysis, interpretation, presentation and future use of results. The last five abilities in the list fell into this stage.

The teachers were requested to respond twice, indicating the approximate fraction of pupils in Higher Grade and Standard Grade respectively, who would in their opinion be competent at these abilities. In order to give the teachers the opportunity to comment on any other aspect of practical work, which they might want to bring to the attention of the researcher, the last page of the questionnaire was provided for comments.

4.2.4 Student questionnaire

The questionnaire given to the students followed a similar pattern to that for the teachers except for Section B. The section dealing with aims was similar, in that the list of aims was merely rephrased so that they were stated as influences e.g. aim 1 'To encourage accurate observation and description' became 'I was encouraged to make accurate observations and descriptions'. A list of these influences is reproduced in Table 4.3. A comparison with Table 4.1 shows a direct correspondence between aims 1 - 11 and influences 1 - 11, facilitating comparative analysis of the responses of the two groups.

Table 4.3 List of influences derived from the aims of practical work for use in student questionnaire.

1. I was encouraged to make accurate observations and descriptions.
2. My interest in chemistry was aroused by doing chemistry experiments.
3. Chemical phenomena (eg. dynamic equilibrium, redox reactions) were made more real to me through my actual experience of them.
4. I developed specific skills in the handling of equipment and chemicals in the laboratory.
5. I was prepared for the practical examination or moderation.
6. I found that the theoretical parts of the syllabus were easier to understand after doing the experiments.
7. My ability to think in a logical reasoning manner has been improved by doing experiments.
8. I was given the opportunity to discover facts and arrive at new principles, eg. by obtaining information from experiments, followed by explanations from books or teachers.
9. Facts and principles already taught were verified in the laboratory.
10. I was given the opportunity to practise seeing problems and seeking ways of solving them in the Chemistry laboratory.
11. The experiments helped me to remember facts and principles taught in class.

The skills and abilities appeared in Section D and the students were asked to rate themselves from 'very competent' through to 'not competent'. The same list was used as in Table 4.2, once again making comparisons with the teachers' responses relatively easy. Section B was completely different from the corresponding section of the teachers' questionnaire. This was done because experiences in the school situation suggested that the students would be unable to give accurate information on particular practicals performed, as had been requested of the teachers.

As an alternative, this section was therefore designed to elicit qualitative information concerning the organisation of the practicals by the teacher. Twelve statements associated with the planning and organisation of practical work were drawn up (see Table 4.4). The students were asked to indicate how often each statement was true. The statements were drawn from four different aspects of the organisation : the first concerned the purpose of the practical; the second the instructions for doing the practical; the third the time available and the size of the group in which the practical was carried out and the last concerned the reporting and assessing of the practical.

Table 4.4 Organisation of practicals: List of statements used in student questionnaire

1. You were required to prepare for the experiment in advance.
2. Verbal instructions for the experiment were given to you by the teacher.
3. You were told to follow the instructions in your text book.
4. Written instructions for the experiment were given to you by the teacher.
5. The instructions used were clear for you to follow them.
6. The purpose for doing the experiment was explained to you by the teacher.
7. You understood the purpose for doing the experiment.
8. You were asked to prepare a written report or write up of the experiment.
9. The group in which you worked was small enough to enable you to participate fully.
10. You had sufficient time to complete the experiment.
11. You never really understood what was being done - you merely followed the instructions.
12. You were tested on your knowledge of the experiment by means of a test, written or verbal.

No further questions were asked in order to restrict the length of the questionnaire and the time needed to answer. However, all data needed for the testing and subsequent acceptance or rejection of the guiding hypotheses could be obtained from the four sections constructed.

4.2.5 Elaboration of aims

The focus of the enquiry was on the aims of practical work. In the review of the literature (see Chapter 2) the various aims used in other enquiries were presented. Section 4.2.3 has indicated the reasoning behind the choice of the list of aims for this enquiry. This section attempts to explain the interpretation placed on each of the chosen aims. It is only with this background that meaningful interpretation of the results of this study could be made. However, it must be remembered that the results of the enquiry, which follow in succeeding chapters, must be viewed in the light of the interpretation of these aims by the teachers participating in the enquiry. These interpretations might differ from what was intended, although every attempt was made in the construction and administration of the questionnaire to minimise this problem.

1. To encourage accurate observation and description

If the pupil is going to participate actively in practical work it is essential that he be encouraged to make observations. At the same time, these observations must be accurate: they should be made deliberately and methodically. Once the observations have been made they are valueless to the class unless he can communicate these observations either verbally or in written form.

2. To arouse and maintain interest in chemistry

One of the most important factors that influence aspects of learning is motivation. The opportunity of taking part in an activity so different from others in his normal school day often fills the pupil with enthusiasm. If this enthusiasm is exploited by the teacher the pupils' interest in chemistry can be aroused. If the source of this interest is encountered regularly then the interest can be maintained.

3. To make chemical phenomena more real through actual experience

Too often pupils complain that chemistry is too theoretical and divorced from real life. Practical work can give the pupil an opportunity of seeing and experiencing those phenomena he has dealt with or will deal with in chemistry. Many pupils believe that they will have a better understanding of the phenomenon if they can actually see it in reality.

4. To develop specific manipulative skills e.g.handling of chemicals.

The pupil is studying chemistry and an intimate part of chemistry is practical work. If the pupil is to become involved with any but the most elementary experiments at school or later at University or Technikon, he must be acquainted with the apparatus of the laboratory and be able to manipulate this apparatus efficiently. The skills under consideration are those directly related to the chemistry laboratory.

5. To prepare the pupils for the practical examination or moderation

Every year some form of external practical moderation is carried out. The pupils are required to repeat particular practicals that have already been carried out earlier in the year. For many teachers the practical work attempted is set only in the context of the examination moderation, as it contributes toward the final mark attained in physical science. If this is the case, the manner in which the practical is performed might be determined by the nature of the moderation.

6. To clarify theoretical parts of the chemistry syllabus

Often the implication of a theoretically derived or abstractly expressed law or problem may be made clearer by a 'real' example. It might be easier to develop a concept e.g. exothermic reaction, if the pupil is able to observe a number of these reactions. Often words and two dimensional symbolic drawings are not sufficient to explain a phenomenon and the child will be aided by a demonstration of the phenomenon. However, according to Kreitler and Kreitler (1974, p.82) there is no conclusive evidence to support this assumption.

7. To promote a logical reasoning method of thought

Many teachers desire their pupils to think 'scientifically'. To this end teachers would like pupils to be able to think deductively when handling experimental data and investigating phenomena i.e. deduce logical conclusions from available information. This 'skill' could also be used in other non laboratory situations.

8. To let pupils discover facts and arrive at new principles

'Guided discovery learning' is an approach that has been widely used in the teaching of science. It allows the pupil to be a 'scientist' and at the same time learn the theory prescribed in the syllabus. If a purely heuristic method is used, it is found to be very wasteful of time. Alternatively, guided discovery allows the pupil to have opportunities of thinking inductively and at the same time covering part of the syllabus. It is an aim most closely associated with the so called 'scientific method' and the syllabus innovations of the sixties.

9. To verify facts and principles already taught

During the course of science lessons many statements are made concerning phenomena. The teacher is often requested to 'show us'. At this stage he may use practical work to verify facts he has given to pupils. This might convince pupils of the 'correctness' of the facts.

10. To give pupils practice at seeing problems and seeking ways to solve them

One of the essential activities of a scientist is that of problem solving. Given a new situation, he is able to recognize the problem and decide which method to select to best approach it. He is able to hypothesise and to test his hypotheses. Practical work could be an opportunity for the teacher to provide situations in which the pupil can be given opportunities to practise these valuable skills.

11. To help pupils remember facts and principles

The teacher may use the laboratory to reinforce subject matter he has taught or is teaching the pupils. Having seen a phenomenon the pupil has a visual picture which could aid him to remember the factual information required. Seeing a number of examples of a phenomenon could help the pupil remember the general principle. An example of this could be 'solubility rules' where repeated application of the rules in a practical could help the pupil to remember them.

4.3 ADMINISTRATION

4.3.1 **Teacher** questionnaire

Before the science teachers were approached to complete the questionnaire, permission was obtained from the Department of Indian Education to send the questionnaires to the schools. A list of schools providing physical science to the senior certificate level was also obtained. This list consisted of schools in three provinces (Natal, Transvaal and Cape), the Orange Free State not having any Indian schools. Seven schools had more than one teacher involved in the teaching of physical science (see Table 4.5 below).

A pre-test of the teacher questionnaire was then carried out by administering it to a group of ten teachers who were asked to complete and comment on the questionnaire. As a result of an examination of responses, comments and advice received, changes were made to the questionnaire, ranging from the order of the questions to simplification of the language. The revised questionnaire was then addressed to 'The Senior Physical Science Teacher' and posted to each school. Accompanying each questionnaire was a covering letter (Appendix B) and a stamped return envelope. Where a school had two or more teachers taking senior certificate science, the appropriate number of questionnaires was enclosed.

The initial posting was carried out late in the school year (November 1982). The reason for posting at that late stage in the school year was the need for teachers to have completed all the practical work for the year and for the practical moderation to have already taken place. Replies were received until late December by which time the schools were closed for the vacation. Schools from which teachers had returned questionnaires could be identified as most had stamped the envelope or questionnaire with the official school stamp and many other teachers signed their names even though this was stated as being unnecessary.

When school reopened for the new year a reminder consisting of the questionnaire, a stamped addressed envelope and covering letter (Appendix B) was sent to those schools from which no replies had been received, but this time addressed to the principal. No further reminders were sent out, as it was felt that persistent harassment of teachers to fill in a questionnaire against their wishes might result in fallacious replies from those teachers. Any teacher who did not wish to participate in the enquiry was simply requested to return the questionnaire uncompleted. This occurred in only four cases. A comparison of the first replies with the last replies did not show any significant differences in the responses. They were thus treated as one group.

Questionnaires were sent to all sixty-one Indian high schools offering physical science at the senior certificate level in 1982. A total of seventy teachers were involved in the teaching of Physical Science at this level. Replies were received from forty-six of the sixty-one schools representing a return of 75%. Of these questionnaires, four were returned uncompleted leaving forty-five questionnaires as the total sample for analysis (see Table 4.5).

Table 4.5 Teacher questionnaires : postal returns showing number (N) and percentage (%) mailed, returned and usable.

	Mailed		Returned		Usable	
	N.	%	N.	%	N.	%
Schools	61	100	46	75	44	72
Questionnaires	70	100	49	70	45	64

Nineteen teachers did not respond to the questionnaire. Various reasons could be postulated for this apparent apathy on their part. One reason could have been that a number of teachers would not have received a reminder, if they had been transferred to a new school as reminders were sent to schools from which no response had been obtained, rather than to individual teachers who could not be identified.

Table 4.6 Teacher questionnaire: returns of questionnaire by Province

Province	Natal	Transvaal	Cape
Number (N)	31	12	2
Percentage (%)	69	27	4

The sample was divided into three groups according to province (see Table 4.6). The majority, 69%, were from Natal. Analysis of the responses by Province showed no significant difference between the replies of the groups and they were thus treated as one homogeneous sample group for the purpose of the enquiry. All forty-five replies were from male teachers. This was not a misrepresentation of the total physical science teacher population, as it was known that the number of female senior certificate physical science teachers was very small, at most one or two. Most female science teachers were involved in the teaching of general science.

4.3.2 Student questionnaire

A pre-test of the student questionnaire was performed by administering a draft copy to a number of first year university students before the commencement of the academic year. They were asked to complete the questionnaire and at the same time, indicate questions which they found ambiguous or difficult to answer. As a result of an examination of the responses and the comments given, changes were made, and the final questionnaire was produced (Appendix A).

In the case of the student questionnaire, permission was obtained from the head of the chemistry department of the University of Durban-Westville (UD-W) for the administration of the questionnaire to the first year chemistry students. The questionnaire was administered at the first practical sessions of the year and collected immediately after completion. The value of the questionnaire was explained to the students before starting and they were asked to exercise care in filling it in. As a result no questionnaires were found that showed evidence of arbitrary responses by the students. Of the students who answered, 390 fell into the category of having completed Senior Certificate (SC) examinations at Indian schools during 1982 (see Table 4.7).

Table 4.7 Student questionnaire : returns from students by senior certificate (SC) year and school category

	SC in 1982 at DIE schools (sample reqd.)	SC in 1982 at other schools	SC in other years	Total
Questionnaires completed	390	47	133	570

These 390 students, representing 49 different schools in three provinces, were taken as the student sample and were treated as one homogeneous group for the purpose of this study.

4.4 ANALYSIS OF DATA

4.4.1 Validity and reliability

Throughout the data collection stage of the study, two dominant criteria were considered. The first was whether the questionnaires were measuring what was intended to be measured i.e. was the data valid. The second was whether or not the data collected would be consistent if the questionnaires were administered a second time.

In order to ensure the validity of the data gathered, common measurement procedures used in other studies were adopted. Where applicable, the results were compared to those from a more general population i.e. the study by Thompson (1975), and the subsequent similarity in results found, reinforced confidence in the validity of the measurement procedures. Every effort was also made to eliminate non discriminating items in the construction of the Likert scales and sources of bias were eliminated by the pre-tests. To test the reliability of the measurement procedure, a number of strategies were considered. A test / re-test procedure was not possible in this study. Normally this procedure is carried out after allowing sufficient time for recall of the test to be poor. However, teachers would have already started a new series of practical experiments with a new class and students would have completed a number of university chemistry experiments. These further practical experiences could have resulted in real changes in their opinions.

As an alternative, certain questions were added to the questionnaire to provide some check on the reliability. This was done by including in the student questionnaire an item that was repeated in a negative form i.e. Section B numbers 7 and 11 (Appendix A). After reversing the scale of the second item to a positive form, the responses were compared (see Table 4.8). It can be seen that the responses are virtually the same with a deviation of less than 3 percent. This deviation could be explained by the fact that the items were not true opposites and also the categories of response were not necessarily equidistant on a scale thus making the inversion of responses for comparison, subject to error.

Table 4.8 Test of reliability for student questionnaire
Comparison of percentage of responses to similar questions posed in a positive and a negative form

CATEGORY	Always	Often	Some-times	Rarely	Never
Item 7	25	43	24	6	1
Item 11 (reversed)	28	41	21	7	2

In the teacher questionnaire, the same response was requested to an item but in different lists. The responses are given in Table 4.9. It can be seen that there were some discrepancies in the responses. It is possible that some teachers misinterpreted the practical description i.e. saw the first as a simple demonstration and the second as a more involved experiment, because it was repeated in both lists. Alternatively a few teachers might have been under the wrong impression as to what was intended by demonstration and by experiment despite the strategies previously mentioned to avoid this occurring.

As a result, the responses to other items were carefully examined. Although minor differences could be found in these responses, there was no evidence of serious inconsistency. Two examples will illustrate this. Item 13 in question I and item 10 in question 2 were intimately linked and if one practical was carried out, the other in all likelihood would also have been attempted. Similarly items 7 and 8 in question 2 are intimately linked. The responses to these items are given in Table 4.10 and it can be seen that the response patterns were very similar.

Table 4.9 Test of reliability for teacher questionnaire
Comparison of number of responses to same item appearing twice in questionnaire

PRACTICAL Investigate the effect of a non-volatile dissolved substance on the boiling point of a liquid			
	Demonstration	Experiment	Not done
Sect.B Quest.1 No.1 (Demonstration list)	29	6	10
Sect.B Quest.2 No.4 (Experiment list)	21	14	10

PRACTICAL Investigate the acidic and basic character of the hydroxides of the elements of period three.			
	Demonstration	Experiment	Not done
Sect.B Quest.1 No.8 (Demonstration list)	19	19	7
Sect.B Quest.2 No.9 (Experiment list)	15	17	11

Further to this, each completed questionnaire was individually examined for any evidence of inconsistency. No obvious cases of facetiousness or inconsistency were found. As a result of the above strategies, it was accepted that the questionnaires used in the enquiry resulted in the collection of data that was considered both valid and reliable.

Table 4.10 Test of reliability in teacher questionnaire
Comparison of number of responses to related items which should provide similar numbers of responses

RESPONSE	Demonstration	Experiment	Not done
Sec.B Quest.1 Item 13	27	12	6
Sec.B Quest.2 Item 10	28	13	4
Sec.B Quest.2 Item 7	5	39	0
Sec.B Quest.2 Item 8	5	39	0

However, the following comment by Philliber et al. (1980, p.55) was at all times kept in mind. "...we really cannot ever be absolutely sure that our measures are valid or reliable. Each of the procedures in current use requires so many assumptions that they themselves can never be validated".

4.4.2 Methods of analysis of data

The statistical analysis of the questionnaire was performed on a UNIVAC mainframe computer with the aid of the Statistical Package for the Social Sciences, SPSS (Nie et al. 1975). Each questionnaire was coded for entering as a data case on a SPSS file. A single SPSS file was created using a variable field that covered both questionnaires. Subsequently, the data was organised into two sub-groups, the teachers and the students. At this stage some of the data was re-coded to reduce the number of categories of response for some questions, in order to make the reported frequencies more relevant. An example was as follows: The qualifications of teachers which were initially in ten different categories, were divided into six groups ranging from B.Sc with post graduate diploma to no formal qualification. The responses of the teacher and student groups were then analysed separately and subsequently the two groups were compared.

Mean scores, standard deviations and percentage response were calculated. Where rankings were necessary, mean ranks were calculated and presented in the form of graphs and tables. This visual representation facilitated qualitative comparisons of data. At the same time, the significance of differences of rankings between groups were assessed statistically, in most instances using Chi-square, t-test or one way analysis of variance where appropriate. In the tabulated results, the level of significance of differences is given at the 0,01 level for the chi-square statistic unless otherwise stated. The data were arranged within the file in such a manner that it was possible to examine the total sample as different sub-groups. The printouts for all these examinations are available for inspection as only those directly related to the research hypotheses are reproduced in the text.

In both questionnaires, Likert-type scales were used to measure differences within a group response eg. the difference in response of a teacher to the eleven different aims. Five point scales were constructed because with seven choices i.e. seven point scale, it was considered that adequate distinctions could not be readily made and a three point scale would not sufficiently differentiate between the responses. Careful consideration was given to the response choices for each scale. An example is that used with the teacher aims e.g. extremely important; very important; important; fairly important; not very important. At first glance this might not appear to cover the complete range of responses expected from teachers as it does not contain a neutral point or an extreme negative response such as 'totally unimportant'.

The nature of the question being asked prevented this type of scale being used. For example, the aims chosen for the study had been shown in other studies to be of some importance at least (see Chapter 2). Consequently, a response choice of totally unimportant would have been irrelevant. All that could be said about the categories chosen was that they form an increasing scale and occupy different positions on that continuum. Respondents were able to distinguish between the choices because of the context within which they appeared.

However, while one respondent might have considered all the aims to be generally very important, another might not have considered any on its own to be especially important. Although not knowing precisely the degree of real importance placed on any one aim by any respondent, it was still necessary to treat all answers on the same basis. This was done by converting categories of response into a rank order using two different methods. Using the first method, the categories of response were weighted according to a scheme similar to the following: Extremely important = 5 ; Very important = 4 ; Important = 3 ; Fairly important = 2 ; Not very important = 1. Secondly, using this weighted five point scale, means and standard deviations were calculated. Thirdly the rank order of the aims was obtained from the means.

Unfortunately, using this ranking method, according to Thompson (1975), does involve a loss of information in that the score for any aim is no longer indicated and two adjacent members in the order may be close in importance while another two may be far apart e.g. given means for aims 3 and 4 as 3,5 and 3,4 respectively, they might be ranked 1 and 2; another two aims could have means of 2,8 and 1,5 respectively and be ranked 9 and 10. In both cases the difference in rank is one position but the difference in means is 0,1 in the first case and 1,3 in the second. This problem can be aggravated by the large degree of tying (equal ranks) due to use of a five point scale for eleven aims as the eleven ranks are consequently reduced to a maximum of only five groups. In a number of cases where an order was sought, it was found that particular respondents would assign, for example 'very important' to a large number of their responses.

An alternative ranking technique was thus also used which involved the transformation of much of the data before analysis could be carried out. This technique, referred to as the mid rank method (Thompson 1975) is described in appendix G . This method results in a much wider range of ranks with each rank assigned to an item depending on the relative importance given to the other items. The method makes no assumptions about the interpretation placed on the wording of the five categories other than that they are ordered, and equalises the responses of those who have been most and least generous in allocating importance. As, the scale is invariant under stretching it makes no difference if a respondent has exaggerated importance, or lack of it, in his replies.

The standard deviation of ranks was also calculated giving a measure of spread and hence of comparative agreement of the ranking for each item. For each sub-group an output was produced which gave an analysis by percentage and raw score of all categories of reply where appropriate. For the aims and abilities a rank order of importance was calculated for the sub-group. These aims were then tabulated in order of the aim number using both tables and graphical means. In this way qualitative comparisons were made between the sub-groups who responded to the questionnaires.

The selection of a suitable statistical technique to aid the analysis of the data and the testing of the hypothesis was made after consultation with a number of colleagues. As indicated earlier, much of the data was gathered using Likert scales and may consequently be considered as having less than interval strength. If the comments by Siegel (1956) are accepted, then no parametric statistical tests (which use means and standard deviations calculated using arithmetical operations on the original scores and are applicable only to normal populations) ought to be used. If they are, then statistical inferences about the hypotheses as a result of such tests would be of doubtful value.

However, after a review of other studies and their approaches to this problem, especially the discussions in Lynch (1976, Ch.2) concerning scales used and appropriate statistics, a decision was made to make use of non-parametric statistics. Where appropriate, parametric statistics were calculated to confirm significant relationships found. These statistics have not been reported but the computer print-outs are available. It should be noted that before parametric statistics were used, the distributions were checked to make sure that they were not markedly skewed or variances grossly different.

To conclude this section on analysis and before the results of the study are presented in the following chapters, the following comment by Stevens places the above discussion of appropriate choice of statistics in perspective. "The question is thereby made to turn, not on whether the measurement scale determines the choice of statistical method, but on how and to what degree an appropriate statistic may lead to a deviant conclusion" (Stevens 1968, p.852).

CHAPTER FIVE

ANALYSIS OF TEACHER QUESTIONNAIRE

5.1 INTRODUCTION

This chapter concerns itself with the questionnaire sent to senior certificate physical science teachers. Firstly, the responses of the teachers to a number of general questions such as the number of classes taught and preferences for the two different parts of physical science, are dealt with. Secondly, the practical experiments and demonstrations that were carried out during the year are reported. Thirdly, the teachers' aims in carrying out these practicals are discussed. Finally the skills the teachers considered the pupils were competent in using as a result of practical work are also reported.

Where appropriate, the data have been presented in terms of the actual frequency of response by the teachers (N.) and as a percentage of the total sample (%). In some cases the actual frequency of N. responses do not add up to forty-five, (the number in the total teacher sample), because some teachers did not answer or make a response for those questions and so these were treated as 'missing cases'. In the sections dealing with the ranking of the aims and abilities, diagrams were also produced to present a visual representation of clustering or to facilitate qualitative comparisons.

5.2 TEACHER CHARACTERISTICS

A summary of the response of the teachers concerning their experience, qualifications, preferences for physics or chemistry and the subject found most difficult to teach is reported in Table 5.1. Examination of the table shows that nearly half the teachers had five or less years of teaching experience. Added to this, the majority of the teachers did not have a degree plus post graduate teaching diploma (specified as the desired qualification by most Education departments for teaching at the senior certificate level). However, a number of teachers indicated that they were upgrading their qualifications by means of part-time study.

Table 5.1 Teacher responses with respect to experience, qualifications, subject preference and subject difficulty

Experience	1-5 years	6-10 years	over 10 years
N.	21	16	8
%	47	36	18
Qualification	Degree +further study e.g. HDE	Diploma	No qualification
N.	18	25	1
%	41	57	2
Preference	Chemistry	Physics	No preference
N.	14	7	23
%	32	16	52
Difficulty	Chemistry	Physics	Equal difficulty
N.	7	23	15
%	16	51	33

Physical science is taught as two separate subjects, physics in Standard 9 and chemistry in Standard 10 (at the end of which the Senior Certificate examination is written based on the previous two years work). On analysis of the above responses it was found that there was an inverse relationship (significant at the one per-cent level) between the subject found more difficult to teach and the subject preferred. Overall, physics was found more difficult to teach while chemistry was preferred. This can be seen as encouraging, to those who feel that chemistry is neglected at school. It is interesting to note that about half the teachers stated no preference while all four first year teachers who responded preferred chemistry to physics. No further significant relationships where found between the four variables given in Table 5.1. The reasons for this preference could thus form the basis for further worthwhile research into physical science teaching.

The teachers were asked to give information about the physical science classes they taught and this is summarised in Table 5.2. Over 80% of the teachers had only one or two physical science classes, most of which comprised less than 30 pupils. Consequently, teachers did not have large numbers of senior certificate pupils for whom they were responsible. More than 75% of teachers had a total of less than 50 pupils to whom they taught senior certificate (SC) physical science. These facts are significant when the organisation of practical work is considered. In most cases it would appear that the average class was not large enough to make pupil experiments impractical nor was the total number of pupils per teacher large enough to cause marking to take up more than a normal proportion of time. For most teachers it would appear that the burden of large classes did not exist, thus making it possible for a reasonable amount of practical work to have been organised for the pupils.

A situation that many teachers find a problem, owing to the different syllabi, is the teaching of both HG and SG pupils in the same class. Nearly seventy per cent of teachers are in this situation of teaching classes of 'mixed' grade pupils. Notwithstanding this, the fact that many classes are 'mixed' grade should not have an effect on the quantity of practical work carried out (see Tables 5.3 -5.5 below) as the practical syllabi are very similar for both grades except for the different theoretical background required from each examination grade. The experiments indicated as 'examinable' are the same while a few of the 'non-examinable' experiments are not required for SG. However, this fact would not have influenced the responses reported as all teachers had HG pupils in their classes.

Table 5.2 Description of classes taught by teachers with respect to composition, size and number of classes, and the total number of SC physical science pupils taught

Composition of classes e.g. HG or SG	Single grade (HG or SG)	Mixed grades (HG and SG)	
N.	13	29	
%	31	69	
Number of classes taught	One class	Two classes	More than two classes
N.	25	10	7
%	60	24	16
Class size (pupils per class)	11 - 20	21 - 30	> 30
N.	13	23	6
%	31	55	14
Total number of SC pupils taught	11 - 30	31 - 50	> 50
N.	20	13	9
%	48	31	21

5.3 PRACTICAL WORK CARRIED OUT

Teachers were requested to indicate which practicals had not been done and which had been performed and in what manner (i.e. as a demonstration or pupil experiment). The practicals were divided into three groups; examinable compulsory practicals, non-examinable compulsory pupil practicals and frequently used demonstrations from current textbooks (see Section 4.2.3, p.57).

The vast majority of teachers (80% or more) indicated that the examinable practicals had been performed by pupils (see Table 5.3 below). This was to be expected as the performance of these practicals by the pupils, and the marks assigned by the teacher, contributed toward their final practical mark. (The performance of these practicals is checked by an external moderator). Three practicals, (Table 5.3 Nos. 3, 10 & 11), had not been carried out to the same extent. The lower response for practical No.3 might be explained by the fact that the techniques used are very similar to those in the previous two practicals on the list and can be covered adequately by theoretical simulation. "There is no point in trying to 'verify' this relationship experimentally, since this relationship between volume and temperature of a gas follows directly from the way in which temperature is defined" (Brink & Jones 1979, p.63). However, the two organic practicals were not carried out to any great extent. Follow up investigations (a number of teachers were individually approached), revealed that few schools had the chemicals available to perform these practicals and as a result the practical examination moderators had not in the past few years examined them.

The response to the second group of practicals, the 'non-examinable compulsory pupil practicals' (see Table 5.4 below), showed a marked decrease overall in the percentage of teachers who had organised them as pupil experiments (as was prescribed by the syllabus). It would appear that as they were not examinable, the teachers gave these practicals low priority even though the syllabus indicated that they were expected to allow the pupils to do them as pupil experiments.

Table 5.3 Examinable compulsory pupil experiments

Percentage of teachers who organised each experiment as either a pupil experiment, a demonstration or did not organise it

EXAMINABLE COMPULSORY PUPIL PRACTICALS	Pupil experiment	Demon-stration	Not done
1. Pressure and volume of a gas	87	13	0
2. Pressure and temperature of a gas	89	11	0
3. Volume and temperature of a gas	73	9	18
4. Factors affecting reaction rates	87	13	0
5. Common ion effect	98	2	0
6. Preparation of a standard solution	89	11	0
7. Standardisation of a strong acid	89	11	0
8. Action of hydrogen sulphide	87	13	0
9. Oxidation of iron ions	84	16	0
10. Hydrolysis of bromoethane	2	14	84
11. Preparation of an ester	11	19	70

Table 5.4 Non-examinable compulsory pupil experiments
Percentage of teachers who organised each experiment as either a pupil experiment or demonstration or did not do them

NON - EXAMINABLE COMPULSORY PUPIL EXPERIMENTS	Pupil experiment	Demon-stration	Not done
1. Effect of non-volatile dissolved substance on boiling point	31	47	22
2. Separation of cations by formation of insoluble salts	28	36	40
3. Acidic or basic character of hydroxides of period 3	40	35	26
4. Potential difference of electrochemical cells	29	62	9
5. Reaction of bromine in CCl_4 with laboratory gas, ethene and ethyne	4	16	80
6. Preparation of a polymer or a plastic	5	9	86

It is significant that forty per cent of the teachers did not organise No.2 which is rarely linked to examination questions while No.4 which is directly related to an important examination section was not organised by only nine per cent of the teachers. The only inference that can be made is that the decision to organize non-examinable practical work is directly related to usefullness in the theory examination. It can also be seen that two of these experiments, (Nos.5 & 6), both organic experiments had been omitted by over 80% of the teachers. The chemicals required to perform these experiments were in most cases freely available so the reason for this apparent 'prejudice' against organic practicals is not obvious. Whatever the reason, the evidence appears to indicate that the pupils are not experiencing organic chemistry practicals.

Table 5.5 Demonstrations outlined in current textbooks

Percentage of teachers who organised each demonstration as a pupil experiment or a demonstration or did not do it

DEMONSTRATIONS	Pupil experiment	Demon-stration	Not done
1. Effect of pressure on the boiling point of a liquid	13	64	22
2. Comparison of the vapour pressures of water, ethanol and ether	7	39	45
3. Solubility of molecular and ionic solids	39	53	7
4. Conductivity of ionic and covalent compounds	37	49	14
5. Changes in temperature during chemical reactions	49	30	21
6. Existence of reversible reactions	20	50	30
7. Factors influencing equilibrium	64	27	9
8. Electrical conductivity of acids	16	41	43
9. Successive dilutions affecting the pH of an acid	27	36	36
10. Electrolysis of a dilute solution	27	60	13
11. Addition of metals to solutions of other metal ions	52	32	16
12. Oxidising and reducing properties of period 3 elements	50	25	25

The final group of practicals consisted of a list of common demonstrations, all of which appeared in the current text books. Examination of the percentages of teachers who had carried out these demonstrations (see Table 5.5 above) showed no clear pattern. Some demonstrations were organised as pupil experiments by a large percentage of the teachers; others were neglected. The reasons for these choices are not clear. Possible reasons could be that teachers used only those practicals that appealed to them, or seemed to have the greatest teaching value, or were 'traditional demonstrations'. One point worth highlighting is that a larger percentage of teachers organised some of these demonstrations (Table 5.5 Nos. 5, 7, 11 & 12) as pupil experiments than used any of the compulsory non-examinable pupil experiments (see Table 5.4). These particular practicals, all dealt with important concepts in the chemistry syllabus (such as equilibrium) and were most probably considered as more valuable aids in the teaching or learning of these concepts than those compulsory practicals which were not practically examined.

Overall it may be inferred that if a practical was examinable (i.e. part of the practical moderation tests) then the vast majority of teachers made sure that it was carried out by the pupils. The teachers then chose certain practicals (with a preference for those directly related to material tested in the SC examinations) which they obviously considered valuable for teaching and gave low priority to the rest, even if they were laid down as compulsory. It was also clear that organic practical work was being largely neglected.

5.4 THE AIMS OF TEACHERS FOR PRACTICAL WORK

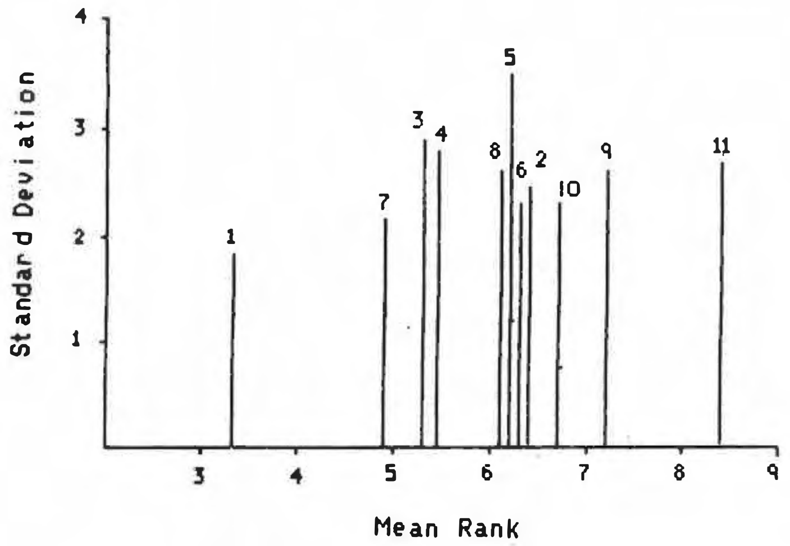
5.4.1. Pupil experiments

The teachers were requested to indicate the actual degree of importance they attach to each of the eleven aims. They were requested to do this separately for both pupil experiments and teacher demonstrations. Table 5.6 summarises the response of the teachers for pupil experiments. (Use of the simple mean rather than the mean rank of teachers responses gives the same ranking for the aims in this case). Abbreviated descriptions of the aims are used in the table. The full descriptions used in the questionnaire can be found in Appendix A and an explanation of each aim with its intended meaning for this enquiry, is given in Section 4.2.5, p.64.

Table 5.6 Teacher ranking of aims for pupil experiments
Mean rank, standard deviation and rank order of
importance of aims

Aim	Abbreviated description	Mean rank	S.D.	Aim order
1	To encourage observation	3,4	1,9	1
2	To arouse interest	6,4	2,5	8
3	To make phenomena more real	5,3	2,9	3
4	To develop manipulative skills	5,4	2,8	4
5	To prepare for the practical examination	6,2	3,5	6
6	To clarify theory	6,3	2,4	7
7	To promote logical thought	4,9	2,3	2
8	To discover facts	6,1	2,6	5
9	To verify facts	7,2	2,6	10
10	To practise problem solving	6,7	2,4	9
11	To remember facts	8,4	2,7	11

Figure 5.1 Teacher ranking of aims for pupil experiments
Mean rank and standard deviation of teacher aims



To provide a graphical illustration of the distribution of the mean ranks of the aims, Figure 5.1 was produced. This figure enables the overall ranking and standard deviation (SD) of each aim mean rank (M.R.) to be seen and clustering patterns to be determined. Note that the smaller the mean rank, the more important the aim is relative to the other aims. The larger the standard deviation, the less the agreement amongst the teachers about the ranking of that aim. Referring both to Table 5.6 and Figure 5.1 it will be seen that there was no unanimity of agreement on the overall ranking of the aims (large SD values) but there was more agreement on some aims (e.g. Nos.1, 2 & 7) than on others (e.g. Nos.3, 4 & 5). The highest ranked aim is number 1 (MR 3,4 'to encourage accurate observation and description') with fairly close agreement amongst the teachers concerning its ranking.

Next in importance came three aims clustered fairly close together, number 7 (MR 4,9 'to promote a logical reasonong method of thought'), number 3 (MR 5,3 'to make chemical phenomena more real through actual experience'), and number 4 (MR 5,4 'to develop specific manipulative skills'). These four aims form a group, which stands out from the rest of the aims, as the relatively most important. This group of aims is separated by a small gap from another group of four aims clustered together. These aims are number 8 (MR 6,1 'to let pupils discover facts and arrive at new principles'), number 5 (MR 6,2 'to prepare the pupils for the practical examination or moderation'), number 6 (MR 6,3 'to clarify theoretical parts of the chemistry syllabus") and number 2 (MR 6,4 'to arouse and maintain interest in chemistry').

The last three aims, number 10 (MR 6,7 'to practise seeing problems and seeking ways to solve them'), number 9 (MR 7,2 'to verify facts and principles already taught') and number 11 (MR 8,4 'to help pupils remember facts and principles') are grouped together as those aims given relatively the least importance. Although provision was made in the questionnaire for additional aims to be added only one teacher added an aim ('to stimulate creativity'). For this reason the original eleven aims were taken as being fully representative of the teachers' aims.

Considering the teachers' ranking of aims for pupil experiments (practicals for the pupils to perform themselves), there would appear to be some pattern to the ranking. The teachers seem to have organised this type of practical work for 'its own sake' rather than using it as a means of supporting the theoretical understanding of the syllabus. They were doing it to 'encourage accurate observations' and 'logical thinking', to 'develop practical skills' and to 'make phenomena more real'. They were not carrying out practical work so that pupils would be able to 'remember facts', 'verify facts' already given or to 'clarify theory'. This emphasis is to a certain extent contrary to the aims expressed in the introduction to the syllabus (see Section 1.2), where 'to facilitate the learning and understanding of facts and principles' and 'to make discoveries' are expressly stated as two of the main aims of practical work carried out by the pupils themselves.

The ranking of some aims was suprising. Aim 2 'to arouse interest' was ranked 8th; a relatively low position. It would appear that teachers did not feel that pupil experiments were able to fulfil the role of arousing and maintaining pupils' interest in chemistry at this stage of schooling. Aim 10, 'to practise problem solving', was also suprisingly lowly ranked (9th). It was expected that this aim would be closely linked to the higher ranked aim 7 'to promote logical thought' and consequently have a more important ranking. From the ranking of the aims it can be assumed that neither problem solving, discovering facts nor verifying facts play a relatively important part in determining the practical approach planned by the teacher. This leaves only a tightly structured activity designed to illustrate phenomena to achieve the aims stated as being the most important. Therefore, the type of common approach used, can only be a combination of approaches one and two from the list suggested (see Section 1.3, p.8) such as a tightly structured activity designed to illustrate a phenomenon. Reference to the practical notes handed out by a teacher (Appendix F) shows that this assumption would appear to be close to reality.

The disagreement amongst the teachers concerning the ranking of aim 5 was found interesting (SD 3,5). Examination of the raw data showed that although 55% considered it only as 'fairly important' or 'not very important', approximately 45% of the teachers considered this aim 'to prepare pupils for the practical examination' as at least 'important'. It would appear that this large percentage of teachers were prepared to concede that this aim definitely was one to which they actually attached relative importance when practical work was carried out. It is interesting to compare this finding with the comment made concerning the ranking of a similar aim in the Kerr enquiry (see Section 2.2, p.14). Notwithstanding the above, the majority of teachers did not consider this aim as being more than 'fairly important,' even though the actual practical experiments and demonstrations they carried out implied differently (Section 5.3)

5.4.2 Comparison with aim rank order for demonstrations.

The mean rank and resulting order of relative importance of the teachers' aims when carrying out teacher demonstrations is given in Table 5.7 with a diagrammatical representation of the spread of mean ranks given in Figure 5.2. The actual description of the aims was identical to those of the pupil experiments and are not therefore reproduced. Study of these results is best done by comparison with the ranking of the aims for pupil experiments. To facilitate the comparison Figures 5.3 and 5.4 were produced showing differences in rank and mean rank orders. The significance of the differences in the mean rank orders was computed using the chi-square statistic and these results are reported in Table 5.8.

Table 5.7 Teacher ranking of aims for demonstrations
Mean rank, standard deviation and rank order of importance of aims

Aim	Abbreviated description	Mean rank	S.D.	Aim order
1	To encourage observation	4,2	2,1	1
2	To arouse interest	4,8	2,3	3
3	To make phenomena more real	5,7	2,3	5
4	To develop manipulative skills	7,1	3,0	9
5	To prepare for the practical examination	7,3	3,1	10
6	To clarify theory	5,3	2,3	4
7	To promote logical thought	4,4	2,3	2
8	To discover facts	6,2	2,7	6
9	To verify facts	6,5	3,0	7
10	To practise problem solving	6,9	2,5	8
11	To remember facts	7,9	2,5	11

Figure 5.2 Teacher ranking of aims for demonstrations
Distribution of mean rank and standard deviations

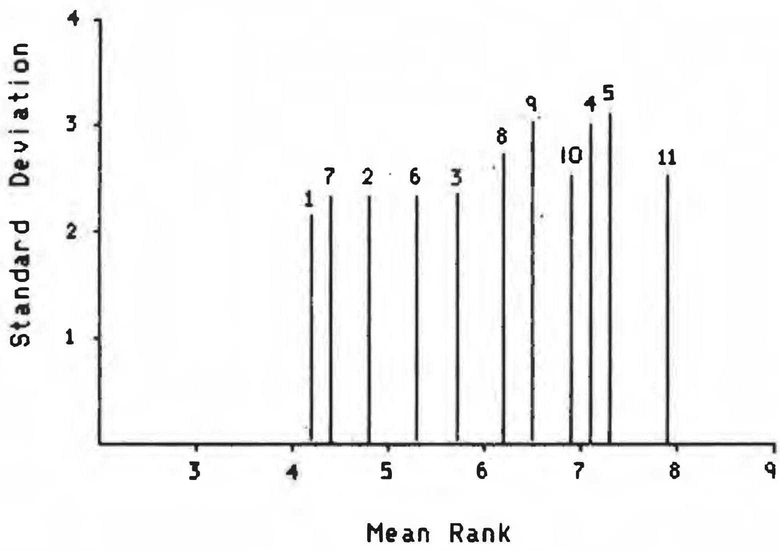


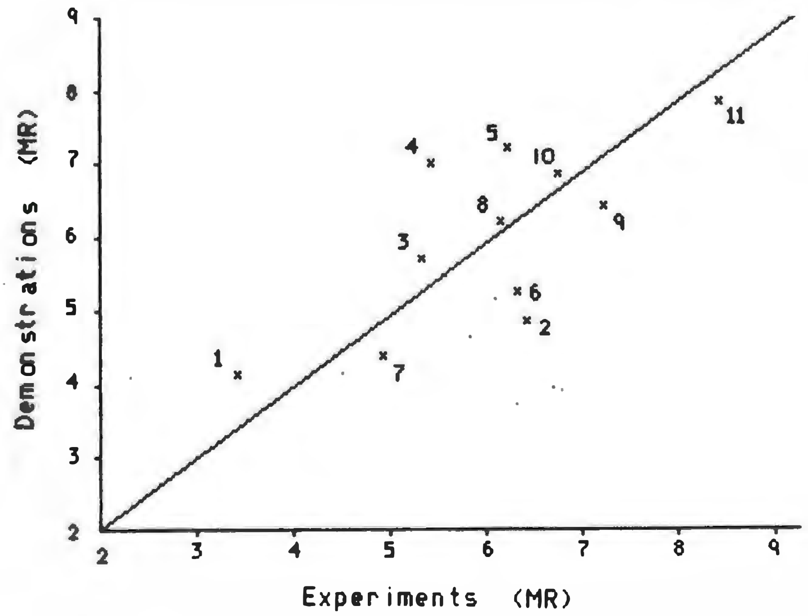
Figure 5.3 Teacher ranking of aims for experiments and demonstrations
Comparison of aim rank order for experiments with aim rank order for demonstrations (aims which have a difference of more than two ranks are linked by a solid line)

Aim order	Aim number for Pupil experiments	Aim number for Teacher demonstrations
1 st	1	1
2 nd	7	7
3 rd	3	2
4 th	4	6
5 th	8	3
6 th	5	8
7 th	6	9
8 th	2	10
9 th	10	4
10 th	9	5
11 th	11	11

Table 5.8 Teacher difference in aims for experiments and demonstrations
Comparison of mean ranks (MR) using chi-square statistic
(** indicates significant differences at the 0,01 level)

Aim Number	1	2	3	4	5	6	7	8	9	10	11
MR for experiments	3,4	6,4	5,3	5,4	6,2	6,3	4,9	6,1	7,2	6,7	8.4
MR for demos	4,2	4,8	5,7	7,1	7,3	5,3	4,4	6,2	6,5	6,9	7,9
Level of significance		**		**	**	**			**		

Figure 5.4 Teachers' ranking of aims for experiments and demonstrations
Graph of mean rank of aim (MR) for experiment by mean rank of aim for demonstration. (The diagonal line represents perfect agreement of mean ranks)



It must be noted that when the simple weighted means of the teachers' responses were statistically compared it was found that in all cases except for aim 1, there was a significant difference (at 0.01 level) in the degree of importance attached to each aim. However, as indicated (Section 4.4.2, p.75) this does not give a true reflection of the overall differences in rank. Consequently only the mean rank differences are discussed.

A number of the aims of the teachers for demonstrations show a similar mean rank of importance as for pupil experiments. There were also a number of differences that were expected. Aims number 4 ('to develop manipulative skills') and number 5 ('to prepare for practical examination') were considered significantly less important for demonstrations. This change was expected, as the pupils needed to actually handle the apparatus themselves to develop manipulative skills and this would obviously not be an important function of demonstrations. Added to this, pupils had to carry out the examinable experiments themselves during the practical moderation and so demonstrations would only play a small role in their preparation. Aim 1 'to encourage observation', although ranked first in both cases, is given significantly less importance for demonstrations. The reason for this is not clear. This could simply imply that handling apparatus and being closer to the apparatus during experiments is considered more likely to encourage observation than demonstrations by the teacher.

The aims for demonstrations that had significantly more importance attached than they did for experiments were number 2 ('to arouse interest'), number 6 ('to clarify theory') and number 9 ('to verify facts'). From the difference in the ranking of aim 2, it was inferred that teachers considered demonstrations of far more interest to pupils than experiments. This is suprising as it would be expected that pupils would prefer, and thus be more motivated and interested in doing experiments themselves. Obviously the teachers considered the experiments that were carried out as not very interesting from the pupils' point of view. The increase in importance of aims 6 and 9, would appear to indicate that the teacher considered demonstrations more a means of supporting the theoretical understanding of the syllabus while pupil experiments were carried out more 'for their own sake'.

It can be seen that the null hypothesis, 'There are no significant differences in teachers' ranking of aims for demonstrations and their ranking of the same aims for experiments' must be rejected and the hypothesis C (see Section 4.3.1, p.50) that there are differences in the rankings with respect to relative importance must be accepted. Further analysis of these rankings of aims is presented in Chapters 6 and 7 where these results are compared with the rankings given by students and rankings reported in other studies.

5.5 PUPIL PRACTICAL SKILLS

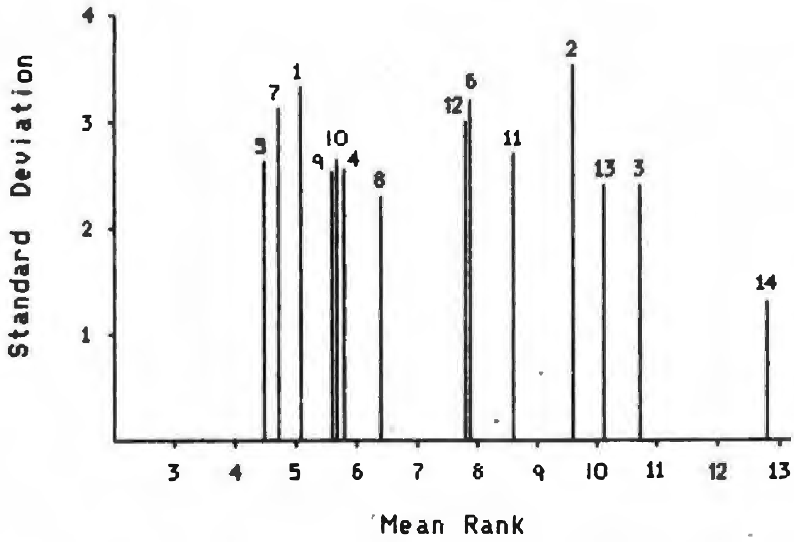
5.5.1 Practical skills of HG pupils

The teachers were requested to indicate the number of their pupils (separately for HG and for SG) who had developed the abilities listed, as a consequence of performing chemistry experiments. The responses given in respect of their HG pupils are summarised in Table 5.9. A diagrammatical representation of the mean ranks and standard deviations is given in Figure 5.5 which enabled any clustering pattern to be determined. An abbreviated description of the ability is given in each case. The complete descriptions of the abilities used in the questionnaire can be found in Table 4.2 (p.60).

Table 5.9 Teacher ranking of HG pupil practical abilities
Mean, mean rank, standard deviation and rank order of practical abilities

Ability	Abbreviated description of ability	Mean	Mean rank	S.D.	Rank Order
1	To understand the aim of an experiment	4,3	5,1	3,3	3
2	To devise or select a procedure	3,1	9,6	3,5	11
3	To recognise limitations in the procedure used	2,9	10,7	2,4	13
4	To follow and understand instructions	4,1	5,7	2,5	6
5	To select and assemble apparatus for a particular experiment	4,5	4,5	2,6	1
6	To determine if the apparatus is functioning correctly	3,6	7,9	3,2	9
7	To use familiar apparatus and materials	4,4	4,7	3,1	2
8	To make accurate observations	4,0	6,4	2,3	7
9	To record the experimental data	4,2	5,6	2,5	4
10	To arrange the data in a tabular/graphical form	4,1	5,6	2,6	5
11	To interpret the results and draw conclusions	3,4	8,6	2,7	10
12	To understand the purpose of the experiment	3,7	7,8	3,0	8
13	To write a concise effective report	3,2	10,1	2,4	12
14	To use the results to make predictions for new situations	2,3	12,8	1,3	14

Figure 5.5 Teacher ranking of HG pupil practical abilities
Distribution of mean ranks with standard deviation

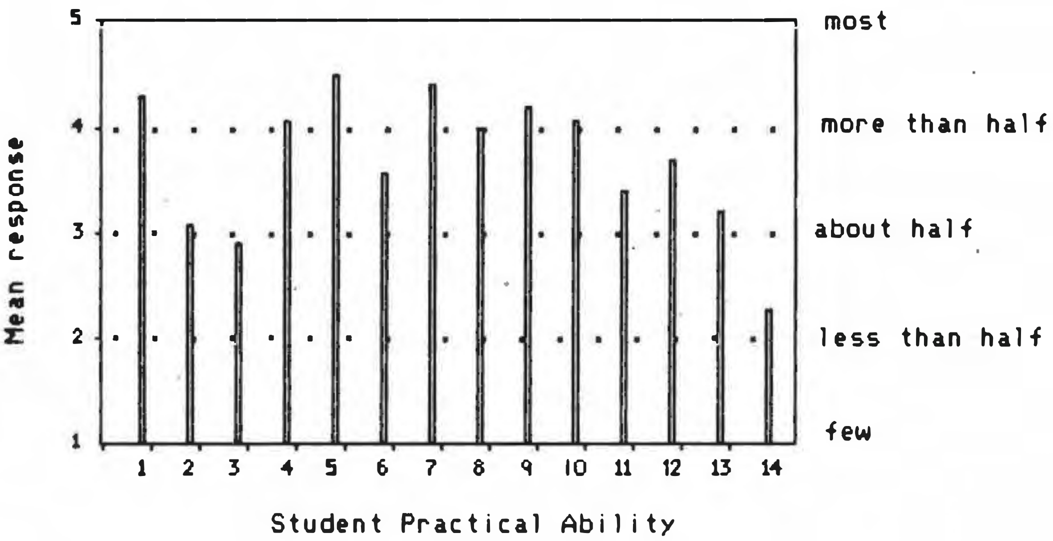


In order to interpret Figure 5.5 it must be remembered that the lower the mean rank, the greater the number of pupils who are considered to have developed that particular practical skill. The variation in magnitude of the standard deviations indicates that there was more agreement among the teachers in some cases (e.g. Nos.5, 8 & 14) than in others (e.g. Nos.1, 2 & 6) as to the number of their pupils who had developed these abilities. Overall, it can be seen that the abilities do form two distinct groups. The only ability which does not fall into one of the groups is ability 14 'use of results in new situations' which is ranked last and has a relatively very high mean rank. There was good agreement amongst the teachers (SD 1,3) that by far the least pupils had this ability.

Examination of the abilities in each of the two groups showed that they formed two coherent groups. The first group of abilities, in which more pupils were considered competent, concerned the 'mechanical' aspects of the experiment, that is, the assembling of the apparatus (number 5), using this familiar apparatus (number 7), understanding the aim (number 1), following the instructions (number 4), making observations (number 8), recording the data (number 9) and arranging it into tables or producing a graph (number 10). These abilities can be considered lower level skills. The second group or 'scientific' abilities (higher level) which pupils were considered to have developed, required pupils to devise or select a procedure (number 2), recognise the limitations and possible sources of error (number 3), determine whether the apparatus was functioning correctly (number 6), interpret the results and draw conclusions (number 11), understand the purpose of the experiment (number 12) and write a report (number 13).

As the teachers were requested to indicate the 'quantity' of pupils who had these abilities, it was also possible to make some quantitative estimate of the number of pupils who were considered to have developed the abilities by examining the simple means for each skill (see Figure 5.6).

Figure 5.6 Teacher ranking of HG pupil practical abilities
Figure showing **estimate** of number of pupils who have developed each practical ability as a consequence of performing chemistry experiments



The abilities can be categorised according to the fraction of pupils considered to have developed the ability :-

i) 'more than half' the pupils have abilities 5,7,1,9,4,8 and 10 (all have simple means greater than four but less than five)

ii) 'about half' the pupils have abilities 12,6,11,2,13 and 3 (all have means greater than three)

iii) 'less than half' the pupils have abilities 3 and 14 (their means are greater than two)

Overall, concentrating on those abilities which fewer pupils had, it can be seen that in the opinion of teachers, about half their higher grade pupils were unable to set up a viable experimental arrangement, analyse and interpret the experiment or effectively communicate what they had done . The teachers were also virtually unanimous in agreeing that the pupils would not be able to use the results to make predictions for new situations. It could be concluded that the ability to perform the experiment i.e. manipulate apparatus, make observations and record data, was limited to specific examinable experiments and were not practical skills transferrable to any laboratory experiment. Given a new general experimental situation, it is likely that at least half the pupils would be unable to cope.

Careful reading of the mark scheme used by moderators of the physical science practical work (see Appendix D) reinforces the conclusion arrived at in the previous paragraph. The scheme states that "In each of the examinable experiments laid down in the syllabus the following qualities of practical work will be evaluated....". It can be seen that the list of qualities (skills, abilities and attitudes) is specific to the examinable experiments and not qualities related to all practical work. Consequently it is possible to drill pupils in these qualities until they are proficient, resulting in good practical assessment marks but very few real abilities transferrable to laboratory work in general.

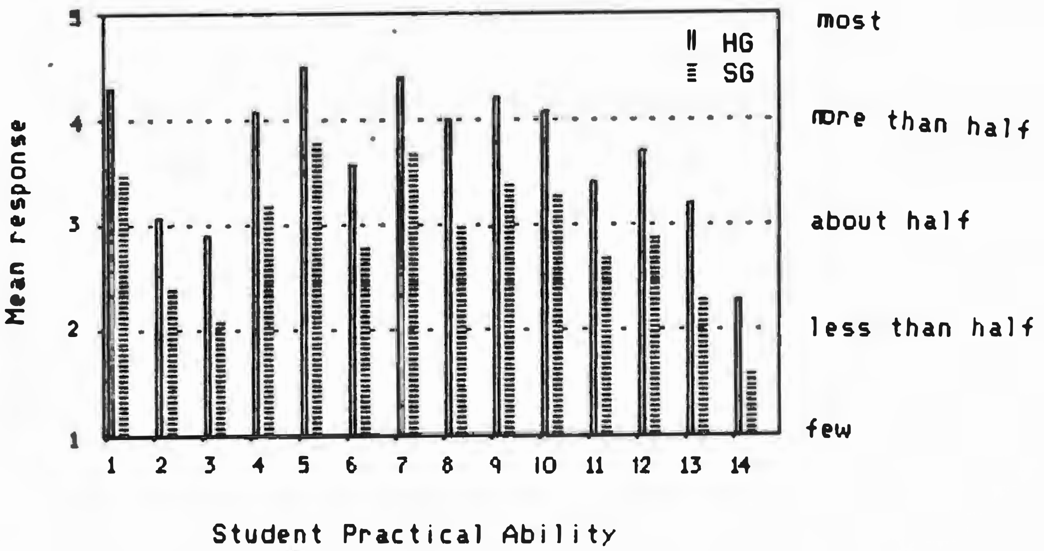
5.5.2 Comparison with SG pupil skills

Table 5.10 Teacher ranking of SG pupil practical abilities
Mean, mean rank, standard deviation and rank order of SG pupil practical abilities

Ability	Abbreviated description of ability	Mean	Mean rank	S.D.	Rank Order
1	To understand the aim of an experiment	3,5	5,1	3,3	3
2	To devise or select a procedure	2,4	9,0	3,8	11
3	To recognise limitations in the procedure used	2,1	10,8	2,7	13
4	To follow and understand instructions	3,2	6,4	2,9	6
5	To select and assemble apparatus for a particular experiment	3,8	4,3	2,4	1
6	To determine if the apparatus is functioning correctly	2,8	7,9	3,1	9
7	To use familiar apparatus and materials	3,7	4,7	2,3	2
8	To make accurate observations	3,0	7,0	2,4	7
9	To record the experimental data	3,4	5,6	2,7	4
10	To arrange the data in a tabular/graphical form	3,3	6,0	3,0	5
11	To interpret the results and draw conclusions	2,7	8,6	2,7	10
12	To understand the purpose of the experiment	2,9	7,5	2,8	8
13	To write a concise effective report	2,3	10,2	2,5	12
14	To use the results to make predictions for new situations	1,6	12,4	1,6	14

The responses of the teachers concerning the abilities developed by the standard grade pupils is summarised in Table 5.10 above. When compared to the higher grade pupils (Figure 5.7) it can be seen that the simple mean is less in every case, implying that fewer pupils have the ability in question. Nonetheless, the rank order is identical to that of the higher grade pupils, so the same interpretation with respect to the groupings can be placed on these standard grade results.

Figure 5.7 Teacher ranking of pupil practical abilities
Figure showing differences in number of pupils competent in each practical ability for SG and HG



The opinion of the teachers that fewer SG pupils had developed these abilities was to be expected. Most pupils enter the examination at the SG level, if they are unable to cope with the HG level rather than a deliberate decision to enter at a less demanding level. Thus, SG pupils are not expected to achieve as well as HG pupils. Notwithstanding this, it is most suprising that teachers did not discriminate between those abilities which they considered SG pupils unlikely to have developed. Surely as many SG pupils would develop abilities such as using familiar apparatus, following instructions and arranging data in tables as would HG pupils. A reason for this lack of discrimination could be that teachers, when completing the questionnaire, filled in responses for the HG pupils and using this as a guide, responded for SG pupils. Study of the actual questionnaires appears to bear this assumption out.

5.6 SUMMARY

Forty-five senior certificate physical science teachers participitated in the enquiry by completing a questionnaire on chemistry practical work. The following paragraphs summarise the results of the analysis of the responses.

Most of the teachers taught one (or possibly two) senior certificate classes, consisting of less than thirty pupils, of mixed ability. In general, the practical work carried out comprised the examinable practicals (with the exception of the organic experiments) and a number of demonstrations or experiments closely associated with the syllabus material tested in the final SC examination. The non-examinable compulsory experiments were not on the whole covered although prescribed as part of the practical syallabus.

Examination of the teachers' aims for experiments and demonstrations implied that teachers carried out practical work more 'for its own sake' than as a means of supporting the theoretical understanding of the syllabus. This was not in complete agreement with the intended aims stated in the introduction to the syllabi. A comparison of the ranking of aims for teacher demonstrations with the aims for pupil experiments, led to the acceptance of the hypothesis that there was a difference in the ranking in importance of aims for demonstrations to the ranking for experiments. It was seen that the teachers stated that they gave greater importance to aims such as motivating, arousing interest and supporting the theoretical understanding of the syllabus when doing demonstrations than they did for experiments.

Analysis of the teachers' responses to the question of the practical abilities developed by their pupils (at which their pupils were competent), placed the abilities into two distinct groups. The first consisted of those abilities relating to the 'mechanical' carrying out of the practicals (lower level abilities) and the second consisting of 'scientific' (higher level) abilities. Fewer pupils were considered to possess the latter abilities. Further, it could be inferred that the skills of at least half the pupils were not transferrable to any great extent to other practical situations besides the examinable practicals.

The following chapter deals with the analysis of the student questionnaire. This is followed by a comparison between the two sets of results i.e. the teachers and students, where any mismatch between what the teachers were trying to achieve and what the students experienced is highlighted.

CHAPTER SIX

ANALYSIS OF STUDENT QUESTIONNAIRE

6.1 INTRODUCTION

This chapter deals with the student questionnaire. The general characteristics of the student sample are first considered, including responses to questions dealing with preferences for the two different parts of physical science that appeared in the first part of the questionnaire. Secondly, the responses with respect to the organisation of practical work are dealt with. Thirdly, the extent to which the students agree with the expected influences of the teachers' aims and the practical abilities in which the students consider themselves competent are considered.

The data are presented in a similar manner to that of Chapter 5. Both actual frequencies of response (N.) and percentages of the sample (%), to the nearest percent, are given. Means, mean ranks (MR), standard deviations (SD) and rank orders are produced where applicable. To facilitate comparisons and accentuate clustering of mean ranks, the data are presented diagrammatically.

6.2 CHARACTERISTICS OF THE STUDENT SAMPLE

The general characteristics of the sample are summarised in Table 6.1. The selection of the sample and return of questionnaires is discussed in Section 4.3.2 (p.70). The students were divided into two main career groups, 56% studying Pure Sciences or Engineering and the remainder following courses in the Health Sciences. 89% had obtained higher grade (HG) senior certificate passes and 11% standard grade (SG) passes. The breakdown of students according to examination symbol is also given in Table 6.1. The majority of the students were male (72%).

Table 6.1 General characteristics of student sample by career group, sex, examination grade and examination symbol

Career group		Pure science and engineering			Health Sciences		
	N.	219			171		
	%	56			44		
Sex		Male			Female		
	N.	280			110		
	%	72			28		
Examination grade		Higher Grade			Standard Grade		
	N.	348			43		
	%	89			11		
Examination Symbol		A	B	C	D	E	F
HG	N.	8	39	105	110	86	1
	%	2	11	30	32	25	0
SG	N.	1	6	5	8	19	2
	%	2	15	12	19	46	5

Some impression of the students' attitude to chemistry and practical work, can be obtained by examining Table 6.2 in which the percentage responses to each attitude question are given. Although 16% of the students did not have a preference, 51% preferred chemistry to physics while only 28% found chemistry more difficult than physics. There is a significant relationship between the subject preferred and the subject found less difficult. It would appear that those students who prefer chemistry find it easier than physics and vice versa. Further studies to reveal why a majority of students prefer chemistry and find it easier could be of value.

Table 6.2 Attitude of students with respect to preference for, and difficulty of subject, the quantity of practical work and the effect of practicals on the examination result

Subject Preference	Chemistry	Physics	No preference
N.	199	128	61
%	51	33	16
More difficult subject	**Chemistry**	**Physics**	**Equal**
N.	109	184	95
%	28	47	25
Quantity of chemistry	**Too much**	**Sufficient**	**Too little**
N.	7	295	88
%	2	76	23
Effect on examination	**Improved**	**Undecided**	**No improvement**
N.	140	194	55
%	36	50	14

76% of the students felt that they had done sufficient practical work. This unexpected response from the students might have been influenced by the practical examination moderation for which the students normally have to do much preparation. On reflection, a more valuable response could have been obtained if the question had been divided into two parts, one dealing with student experiments and demonstrations and the second with examinable and non-examinable practicals. Used in that manner, the question would reveal if there were sufficient examinable practicals and if further non examinable practical work was desired.

It also appears significant that 50% of students were undecided as to whether their written examination mark had been improved because of the practical work, and a further 14% considered that it had not improved their results. This is suprising considering the teachers' emphasis on practicals directed at the supporting of the syallabus content (Section 5.3, p.84). A question that needs to be answered is 'will there be a change in attitude toward practical work on the part of the students if the practical component did not contribute at all to the final SC assessment?' It seems at present that few students would consider practical work of much value if it were not for the separate practical component which contributes materially toward their final result.

6.3 ORGANISATION OF PRACTICAL WORK

In an attempt to determine the manner in which the experiments were organised by the teachers, the students were asked to indicate how often they felt statements concerning the organisation and conduct of the laboratory experiments were true. Each response was given a weighting, 'never true' being 1 and 'always true' being 5. The mean, standard deviation and response for each category is given in Table 6.3 below. An abbreviated description of each statement is given. The actual statements used can be found in Table 4.4 (p.63). A visual representation of the relative frequency of each organisational statement according to the students is given in Figure 6.1.

The responses of both higher grade and standard grade students were treated as a single homogeneous sample. The justification for this lies in the fact that about 70% of classes (see Table 5.2, p.83) consist of students at both grades and the students would almost certainly experience the same organisation whatever their grade. It is very rare for teachers to organise separate experiments for the two grades. To verify this assumption the two groups were statistically compared and they only differed significantly (0,01 level) for statement eleven. More SG than HG students admitted that they 'on occasion never really understood what was being done'. This was expected and adds validity to the assumption made.

Figure 6.1 Organisation of practicals
Bar graph showing mean response of students to each 'organization' statement

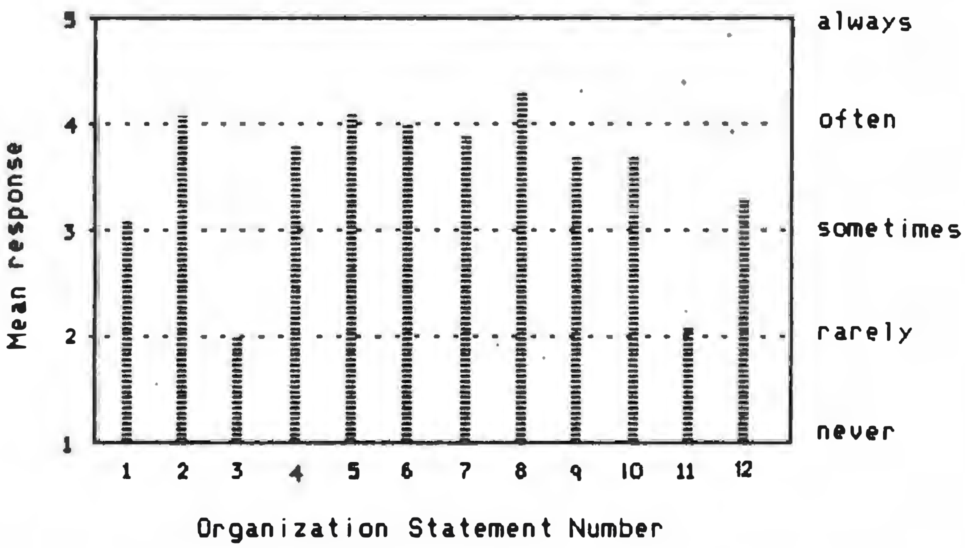


Table 6.3 Organisation of practical work in the opinion of students Mean frequency, standard deviation (SD) and percentage responses with which organisational statements are accepted as being true

Statement	Mean	SD	Percentage: Never true 1	2	3	4	Always true 5
1. Required to prepare in advance	3,1	1,1	9	22	36	20	13
2. Verbal instructions were given	4,1	1,0	2	5	16	30	47
3. Text book instructions were used	2,0	1,1	40	30	21	6	3
4. Written instructions were used	3,8	1,3	8	10	19	23	40
5. The instructions were clear	4,1	0,9	1	4	17	40	39
6. The purpose of the experiment was explained	4,0	1,0	2	7	22	31	39
7. You understood the purpose	3,9	0,9	1	6	24	43	26
8. A report was written on the experiment	4,3	1,2	5	6	10	16	63
9. The group was small enough to participate fully	3,7	1,3	7	14	20	23	37
10. Sufficient time was given for the practical	3,7	1,0	3	9	23	46	19
11. You never really understood what was being done	2,1	1,0	28	41	21	7	2
12. You were tested on the experiment	3,3	1,2	8	18	26	31	18

The results given in Table 6.3 and Figure 6.1 give an indication of what was experienced during the organisation of typical school practicals. More often than not the students: i) were given both verbal and written instructions which they felt they were able to follow; ii) were given an explanation of the purpose for doing the experiment which they understood; iii) felt that they had sufficient time to complete the practical and the groups in which they worked were small enough for them to participate fully; iv) were required to prepare a report of some nature. The students seldom : i) were asked to prepare for the experiment in advance; ii) were asked to use the text book instructions; iii) merely followed the instructions for the experiment without understanding what was being done.

A number of these results deserve further examination. The fact that 31% of students were seldom asked to prepare for the practical indicates that this important aspect of the practical was being neglected by a number of teachers. Where it was done, it would be interesting to investigate exactly what form this preparation took and what value it held to the students. Only 9% of students indicated that the text book practical instructions were used. The prescribed texts for the schools contain instructions for virtually all the examinable practicals. If they are not being used to any extent the value of including them in the text book could be questioned. Another point related to the above, worth investigating, is the actual source of the instructions that the teacher gives to the students. Do teachers simply duplicate the text book instructions or use official DIE practical guides (extract in Appendix E) or other sources?

Nearly 40% of the students stated that the purpose of the experiment was 'always' explained to them by the teacher but only 25% indicated that they 'always' understood. Taken with the figures that 30% of the students sometimes carried out experiments without understanding the purpose of the experiment, the results should be viewed seriously. It can be inferred that, in the opinion of the students, the teachers were not very effective in explaining the purpose of particular practicals. The fact that only 26% of the students indicated that they were rarely or never tested on the practicals shows the importance attached to assessment by the teachers. If practicals had been planned as problem solving or discovery type activities then less testing could have been expected. Therefore, this result once again reinforces the inference that the practicals were mostly of a tightly structured nature (Section 5.4.1).

The above information only gives a glimpse into some of the organisational aspects of the practicals. Although the information gathered in this part of the study is considered as exploratory it has given some interesting insights and pointers for further investigation. It is most probably necessary to go into the classroom and observe the practical activities before any further worthwhile results would emerge.

6.4 INFLUENCES OF PRACTICAL WORK

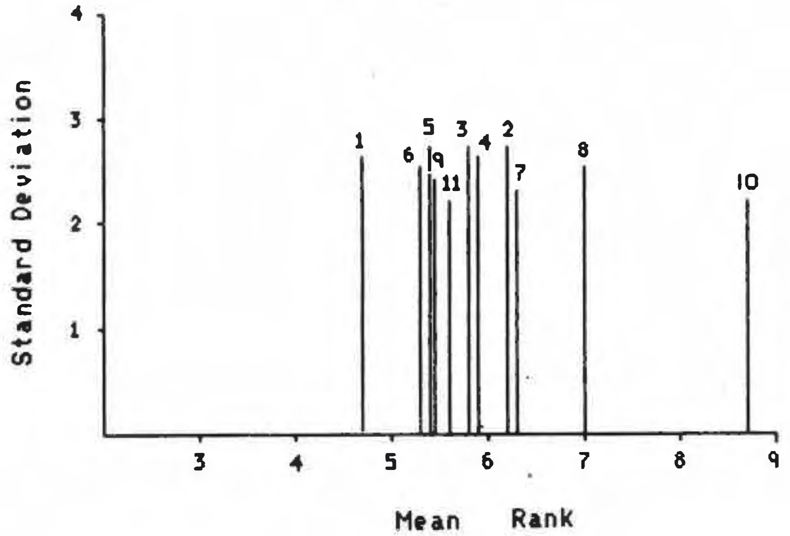
The students were asked to state the extent of their agreement with the possible results or influences of teachers' aims for practical work. It was expected that this would give some indication of the differences between what the teachers were trying to achieve and what the students were experiencing. Thus each of the eleven influences used is derived from the aim presented to the teachers (see Table 4.1, p.58). In the analysis of the results, it was accepted that the students did not necessarily have the ability to assess the educational value of the experiments which they had done at school. Nevertheless, the responses obtained gave a good indication of how each student felt he had personally been influenced.

Table 6.4 Student ranking of influences of practical work
Mean rank, standard deviation (SD) and rank order

Influence description	Mean rank	SD	Rank order
1. I was encouraged to make accurate observations	4,7	2,6	1
2. My interest in chemistry was aroused	6,2	2,7	8
3. Chemical phenomena were made more real	5,8	2,7	6
4. I developed specific manipulative skills	5,9	2,6	7
5. I was prepared for the practical examination	5,4	2,7	3
6. I found theory easier to understand after doing the experiments	5,3	2,5	2
7. My ability to think logically has been improved	6,3	2,3	9
8. I was given the opportunity to discover facts	7,0	2,5	10
9. Facts and principles were verified in the laboratory	5,4	2,4	4
10. I was given opportunities for problem solving	8,7	2,2	11
11. The experiments helped me to remember facts and principles	5,6	2,2	5

The replies of all students were treated as one group and Table 6.4 above summarises their responses. An abbreviated description of each influence is given together with the mean rank, standard deviation and rank order of influence. Full descriptions of each influence can be found in Table 4.3 (p.62). A graphical illustration of the mean rankings and the relative distribution of influences is given in Figure 6.2 . The smaller the mean rank, the greater the degree of influence perceived by the students. The larger the standard deviation, the less is the agreement amongst the students about the relative ranking.

Figure 6.2 Student ranking of influences of practical work Distribution of mean ranks and standard deviations of influences



The most significant feature which emerges when Figure 6.2 is studied, is the lack of a group of teacher aims which stand out as having been of most influence on the students. Obviously the students do not recollect any as having had special emphasis. There are no influences about whose ranking the students disagree significantly. The extent of this agreement is shown by the similarity of standard deviations for each influence. When the relative grouping of mean ranks are compared, it can be seen that the influences are divided into three groups. The first group consists of only influence number 1 (MR 4,7 'encouraged to make accurate observations'). This influence stands out from the rest as the influence with which the students agree the most.The second group of perceived influences consists of a block of eight influences:- the first four are number 6 (MR 5,3 'the theoretical parts were made easier'), number 5 (MR 5,4 'prepared for the practical examination'), number 9 (MR 5,4 'facts already taught were verified') and number 11 (MR 5,6 'helped to remember facts'); the second four, separated from the first by a comparatively small gap are number 3 (MR 5,8 'chemical phenomena were made more real'), number 4 (MR 5,9 'developed specific skills'), number 2 (MR 6,2 'interest was aroused') and number 7 (MR 6,3 'ability to think logically was improved'). The third group of influences, separated by a relatively large gap from the second group, which the students agree have had the least influence on them are number 8 (MR 8,7 'given opportunity to discover facts') and number 10 (MR 8,7 'given opportunity to practise problem solving').

Overall, the following picture emerges. As a result of doing practical work in the form of chemistry experiments, the students responded that they were influenced in a number of ways. The most important influence by far was that they were encouraged to make accurate observations and descriptions. Following this, they agreed that: the practical work had helped them remember facts and principles taught in class; facts and principles already taught were verified in the laboratory and the theoretical parts of the syllabus were found easier to understand after doing the experiments. It is significant to note that these three all relate more to supporting the theoretical understanding of the syllabus material than to practical work for its own sake.

The students agreed that they had been prepared for the practical examination or moderation. To a lesser extent, they agreed that: chemical phenomena were made more real to them through their actual experience of the phenomena; they developed specific skills in the handling of equipment and chemicals in the laboratory; their interest in chemistry was aroused and; their ability to think in a logical manner was improved by doing experiments. By far, the two that were ranked of least influence were that they were given the opportunity to discover facts and arrive at new principles and were given the opportunity to practise seeing problems and seeking ways of solving them in the chemistry laboratory.

In an attempt to see if there might be any significant difference between the replies of the standard grade (SG) and higher grade (HG) students, the two groups were analysed separately and statistical tests of significance made (chi square). The results are summarised in Table 6.5.

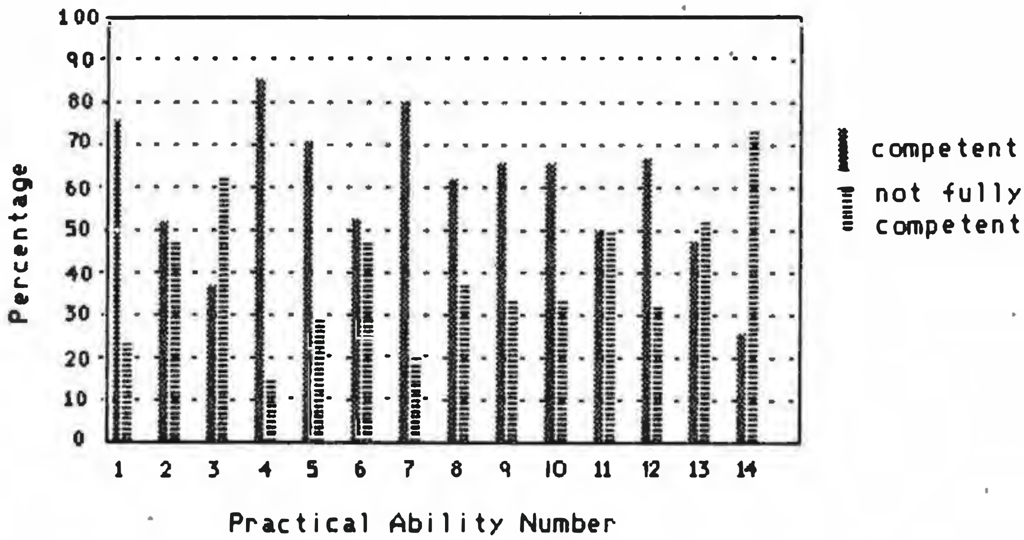
Table 6.5 Student ranking of influence of practical work
Comparison of HG and SG ranking of influences showing mean ranks and rank orders for both HG and SG

Aim number	1	2	3	4	5	6	7	8	9	10	11
Mean Rank											
H.G.	4,7	6,2	5,8	6,0	5,3	5,3	6,3	6,9	5,4	8,6	5,6
S.G.	5,1	6,1	5,8	5,3	5,6	5,0	6,4	7,0	5,1	8,9	5,7
Rank order											
H.G.	1	8	6	7	2	3	9	10	4	11	5
S.G.	2	8	7	4	5	1	9	10	3	11	6

6.5 STUDENT PRACTICAL SKILLS

The students were requested to rate themselves on a five point scale from 'very competent' to 'not competent' with respect to the same list of chemistry experimental abilities as was presented to the teachers (Table 4.2, p.60). This would indicate the degree of competence the students considered they had developed as a result of performing experiments. The percentage of students who considered themselves at least competent are given in Figure 6.3 together with the percentage who consider themselves not very competent.

Figure 6.3 Student practical abilities
Bar chart showing percentage of students considering themselves competent for each practical ability



As the understanding of the word competent varies for different students, the responses were transformed (Section 4.4.2, p.75) to enable a ranking of abilities to be obtained. The means, mean rank, standard deviations and rank orders are summarised in Table 6.6 below. Figure 6.4 gives a visual representation of the distribution of these mean ranks. This diagram shows the competence of the students at an ability, in relation to all the abilities in the list.

A low mean rank for an ability indicates that more students feel they are competent at that ability, relative to other abilities with higher mean ranks. Figure 6.3 on the other hand gives the actual percentage of students who have stated that they are competent or not very competent at a particular ability. Study of both figures shows that both the mean ranks and the percentage range for each of the abilities fall into four distinct groups.

Figure 6.4 Student ranking of practical abilities
Distribution of mean ranks and standard deviation

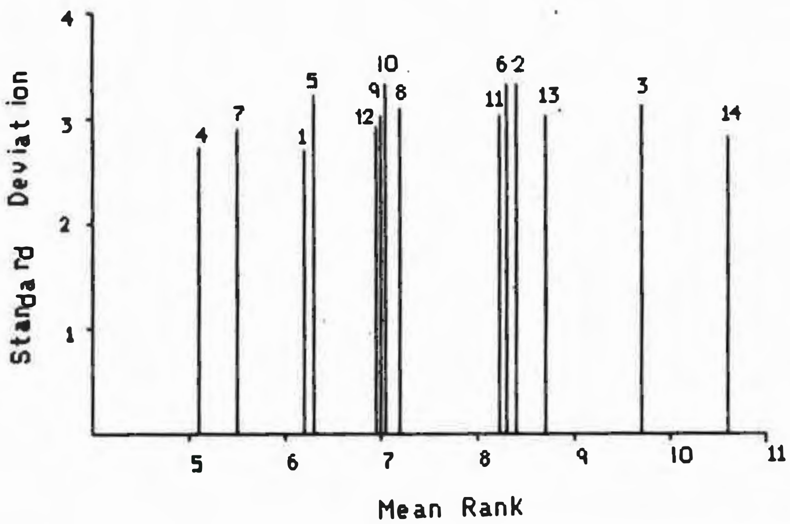


Table 6.6 Student ranking of practical abilities
Mean, mean rank, standard deviation (SD) and rank order of abilities

Ability	Description	Mean	Mean rank	S.D.	Order
1	To understand the aim of an experiment	3,9	6,2	2,7	3
2	To devise or select a procedure	3,5	8,4	3,3	11
3	To recognise limitations in the procedure used	3,2	9,7	3,1	13
4	To follow and understand instructions	4,1	5,1	2,7	1
5	To select and assemble apparatus for a particular experiment	3,9	6,3	3,2	4
6	To determine if the apparatus is functioning correctly	3,5	8,3	3,3	10
7	To use familiar apparatus and materials	4,0	5,5	2,9	2
8	To make accurate observations	3,7	7,2	3,1	8
9	To record the experimental data	3,7	7,0	3,0	6
10	To arrange the data in a tabular/graphical form	3,8	7,0	3,3	6
11	To interpret the results and draw conclusions	3,5	8,3	3,0	9
12	To understand the purpose of the experiment	3,7	7,0	2,9	6
13	To write a concise effective report	3,4	8,7	3,0	12
14	To use the results to make predictions for new situations	3,1	10,6	2,8	14

It is clear that the students consider themselves most competent in abilities number 4 ('to follow and understand instructions'), number 7 ('to use familiar materials'), number 1 ('to understand the aim of an experiment') and number 5 ('to select and assemble apparatus to perform a particular experiment'). At least 70% of the students feel that they have these abilities. Following this first group is the second distinct group of four abilities: number 8 ('to make accurate observations'); number 9 ('to record accurately the data'); number 10 ('to arrange the data in tabular/graphical form') and number 12 ('to understand the purpose of the experiment'). Approximately 60% of the students feel that they have these abilities.

Reference to Figure 6.4 shows that there is now a distinct gap between this and the next group of abilities. About 50% of the students consider that they are competent at these abilities: number 2 ('to devise or select a procedure'); number 6 ('to determine whether the apparatus is functioning correctly'); number 11 ('to interpret results and draw conclusions') and number 13 ('to write a concise effective report or write up'). Finally abilities number 3 ('to recognise limitations and possible sources of error in the procedure selected') and number 14 ('to use the results to make predictions for new situations') form an isolated group at the end of the scale. Less than 40% of the students feel competent at these abilities.

If a general description of the abilities which the majority of the students believed they had, were to be given, it can be seen that they would comprise abilities related to the 'mechanical' or lower level abilities of practical work such as assembling the apparatus, following the instructions, making observations and tabulating the results. However, the response of the students to the 'interpretative' or higher level practical abilities given in the list show that the majority do not perceive themselves to be competent in these important abilities. Examples of these are: interpreting the results, recognising limitations in the procedure selected, communicating the results in a report and using the results in a new situation. Whether the students consider themselves competent in these abilities only for the examinable practicals, which they might have repeated a number of times, or for all practical activities is not known. However, it could be inferred from the nature of the abilities at which they feel competent i.e. lower level, that it is likely that they would be transferrable to other situations. On the other hand, the higher level abilities are unlikely to be transferrable due to the low level of competence even in the practicals with which they are familiar.

In order to see if there was any significant difference in the ranking of influences by higher grade students to that of the standard grade students, the mean ranks were statistically compared (chi square). There were no significant differences between the two groups at the 1% level. At the 10% level a difference was found for ability number eleven 'to interpret results'. Obviously the SG students feel that they have significantly less competence in this ability than in others. Notwithstanding the above difference at the 10% level, the rankings were very similar. This was not unexpected as students entered for both examination grades would have experienced the same practical work due to the high percentage of mixed grade classes.

6.6 SUMMARY

390 university students answered a questionnaire on the chemistry practical work they had experienced during the previous year while preparing for their senior certificate examination. The questionnaire was administered before the students had experienced any practical work at university which could have influenced their responses. The vast majority had obtained higher grade passes and had preferred chemistry to physics at school. Most of the students felt they had done sufficient practical work but this response was considered to refer mainly to the examination practicals rather than all practical work. Approximately half the students were undecided as to whether the practical work had improved their written examination results.

The responses of the students to questions concerning the organisation of practical work indicated that the students were normally given written and verbal instructions by the teacher and an explanation of the purpose of the experiment. Most students considered that sufficient time had been given to complete the practical and that their groups were small enough for full participation. At the conclusion of the practical they were required to write a report. Half the students indicated that they were often tested on the practical. Three points that deserve more attention are that: only on a few occasions were students required to prepare in advance for the practical; although it was agreed that teachers explained the purpose of the practical, a significant percentage of the students still did not understand the purpose; and the text book was used for instructions to the students in only a small number of cases.

The students agreed that the practical work teachers had organized had influenced them most in respect of aims associated with supporting the theoretical understanding of the syllabus material. However, they had not been influenced by aims associated with giving them opportunities to experience problem solving or to discover facts and principles themselves. They considered that, as a result of practical work, they had become competent at a number of practical abilities, most of which can be considered as mechanical or lower level abilities. Fewer students considered themselves competent at the higher level skills. For those that did indicate competence, it was inferred that this was restricted to the specific practicals covered during the year rather than applicable to all practical activities.

CHAPTER SEVEN

COMPARISONS

7.1 INTRODUCTION

The separate analysis of the student and teacher questionnaires resulted in the disclosure of a number of interesting responses concerning both the teacher and the student samples. A comparison of these results was made to determine whether what the teachers aimed to achieve, was what the students thought had been achieved, and to see the difference between teachers' opinion of students' practical abilities and the students' own estimation of their competence. This was facilitated by the initial design of the questionnaires which had been constructed to make these comparisons possible.

Notwithstanding this, any comparison of replies from two different sample populations is a very difficult task. The conditions under which each questionnaire is answered will be different, as will be the sample sizes and the understanding of certain questions due to the different viewpoints of the participants. To facilitate comparisons, the mean ranks for both samples for the relevant questions were compared to indicate if there were any significant differences in the rankings calculated. In most cases, only differences at the 1% level were accepted. i.e. if the probability of the difference occurring by chance was more than one chance in a hundred then no difference was said to exist.

The mean ranks were compared rather than the simple means or raw frequencies for a number of reasons. The actual questions asked were not in both cases identical due to the nature of the samples and questions. The manner in which particular words in the question, for instance 'competence', could be interpreted were bound to be different in the two samples due to the different expectations of teachers and students. For these reasons, mean ranks were compared as these gave a relative indication of the agreement with or importance of, particular items in a list. Graphs and tables of these values were also produced to give an opportunity of visually discerning differences in each case. The results are compared with those from other studies. This was difficult because of problems peculiar to each of these studies. The strategies used in each case to enable some form of qualitative comparison are given.

7.2 COMPARISON OF AIMS WITH PERCEIVED INFLUENCES.

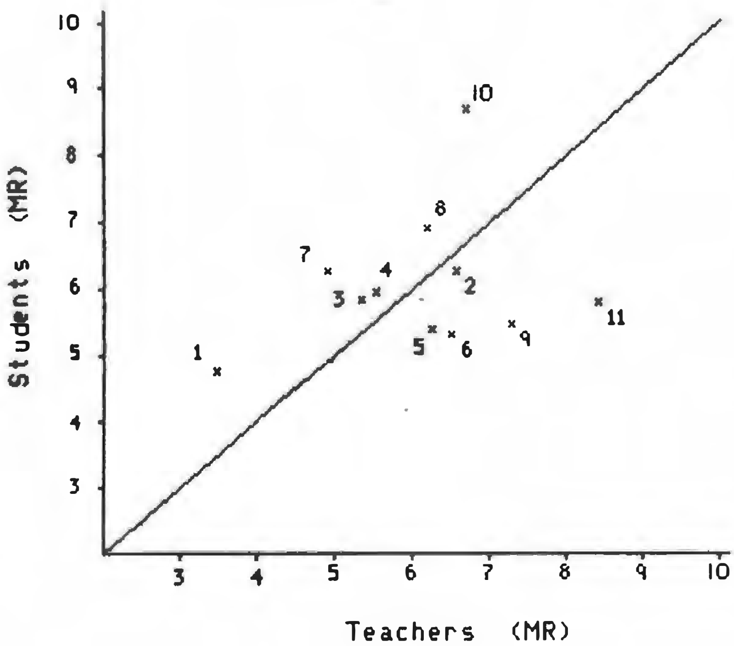
The teachers were asked to indicate the actual degree of importance they attached to each of the aims in the list, while the students were asked to indicate the extent of their agreement with each of the aims, stated as an influence. The mean ranks for the two groups, the teachers and the students, (one indicating the relative importance of the aim and the other indicating the relative degree of agreement with the influence of the aim), are given in Table 7.1. The responses to each pair i.e. aim / influence were statistically analysed to see if there was a difference in the relative rankings and any differences found at the one per cent level of significance are indicated.

To aid the interpretation of these differences in the mean rankings of the aims / influences, Figures 7.1 and 7.2 were produced. Figure 7.1 is a graphical representation of the mean rank for each aim of the teachers plotted against the mean rank of the influence attributed by the students. Any aim which was plotted on the actual 45 degree solid line would indicate that the degree of relative importance attached to the aim by the teachers was equalled by the relative influence felt by the student.

Table 7.1 Comparison of aims and perceived influences
Mean ranks and rank orders are tabulated with statistically significant differences at the 1% level indicated with **

AIM NUMBER	1	2	3	4	5	6	7	8	9	10	11
MEAN RANK											
Teachers	3,4	6,4	5,3	5,4	6,2	6,3	4,9	6,1	7,2	6,7	8,4
Students	4,7	6,2	5,8	5,9	5,4	5,3	6,3	6,9	5,4	8,7	5,6
Differences					**	**	**		**	**	**
RANK ORDER											
Teachers	1	8	3	4	6	7	2	5	10	9	11
Pupils	1	8	6	7	3	2	9	10	4	11	5

Figure 7.1 Comparison of aims with perceived influences.
Graph of mean rank of teachers' aims versus students' perceived influence



For example aim 2 was given a certain degree of importance relative to the other aims by the teachers and the students perceived the influence to that same degree relative to the other influences. Aims plotted above the line indicate less relative influence for the students when compared with the teachers' more important ranking, whereas aims plotted below the line indicate the opposite. Figure 7.2 gives the simple rank order attributed to the aims and influences by the teachers and students respectively.

Figure 7.2 Comparison of aims and perceived influences
Teacher aims and influences perceived are given in
rank order of importance

Rank order	Aim number	Influence Number
1 st	1	1
2 nd	7	6
3 rd	3	5
4 th	4	9
5 th	8	11
6 th	5	3
7 th	6	4
8 th	2	2
9 th	10	7
10 th	9	8
11 th	11	10

There were a number of similarities in the mean rankings of the two groups. The rankings of aims number 1, 2, 3 and 4 show no significant differences at the 1% level. The relative degree of importance attached to these aims is matched by a similar degree of agreement by the students concerning the influence perceived. The teachers 'encouraged observations' as their prime aim and the students similarly perceived this to be the greatest influence of the experiments they experienced.

Similarly, the teachers considered 'arousing interest' as only eighth in their list of priorites for aims and the students perceived this aim as being eighth in order of influence on them. Although the rank orders show significant differences for aims 3 and 4 (teachers, third and fourth; students seventh and eighth) the mean ranks were not significantly different indicating that the importance attached to these aims, 'making phenomena more real' and 'developing skills' respectively, had the desired influence on the students even though the students perceived them as being of relatively low influence.

The aims which the teachers rated significantly higher, are numbers 7 and 10, 'to think logically' and 'to give opportunities for problem solving'. The students disagree with the relative importance accorded these aims and feel that they were not given opportunities to practise problem solving, nor were their abilities to think logically improved by doing experiments. Although there is also a significant difference in their mean rankings for aim number 10, it must be noted that both the teachers and the students gave this aim (problem-solving) a very low rank. The teachers did not attach much importance to this as an actual aim and as a result the students did not experience a significant change in their problem solving skills.

The students rated influences 5, 6, 9 and 11 significantly higher in their ranking than the importance attached to aims by the teachers would have merited. Besides number 5, these influences are all associated with supporting the theoretical parts of the syllabus i.e. number 6 'the theoretical parts were easier to understand', number 9 'facts and principles were verified' and the number 11 'remembering of facts was helped'. The higher ranking of third for influence number 5, 'preparation for the practical moderation' infers that the students felt that there was more importance placed on this aim than others even though the teachers did not admit to placing as much emphasis on this aim of practical work as on other aims they had, ranking it only sixth in importance.

Although the comparison of the aims and perceived influences does show some similarites, it is more marked by differences. For six of the eleven aims there are significant differences in the responses of the teachers and the students. There appears to be a significant mismatch between what the teachers state they were attempting to achieve, and what the students considered was achieved. Consequently, the null hypothesis that there are no differences is rejected and the hypothesis A (Section 4.1.3, p.50) is accepted i.e. There are significant differences in teachers' rankings of aims in order of importance for experiments and pupils' ranking of the associated influences of these aims.

7.3 COMPARISON OF FINDINGS CONCERNING SKILLS AND ABILITIES

As a result of performing the chemistry experiments organised by the teacher, the students acquired a number of skills or practical abilities. The students were asked to indicate to what extent they felt they were competent at each ability and the teachers were asked to estimate the approximate fraction of their students who they considered were competent at the skills. Although the standard grade (SG) and higher grade (HG) students were likely to have experienced the same practical work, the teachers' expectations for each group would have been different thus possibily influencing the attainment of abilities. For this reason, the two groups have been separated for the purpose of analysis.

Reference to Sections 5.5.2 and 6.4 shows that there were very few differences between the teachers' replies for the two grades of student and between the SG and HG student rankings of their abilities. In fact, the teachers' rank order was identical for both grades. In the case of the two student groups only one significant difference was found and that only at the 10% level. For this reason, the comparisons of the teachers with the HG students was expected to be very similar to that with the SG students. Consequently, only the comparison of the teachers ranking of HG students abilities and the HG students responses themselves, have been made. The responses and mean ranks were in each case statistically analysed to see if there was a significant difference in the rankings (Table 7.2). The only significant difference obtained at the one per cent level was that for ability number 14. No other differences were found below the ten per cent level of significance. Table 7.3 giving the abilities in rank order was also produced to aid the comparisons.

Table 7.2 Comparison of ranking of student practical abilities
Mean ranks and rank order for each ability according to teachers and HG students themselves

Ability	MEAN RANK		RANK ORDER	
	Teachers	Students	Teachers	Students
1	5,1	6,1	3 rd	3 rd
2	9,6	8,4	11 th	10 th
3	10,7	9,7	13 th	13 th
4	5,7	5,1	6 th	1 st
5	4,5	6,3	1 st	4 th
6	7,9	8,4	9 th	11 th
7	4,7	5,6	2 nd	2 nd
8	6,4	7,1	7 th	8 th
9	5,6	6,9	4 th	6 th
10	5,6	6,9	5 th	5 th
11	8,6	8,2	10 th	9 th
12	7,8	6,9	8 th	7 th
13	10,1	8,8	12 th	12 th
14	12,8	10,6	14 th	14 th

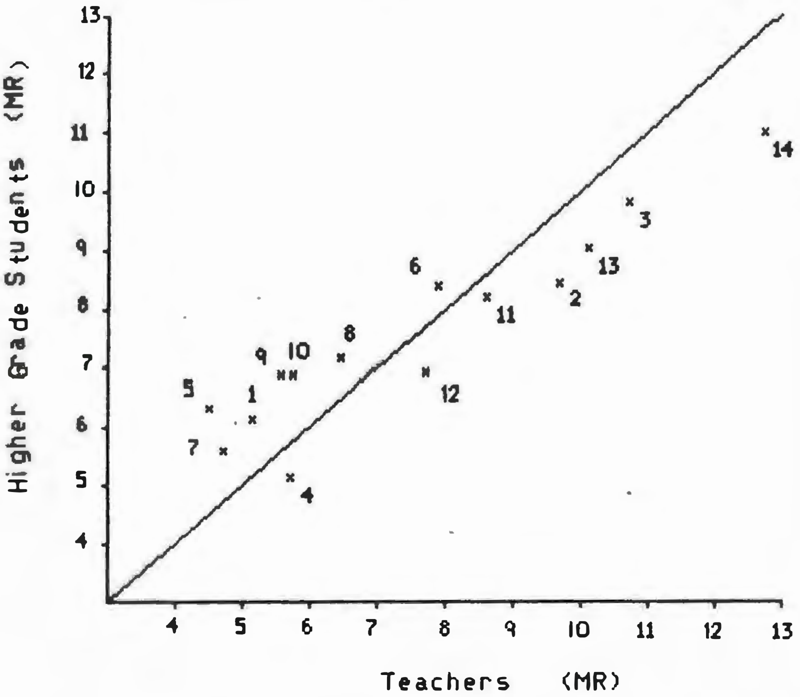
Consider ability number 14 which shows a difference in the mean ranks at the 1% level but has the same rank order for the teachers and both student groups. Ability 4 on the other hand does not have a significant difference in the mean ranks but has a marked change in rank order from first for the HG students to sixth for the teachers. For this reason, the interpretation of the comparisons based on a single set of results could lead to erroneous conclusions. To ensure that this did not occur Figure 7.4 was produced.

Table 7.3 Comparison of rank orders for practical abilities Abilities in rank order according to HG students and teachers

Rank order	ABILITY NUMBER HG students	Teachers
1 st	4	5
2 nd	7	7
3 rd	1	1
4 th	5	9
5 th	10	10
6 th	9	4
7 th	12	8
8 th	8	12
9 th	11	6
10 th	2	11
11 th	6	2
12 th	13	13
13 th	3	3
14 th	14	14

Examination of Figure 7.3 shows that a number of the plotted mean ranks, (those with low values), are above the 45 degree 'agreement' line; those with high values are below the line and those in between are clustered close to the line. Taken with the lack of statistical differences these results indicate that the teachers have used the extremes of the response scale when answering the questionnaire while the students have limited their responses to the middle values of the scale. Because of this answering pattern, differences detected at the two ends of the mean rank scale are not true differences but rather differences in degree.

Figure 7.3 Comparison of ranking of abilities
Graph of mean ranks according to teachers versus
mean ranks according to HG students.



As an example consider ability 14 'use the results in a new situation'. This ability is given a mean rank of 12,4 by the teachers and a mean rank of 10,6 by the students. There is obviously a significant difference between the absolute values of these mean ranks. However, examination of Table 7.3 show that it has the same rank order, 14 for both groups. Both the teachers and the students agree that, of the abilities, this is the one in which they (the students) have the least competence, relative to the other abilities. 25% of the teachers responded that only 'very few' students had this ability while only 1% of the students were prepared to report that they were "not competent'. With hindsight, it is appreciated that the categories 'not competent' and 'very competent' were too extreme for the students and the middle of the scale should rather have been expanded.

If the above comments are considered, the comparison between the mean ranks for the teachers and for the students show a remarkable lack of differences. There appears to be close agreement with respect to the ranking of the abilities. Those abilities the teachers consider the students should have, the students feel competent at and vice versa. There is one exception to the overall pattern. The break in the normal pattern is shown by examining Figure 7.3 where ability 4 is plotted below the 'agreement line' as opposed to the general pattern mentioned earlier due to the answering pattern. Ability 4 'to follow and understand instructions' is an ability which the students consider to be one in which they are more competent than most others (ranked first). However, the teachers have ranked this as sixth. The teachers obviously do not agree with the students that they are as competent as they think they are.

Taking all these comparisons into consideration, the following pattern emerges. The teachers and the students agree concerning the practical abilities that the students have. Where there are differences, these can be traced to the answering pattern of the students who were not prepared to explore the extremes of the Likert response scale. This resulted in differences in the rank orders but no significant differences in the mean ranks when the responses were analysed. Using the above interpretation and analysis of the rankings the null hypothesis is accepted. The hypothesis B (Section 4.1.3, p.50) that; "there are significant differences in the teachers' ranking of practical abilities at which pupils are competent and pupils' ranking of these same abilities for which they consider themselves competent" must be rejected.

7.4 COMPARISON OF RESULTS WITH OTHER STUDIES

7.4.1 Transformation of results before comparisons.

The comparisons that can be made of the results of this study with those of other studies are limited. The only section that is common to a number of other studies, is that dealing with the aims of practical work. Even comparisons in this section alone are difficult, the reasons being: very few studies used the identical set or list of aims; the lists were produced in different situations resulting in slightly different emphasis in each case; some enquiries had comphrehensive lists (e.g. Thompson 1975) while others (e.g. Lynch 1976) had fewer aims in their lists. To enable a comparison to be made, the aims found in the present study were considered as the basis for comparison and similar aims were extracted from the other studies for comparison.

A further complication to the comparisons was that the actual question that the teachers were asked to respond to was different in most studies. The enquiry by Lynch (1976, Appendix 19) for instance, prefaces the question with the following comments:

> (i) Practical work here is taken to include demonstrations by the teacher and laboratory work by the pupils......
>
> (ii) It is very important that this section reflects your considered opinion about the ideal purpose served by practical work......

In particular, three specific differences in emphasis can be identified:

i) practical work with respect to both chemistry and physics was being considered whereas the present study considers only chemistry.

ii) practical work in the above context includes both pupil experiments and teacher demonstrations whereas these were considered separately in the present study.

iii) the ideal purpose (aim) was requested while the present study emphasised the actual aims.

To overcome some of these differences and thus make comparisons possible, the responses of the teachers to pupil experiments and demomstrations have been combined into a single category 'practical work'. The effect of this transformation of the data is shown in Table 7.4. The mean ranks for the pupil experiments and teacher demonstrations have been added and a new rank order determined. Figure 7.4 shows the changes that have occurred, once again emphasising the different results that can be obtained depending on the emphasis of the question asked (see Section 5.4.2 for comparison between demonstration and experiment rank orders).

Table 7.4 Determination of revised rank order for 'all practical work' Mean ranks for experiments and demonstrations, combined mean rank and new rank order are given

Aim number	1	2	3	4	5	6	7	8	9	10	11
MEAN RANKS											
Experiments	3,6	6,4	5,3	5,4	6,2	6,3	4,9	6,1	7,2	6,7	8,4
Demonstrations	4,2	4,8	5,7	7,1	7,3	5,3	4,4	6,2	6,5	6,9	7,9
All practicals	7,8	11,2	11,0	12,5	13,5	11,6	9,3	12,3	13,7	13,6	14,3
New rank order	1	4	3	7	8	5	2	6	10	9	11

Figure 7.4 Transformation of rank order for experiments, demonstrations to give a revised combined rank for all practical activities

Order	AIM NUMBERS		
	Experiment	Practicals	Demonstration
1 st	1	1	1
2 nd	7	7	7
3 rd	3	3	2
4 th	4	2	6
5 th	8	6	3
6 th	5	8	8
7 th	6	4	9
8 th	2	5	10
9 th	10	10	4
10 th	9	9	5
11 th	11	11	11

A short description of each study with which comparisons were made will place the comparisons in context. The four studies, Kerr (1963), Thompson (1975), Lynch (1976) and Naik (1979) are all reviewed in Section 2.2 where the original aims used, are reproduced for reference. The data used from the Kerr study were the rankings of chemistry teachers for the sixth form (1963, p.27 Table 3). All ten aims used by Kerr correspond to aims used in the present study except for the aim numbers which were different and consequently were adapted before being used in Figure 7.5. From the Thompson enquiry (1975), only the responses of the sixth form chemistry teachers were used. This particular enquiry used a list of 20 aims, eleven of which were chosen for use in the present study. Only these eleven aims common to both this and Thompson's study were selected and consequently their rank orders had to be modified to be out of eleven rather than the original twenty. Table 7.5 shows the final revised rank order.

Table 7.5 Transformation of rank order of aims from Thompson study for the purpose of comparison with present study rankings

Aim number for present study	Corresponding aim number for Thompson study	Original rank order out of 20	Revised rank order out of 11
1	7	1 st	1 st
2	12	6 th	5 th
3	2	2 nd	2 nd
4	16	4 th	4 th
5	20	16 th	10 th
6	10	13 th	8 th
7	6	3 rd	3 rd
8	8	14 th	9 th
9	17	19 th	11 th
10	4	12 th	7 th
11	3	8 th	6 th

Adapted from Thompson (1975 Table 6,0 p.38).

The enquiry by Lynch (1976), which included a report dealing with Indian schools by Naik (Lynch 1976, Ch.13) had a number of fundamental differences from the present study:

i) the results were reported for physical science and biology;

ii) the aims for Standards 8, 9 and 10 as a group were requested and;

iii) the responses were with respect to ideal aims not actual aims.

However, an advantage was that the students were asked to respond with respect to the influence of the aims, making comparisons in this area possible. Ten aims were used, some of which do not appear in the present study and two which each encompass two aims of the present study e.g. aim 4 'making the subject more real and interesting' and aim 5 'encouraging problem solving and self-discovery methods', were each considered as two individual aims for the present study. Table 7.6 shows the renumbering of the aims to give equivalent numbers to the present study.

Table 7.6 Determining of equivalent aim numbers for Lynch enquiry to facilitate comparison of aims with present study

Present study	1	2	3	4	5	6	7	8	9	10	11
Equivalent aim number of Lynch	1	4*	4*	6	8	3	2	5*	-	5*	-

* these aims in the Lynch enquiry encompassed two aims

\- there was no equivalent aim in the Lynch enquiry

It could be argued that some of the aims used were not strictly equivalent due to their different wording and interpretation placed on them in the studies. However, to enable qualitative comparisons, approximations have been attempted e.g. for Lynch aim 8 'satisfying the minimum requirements of the syllabus' was considered equivalent to aim 5 in the present study, 'to prepare the pupils for the practical examination or moderation'. These were considered equivalent as the practical moderation in Indian schools involves the practicals prescribed in the syllabus. If a teacher prepares his pupils for the moderation, he will have to satisfy the 'minimum requirements' of the syllabus. The analysis by Naik (1979) of the responses with respect to Indian schools was part of the Lynch enquiry and used the same questionnaire. Consequently, the aims were identical and the foregoing comments and transformation of aim numbers also refers to the Naik study.

7.4.2 Comparisons between studies on teacher aims

To make qualitative comparisons between the results of the studies easier, Figure 7.5 was produced. It indicates the revised rank orders for each study. Those aims which are linked by lines would appear to have significantly different rank orders from one study to the next. The changes in rank order that occurred from the Kerr enquiry to that of Thompson's are commented on by Thompson (1975, p.42).

> It would appear that the function of chemistry practical work in supporting theoretical understanding of the subject has become much less important over the past thirteen years.... The most positive increases are seen in the need to motivate students more than appears necessary thirteen years ago, and in the largest increase of all (Aim 3) involved personal experience with relevant material.

The trends mentioned above can be seen by studying Figure 7.5. Aim numbers 6, 8 and 9 decreased in rank order while aims 3 and 2 increased.

A comparison of the findings of Thompson with the present study showed some marked similarities in the rank orders. In the first five ranks, four of the same aims appear, namely numbers 1, 2, 3 and 7. Aims 9 and 5 were also similar in ranking with both enquiries finding that they were given relatively low ranks. Thus it would appear that the teachers surveyed by Thompson and the Indian teachers surveyed in the present study, agreed that encouraging accurate observation, arousing interest, making phenomena more real and promoting logical reasoning thought, were the more important aims for chemistry practical work. They also agree that verifying facts and principles and preparing pupils for practical examinations are not relatively important aims for practical work.

Differences between the two enquiries were also evident. Thompson reported that helping pupils remember facts and developing manipulative skills were relatively important (ranks 6th and 4th), but the present study finds much less importance attached to these aims (ranks 11th and 7th).

Figure 7.5 Comparison of rank orders of aims for different studies Kerr(1963), Thompson(1975), Lynch(1976), Naik(1979) and present study aim rank orders.

RANK order	Kerr 1963	Thompson 1975	Present study	Naik 1979	Lynch 1976
1 st	1	1	1	2 & 3	2 & 3
2 nd	6	3	7		
3 rd	8	7	3	1	1
4 th	7	4	2	8 & 10	6
5 th	4	2	6		7
6 th	9	11	8	6	8 & 10
7 th	10	10	4	7	
8 th	5	6	5	4	4
9 th	3	8	10	-	-
10 th	2	5	9	5	5
11 th	-	9	11	-	-

AIM NUMBER AND ABBREVIATED DESCRIPTION

1 - accurate observation

2 - arousing interest

3 - making phenomena more real

4 - developing manipulative skills

5 - prepare pupils for practical examination

6 - clarifying theoretical work

7 - promoting logical, reasoning thought

8 - finding facts

9 - verifying facts and principles

10 - solving problems

11 - helping pupils remember facts

Aims 6 and 8 were also given dissimilar rankings, with the Indian teachers considering clarifying theoretical work and finding facts and principles of relatively more importance. Besides these differences, the two studies have produced very similar rank orders. This is a little suprising as the syllabi are quite different, the facilities and support available to the teachers in the U.K. are far better established and a greater percentage of the teachers have higher qualifications.

The next comparison shown is that with Naik (1979). Three of the same four aims, numbers 1, 2, and 3 appeared in the first five rank orders. Both studies report aim 5 as being given a relatively low ranking and aim 4 had a similar low relative ranking as in the present study. Only two signifiant differences were apparent. Aim 7, promoting logical reasoning thought, was given more importance and aims 8 and 10, 'finding facts and principles and seeing and solving problems' were given less importance in the present study. These differences could be due to the difference in the sample responding to each of the surveys. The survey by Naik involved Physical Science and Biology for Standards 8, 9 and 10 whereas the present study dealt only with chemistry in Standard 10.

However, the change in rank of aims 10 and 8 was not considered to be solely attributable to the difference in sample but was more likely to be a result of the question posed in the questionnaires. When teachers were asked to respond with respect to the ideal aims, problem solving was given a high relative position in the rank order (third) but in the present study where actual aims were requested, problem solving was given a low rank (ninth). The difference between actual and ideal aim in this case, appears to be significant. Notwithstanding this, it could be inferred from the comparisons between these two sets of results that there is very little difference between the 'ideal' aims of chemistry teachers and 'actual' aims except in the case of problem-solving and discovery learning (finding facts).

Comparison with the enquiry by Lynch was very similar to that by Naik. This could be of significance. The responses to the study by Naik were restricted to Indian teachers but those of Lynch included teachers from many education departments and cultural groups throughout South Africa. Thus it might be concluded that the results of this comparison might not only be applicable to Indian teachers in the Division of Indian Education but might also be applicable to a much wider range of teachers in other Education Departments in South Africa.

7.4.3 Comparison of influences perceived by students

In order for a comparison to be made between the influences felt by the students in Naik's sample with those of the present survey, the influence numbers were changed to correspond with those of the present study and influences for which there were no equivalent influences in both studies were removed. Thus influences 9 and 10 from the Naik list were removed (see Table 2.3, p.20) and influences 5, 9 and 11 removed from the present study list, as these influences do not appear in both lists. The resulting comparison between the influences is shown in Figure 7.6 which gives a revised rank order ignoring those influences which were not found in both studies. The influences correspond with those given in Table 4.3 (p.62).

The rankings are very similar even though 41% of the sample used by Naik contained students studying only biology. Influences 7, 8 and 10 are lowly ranked in both cases. The students do not consider that the teachers' aims have resulted in them having been influenced with respect to their ability to think in a logical reasoning manner, or that they were given opportunities to discover facts or to practise problem solving. Influence 6, 'the theoretical parts were made easier,' together with influence 3, 'making phenomena more real' were considered an important influence of practical work by the students in both studies.

Figure 7.6 Comparison of influences perceived by students Naik (1979) and present study

Rank order	Influence number	
	Present study	Naik
1 st	1	2&3 *
2 nd	6	
3 rd	3	6
4 th	4	1
5 th	2	4
6 th	7	7
7 th	8	8&10 *
8 th	10	

* indicate equal ranks

One of the significant differences appears to be that for influence 2, 'interest in chemistry was aroused', which was given a joint ranking of one by the students in the Naik enquiry but a ranking of five in the present study. It would appear in the last few years that the students are not finding chemistry practical work as interesting as did their peers in earlier years. One reason for this could be the introduction of television programmes with scientific bias, where demonstrations of exciting phenomena are shown with great clarity and often in slow motion. Having watched these programmes, the students are unlikely to find simple demonstrations and experiments in the laboratory very stimulating. Consequently, students did not perceive that the teachers were concentrating on this aim as much as before (even if the teachers were). However, making phenomena more real retains its relatively high ranking. On the other hand, the students felt that the teachers were concentrating on the aim of accurate observation (influence 1), far more than the the students did at the time of the Naik study.

7.5 SUMMARY

The student responses were compared with those of the teachers. Both the mean ranks and aim orders were considered together with the differences in answering pattern between the students and teachers, before a decision concerning the significance of any difference was made.

The comparison of the aims of the teachers with the perceived influences brought to light a number of significant differences. There appeared to be a mismatch. The teachers were emphasising aims supporting practical work for its own sake, e.g. promoting logical reasoning methods of thought, but the students were not influenced significantly by this. Rather they perceived the greater influences to be support of the theoretical syllabus material. Consequently, the hypothesis A (Section 4.1.3, p.50) suggesting that there were differences in the rankings of aims and influences was accepted.

Comparison of the practical abilities that the students obtained as a result of practical work showed a marked similarity in rankings. The students considered that they had a number of abilities (associated with lower level abilities) and the teachers agreed with them. Where the students felt they lacked an ability (those higher level scientific abilities) the teachers also agreed that they did not have the ability. Due to this agreement, the hypothesis B (Section 4.1.3, p.50) suggesting that there were differences, was rejected.

The comparison of the results of the present study with those of other enquiries (Kerr 1963, Thompson 1975, Lynch 1976) was shown to be difficult for a number of reasons, among them being the difference in the lists of aims constructed for each study and the questions which the respondents answered. However, the results of these studies were compared after making allowances for the differences in the aims and questions asked. It was found that the teachers, whether those surveyed in the Thompson enquiry in England or in the Lynch study in South Africa or in the present study, all agreed concerning the most important aims of chemistry practical work. However, differences were found in the relative ranks of some aims. An important difference was that of problem-solving which was highly ranked when ideal aims were considered but given a much lower rank when actual aims were considered.

When the influences perceived by the students in the present study were compared with a previous study by Naik (1979) among Indian students, the similarities in ranking for those influences which appeared in both enquiries were striking. However, one influence 'arousing interest' had dropped significantly in its rank position which could possibly be attributed to the increasing availability of scientific programmes on television or a change in the interest patterns of students.

The following chapter deals with the interpretations that could be placed on the rank orders reported and suggests various strategies for improving the match between teacher aims and the resulting influence on their pupils.

CHAPTER EIGHT

CONCLUSION

8.1 SUMMARY OF FINDINGS

The findings of the present study do not differ to any great extent from the general body of results recorded previously. It was found that while teachers had emphasised aims relating to practical work for its own sake as being of more importance, students had perceived the most important influence of their aims as being directed at supporting the theory or syallabus material. Finding facts or discovery learning, ranked very low by students, was also given a relatively high ranking by teachers compared with lower ranking of aims directed at supporting the theory. However, there was agreement between both groups as to the low relative importance of the aims of creating interest and problem solving. Overall there was a mismatch, with six of the eleven aims being ranked by the teachers in an order of importance significantly different to that given by the students. However, when the teachers' aims for doing demonstrations were considered separately, it was found that the aims creating interest and supporting theory were given more importance than in the case of pupil experiments.

The practicals indicated in the syllabus as 'examinable' were usually carried out, as were a number of 'demonstrations' linked to important parts of the theory. The latter were often carried out by groups of pupils (as pupil experiments rather than teacher demonstrations). Experiments indicated in the syllabus as 'compulsory but not examinable', together with the organic practicals, were largely neglected (or performed as demonstrations contrary to syllabus requirements). In respect of practical organisation, the students indicated that they were normally given written and verbal instructions for the experiments, sufficient time to complete the same, and that a written report was usually required. However, preparation for the experiment was seldom required and a significant percentage of students did not in many cases understand the purpose of the experiment in which they were involved.

There was agreement between teachers and students as to the skills acquired by students as a consequence of the performance of practical work. Students were felt to be competent in carrying out the lower level skills such as assembling the apparatus, taking readings and tabulating the data. Unfortunately, in most cases higher level skills, such as interpreting the results and finding limitations in the procedures which are related to a logical reasoning method of thought, were found to be lacking. The incompetence of students at report writing and their inability to apply the results previously obtained in new situations were further disturbing findings of this study. (This aroused suspicion that those skills which students had acquired were most probably restricted to the activities of the examinable practicals and were not transferrable to practical activities in general.)

8.2 IMPLICATIONS OF FINDINGS

In its essence the most disturbing finding of this study has been the difference found between what teachers stated were their most important aims and what students perceived as being the most important influence of practical work. Also rather worrying is the lack of competence of students in the higher level skills necessary for adequately doing experimental work in a chemistry laboratory. The finding that a significant percentage of students did not in many cases understand the purpose of the experiment in which they were involved is similar to that found by Moreira (1980). He reports that in many instances students perform experiments without a clear idea of what they are doing or of the underlying concepts. Reference to the practical skills students had learned also shows that the teachers were aware that they were not competent at the very skills necessary to achieve the aims as put forward by the teachers.

Although the teachers emphasise the aims of promoting a logical reasoning method of thought and finding facts, they do not seem to have been planned for either in approach adopted or practical activities chosen. The question arises as to how the teachers tried to achieve their aims. It must be assumed that the students' opinions have been formed mainly by their experiences of practical work which was organised and planned by the teachers with particular aims in mind. Consequently, it would seem fair to look to the teachers for the reasons for the mismatch between what they supposedly had in mind and what students perceived. A number of possible reasons, which would account for the mismatch, follow.

8.2.1 The approach

The approach used by the teacher to plan for pupils to carry out practical exercises is not effective because the objectives stated by him as being among the most important are not being achieved. He recognises and identifies his most important objectives and constructs a plan. Unfortunately the feedback that he is receiving does not show him that there is a mismatch between what he is attempting and what the pupils think is his intention. Alternatively, he is aware of this mismatch but is unable or unwilling to change his approach to correct it. He continues to use the same ineffective approach with the inevitable unsatisfactory result.

The fact that his pupils are misreading his intentions shows that the objectives are not evident to the pupils, from which it can only be deduced that the true objectives are not clear to the teacher. In many cases the teacher seems to have only a vague notion that practical work is 'good for them', 'in the syllabus' and 'part of science'. Although specific lesson objectives are often produced, there does not seem to be any linking of these objectives to the broader course objectives to achieve a co-ordinated approach so that all important aims are achieved during the year's practical work. Instead it appears to be a 'piecemeal, take it as it comes in the syllabus' approach. It would be very rare to find a teacher who designs an approach to a particular practical in order to achieve specific objectives which are then made apparent to the pupils. It is also suspected that the motivation for the method chosen for carrying out a particular practical (i.e. pupil experiment or teacher demonstration) is often the teacher's familiarity with an approach rather than the achievement of particular educational objectives. To support this reason for the mismatch a comparison of the findings from the work of Kerr(1963) and Thompson (1975) shows that teachers' use of practical work changed much less quickly than science curricula during the intervening fourteen years. This suggests that the use of practical work is in practice only loosely tied to course objectives.

8.2.2 Assessment

The assessment which takes place during the year and the final control test which is carried out in most schools at the end of the year is influencing the choice of which practicals are carried out as well as the manner in which they are done. Consequently this method of assessment is reflected in the perception by the pupils of the aims. Most teachers are loath to admit that assessment does influence their teaching. However, from comments made by teachers and private conversations with pupils, it does appear that pupils are drilled in certain examinable experiments to such an extent that they can actually perform the experiment without instructions. In addition, virtually all aspects of each examinable experiment are explored in detail so that most questions concerning that particular experiment can be answered. (One department of education produced for each practical a list of questions from which the assessment questions were to be drawn).

Consequently, the pupils will be biased towards learning the content of a practical rather than understanding the process associated with it. It is no wonder that these pupils would see the role of practicals as one of remembering facts, (in this case about one particular experiment). This approach of rote learning is not particularly good for inculcating an appreciation of scientific method or developing logical reasoning methods of thought, one of the teacher's most important aims. In support of the above inference of a 'covert' attitude to practical work and assessment, Gonzales and Gilbert (1979) showed that teachers' opinions about laboratory work are inconsistent. Whilst rating of low importance the aim 'to prepare pupils for examinations' the same teachers gave a high ranking to the objective 'make accurate observations and descriptions' the feature most teachers consider important in the determination of pupil's practical assessment. The same relative ranking of aims is found in the present study with the consequent associated implications.

8.2.3 Discovery learning

To allow pupils to use practical work to 'discover for themselves' seemed to be the ideal and to a great extent it was, and still is, one of the preferred teaching methods. Dealing with the demands of practical work, Johnstone and Wham (1982, p.71) state,

> It is almost an article of faith to assert that practical work reaches its highest form when done by the pupils themselves rather than by demonstration, because pupils are in a position to engage in discovery learning (albeit 'guided discovery'). However, when attempts have been made to measure the learning taking place during practical work, a rather pessimistic picture emerges.

Many teachers tried this method without having been trained or even being fully conversant with the implications of its use, only to abandon the method as the pupils did not seem to be learning. However, there still lurks the feeling that this is the educationally ideal method that should be used.

Consequently, when planning practical work teachers often included an element of discovery or problem solving to give the practical 'respectability'. However, this dualistic approach to aims only resulted in the pupils being confused about what the purpose of the practical was. The pupils were being asked to find facts, encounter new syllabus content and learn new skills at the same time - an impossible task. To make sense of the experiment, they resort where possible to text books, classmates or the teacher to obtain the 'right answer'. When problem solving (possibly seen as a form of discovery teaching by the teacher) was also attempted it too proved unsuccessful as the pupil was often asked to solve a problem, the answer to which was in his textbook along with the associated theory. Consequently, he sees the practical work as merely supporting theory. When the answer in the book is not obtained as a result of 'the experiment not working', further conflict arises and the teacher's important aims of promoting logical thinking recede even further from the pupil's perception.

8.2.4 The consequence

If the mismatch between the stated aim and actual learned ability is allowed to continue, pupils will continue to leave school with only a limited range of practical skills. These low level skills are to a certain extent valueless without the higher level skills which few pupils possess. If the present state continues the pupils will continue to have the wrong impression of what the purpose and value of pratical work is, and hence obtain an impoverished view of science as a discipline. The pupils understand the content but are not competent at using scientific processes or methods. Upon entering tertiary institutions, their skills inevitably are found to be lacking and this must result in a compounding of the problem.

This mismatch of stated and achieved aims can and probably does result in time wasted and energy expended while pupil and teacher interact at cross purposes.
For the teacher a certain amount of frustration and apathy is certain to occur. If the reasons for the mismatch can be removed, then this is sure to lead to both greater efficiency and satisfaction on the part of teachers and added meaning to the discipline of science for the pupils.

In spite of having suggested some of the possible reasons for and results of the conflict, one question does remain unanswered; 'When carrying out practical work which objectives should be emphasised?' While teachers say one thing, pupils perceive something else. If support of theoretical work is the most important aspect then all that remains to be done is to increase the efficiency of the practical as a teaching and learning method and to convince teachers that this is the aim of practical work on which they should concentrate (in other words demonstrations will suffice in most cases). However, if the primary aim of practical work is for the pupil to gain 'process' skills, new approaches are required in the laboratory as those presently in use are leading to a conflict of aims and a lack of real laboratory skills. To gain a proper appreciation of scientific methodology, the approach to practicals will have to change in yet another way.

8.3 THE UNIQUE ROLE OF PRACTICAL WORK

Practical work has a unique role to play in school chemistry which no other activity can take . From a study of the previous work (Section 1.2) it would appear that at no stage has this role for practical work been completely spelled out. In the Republic of South Africa, reports of the HSRC and subject associations (see Section 1.2) have emphasised the role of school practical work with respect to 'the process of science' while the introductions to syllabi produced by education departments have tended to concentrate more on the idea of practical work being an efficient means of learning and experiencing scientific phenomena (i.e. learning about science). Consequently, it appears that the practical work can be said to have a dual role , the first related to the understanding of science as a process (e.g. developing skills to solve new problems and gain new knowledge) and the second related to the learning about science i.e. a body of knowledge. There are few teachers who will not recognize this dual role but many who might attempt to integrate the roles or emphasise one role to the detriment of the other. The attempts of teachers to integrate the two roles is considered the underlying reason for the conflict found to be present in school practical work (i.e. the mismatch between aims and also the lack of essential skills). Further, it is felt that the role relating to the process skills is the role that should receive most emphasis at this point in time.

5.3.1 Learning about science

Consider first the role, 'learning about science'. Careful analysis of the many advantages of using practical work in this role will show that most of them can be achieved by other activities. Text books, slides, video programmes and computer simulations, will all enable a pupil at the senior secondary level of schooling to adequately learn about science as it is currently presented in South African school syllabi (i.e. see phenomena, develop concepts and discuss their application in everyday life). It is accepted that the concepts developed without doing practical work might ,in some way, be different due to the fact that the pupil was not able to 'do it himself' or see phenomena for 'real'. There is no conclusive evidence that a concept developed will be inferior in any way, in the case of a pupil who sees an abstract presentation rather than a concrete illustration of a concept. Neither is there evidence to suggest that practical work is superior in the development of concepts to these other aids. Yager et al.(1969) working with biology pupils reported that the use of the laboratory did not result in significant gains in the development of concepts or understanding of scientific method. Only in the area of manipulative skills did the laboratory course result in significant gains over other methods. Shayer (1978) has demonstrated that the practical foundation of the course followed by the pupils, in that instance Nuffield Combined Science, played no significant part in determining their achievement. The acquisition of scientific concepts was almost wholly determined by the child's developmental level. Consequently, there appears no reason why practical work should be emphasised when the aims of teachers are directed at the learning of syllabus content (i.e.learning about science).

8.3.2 Process skills

When practical work is considered by the teacher as the means of developing process skills rather than as a teaching aid, it is obvious that in learning skills which will allow pupils to deal with new problems and uncover new knowledge we are now considering the unique role of practical work in the school situation. Only by physically doing can the practical manipulative skills be learnt. These basic manipulative skills are the prerequisites for the development of the higher level process skills (Houston 1970). It would appear that no other activity in the classroom can replace this role of practical work. "While some of these traits can be enhanced elsewhere, the laboratory offers unique opportunities for their development" (Lunetta et al. 1981). It is a role that needs to be emphasised. It is only when the manipulative skills are learned and the process skills developed with use by the pupil that the separate aim of developing a logical reasoning approach to practising science can be accomplished.

When attempts were made to integrate this role of developing process skills with the role of supporting theory (as it would appear many teachers were consciously or unconsciously attempting), the practical lost its primary role and assumed a role of a teaching aid. A factor contributing to the reduction in emphasis on process skills was the emphasis on repeating practicals which were theory orientated so as to prepare the pupils for a practical examination. This was further exacerbated by the complete lack of consideration of the practical process skills in any part of the final senior certificate examination. The emphasis in the assessment was on the content of science. Consequently the pupils must have assumed that this was the overall emphasis and importance of practical work.

8.3.3 Practical skills for school chemistry

What exactly is meant by using practical work as a means of developing 'process skills'? This might mean different things to different people but in the context of school chemistry practical work can be considered among other things, as giving pupils the means of gathering new information, verifying information, ordering and classifying information and assessing its value with respect to the body of knowledge already accepted. The process skills may be divided into two categories. The first is orientated toward those skills necessary for the gathering and verification of information. These are essentially manipulative skills and must be mastered before the second category of skills can be meaningfully developed. These involve the interpretation and assessment of the information gathered.

The pupil should ultimately gain proficiency in the skills mentioned by Swain (1974) and used in the student questionnaire (Table 4.2, p.60). Then, instead of only learning about science and experiencing some of the phenomena of science, the pupil would have to practise the skills of the scientist, in this particular case a chemist, and to do this he would need to appreciate that he was in the position of being an apprentice scientist. Eventually, having developed a correct understanding of what goes on in the practical work he will see what the scientist actually does when he practises his profession.

To suggest that the process skills be emphasised and that practical work be distanced from the teaching of the content so as to emphasise its uniqueness and value, is to ask for a complete change of attitude toward school practical work. Note, however, that this does not mean that practical work for the purpose of learning theories and principles should be completely abandoned. On the contrary, its value in this role will be reinforced because a practical would effectively become a demonstration and therefore there will be no elements such as problem solving or learning new skills to confuse the pupil. Alternatively if the pupil is allowed to interact with the phenomena in a 'hands on' situation, he will possess skills enabling him to do so effectively and will appreciate the need and value of such interaction. At present, the pupil appears to be asked to interact with new content (discover) and learn the process skills at the same time, resulting in a confusion as to the primary aim and an information overload. (Johnstone 1982, p.72)

8.4 A NEW ATTITUDE

It is only when a change of the teacher's attitude occurs, as will be evidenced by change in the aims being emphasised and in appropriate practical activities being offered , that the damaging mismatch between the aims perceived by pupils and those actively pursued by the teachers will be eliminated. Both the teachers and pupils must be made aware of the dual but separate roles of practical work at school level: i) as a teaching aid for illustrating theory and; ii) as a means of learning process skills. The teachers must recognize that each role has value but attempts at integrating these roles will in all likelihood result in the pupils not being influenced in the manner attempted as found by this study. It is unrealistic to continue to believe that: i) the majority of pupils have the mental ability to learn complex theories by participating in discovery type practicals at a senior certificate level or; ii) that pupils will appreciate the value and learn the essential skills of the chemistry laboratory by learning a 'practical'. Careful consideration needs to be given by teachers and examiners to the aims to be emphasised, the approaches to be adopted, the activities to be selected and the organization of practical activities. New strategies need to be evolved for coping with the change in emphasis in the roles of practical work.

8.4.1 Emphasis on separate roles

Firstly an environment must be created for the pupil in which he will be able to perceive the dual role of practical work and be prepared to accept them both as being important to him. In this sense, the pupil must see the role (as he does now) of practical work as helping him to learn about science, to interact with scientific phenomena, to develop concepts and to demonstrate proper understanding in his examinations. However, he must see the essential role of practical work as being a means of developing process skills for the gathering of new information, skills which have been found vitally necessary by scientists and which will be valuable to practise while at school and in later life.

As far as the teacher is concerned, this implies that he must not only appreciate these dual roles but more important, realise that the development of process skills is essential. In order to emphasise this importance, it is suggested that a particular part of the syllabus be reserved for the learning of these skills and for developing an appreciation of their importance in natural science. The pupils would then have opportunities to concentrate on skills without having syllabus content or theory interfering. It would become clear to the pupils that the skills were just as important as the content. The 'right' answer to the experiment would not be an issue. What would be important would be the manner in which interaction between pupil and the observed phenomenon took place.

For the teacher, this would give opportunities to focus on particular skills without having the distraction of any other aims (especially the illustration of new material). Once pupils had begun to appreciate the value of the practical process skills, their interaction with phenomena to be examined during the rest of the year would be more fruitful. Students would begin to develop the skills of thinking logically and rationally as is desired by teachers at present.

The opportunity to assess the value of such a plan is available at the present time. The Division of Indian Education has introduced into the Standard Nine syllabus two periods of three weeks during which time optional topics may be studied. This could be an ideal opportunity to plan a six week course to concentrate on the development of the skills outlined by Swain (1974). This should be done at the beginning of the year and would not interfere with the factual content of the rest of the syllabus.

8.4.2 Elimination of the mismatch

Secondly, whether or not an ambitious scheme such as outlined above is carried out, there remains the fundamental requirement that the mismatch concerning objectives must be eliminated. To do this the following strategies should be attempted:

i) When a practical activity is planned, the objectives must be limited to a small number. If all attention is focussed on one or two objectives, the chances of misunderstanding occurring will be markedly reduced. Consider a practical activity planned by the teacher for the sole purpose of interesting and motivating the pupils e.g. an exciting demonstration without explanation (but with reference to a source of explanation for those interested). The pupils can focus all their attention on the 'happening', knowing that nothing needs to be specially remembered or learnt for examination purposes.

ii) The teacher needs to appreciate that the practical skills are hierarchical in nature (Houston 1970). There is no purpose in setting a pupil the task of designing a practical when he is physically unable to do it, never mind interpret observations or data collected. Consequently, the teachers must plan ahead, such that the basic physical and lower level cognitive skills are learnt before the higher level skills are attempted. It is also important that pupils be given opportunities to use the skills once they have become competent in them.

iii) The practice of carrying out a practical before the objectives are determined should be discouraged. If a practical is set down as compulsory in the syllabus, the teacher should first determine why this is so. Then he must include these objectives in the planning of this practical activity for his pupils. Once the objectives have been clearly defined, then an appropriate approach can be chosen. If practical activities are not indicated in the syllabus then it would be best if practicals were designed each to meet specific objectives. e.g. If the teacher needs to show pupils a reversible reaction to support theoretical work already covered, then a demonstration should be planned to achieve that particular objective.

8.4.3 Assessment

Thirdly, the form of assessment of practical work needs to be revised. It would appear that the cause of pupil and teacher preoccupation with certain practicals is a result of the decision that these particular practicals are examinable. This results in pupils concentrating on learning the 'practicals' rather than the skills. An example of this practice concerns instructions. At the moment, the pupil can learn by rote the instructions for all the examinable practicals. When evaluated his memory is being tested not his skill at interpreting and carrying out instructions. What should be given to the pupil for the assssment is a completely new set of instructions for interpretation. Only then can his actual skill be determined. The knowledge that this type of assessment was to occur would undoubtedly turn pupils' attention from the set of examinable practicals to the skills themselves.

The assessment of a pupil with respect to practical skills could then take the form of two tests. The first would require the pupil to demonstrate that he had skills such as manipulative skills, ability to make accurate observations and ability to set up commonly used apparatus. This could be attempted using simple evaluation techniques such as those devised by Mathews (1969) or Lunetta et al.(1981). The second could take the form of a written test where skills such as interpreting data, evaluating experimental design and communicating results could be determined. In these examinations new practical situations would need to be devised, encouraging pupils to concentrate on skills and processes rather than particular practicals. It would also free the experienced teacher to choose practical activities which he considered most effective in developing the manipulative and process skills required.

8.5 THE RESULT

The mismatch between the teacher's most important aims for chemistry practical work and the perceived influence of these aims has been shown to exist. Further it has been found that both teachers and pupils agree that the high level practical skills so necessary for effective participation in experiments are not part of the skills at which pupils are competent. Reasons for these problems have been suggested and strategies for effectively overcoming them have been presented. It is felt that these strategies should result in a more balanced set of objectives being achieved with a minimum of misinterpretation of the teacher's overall aims by the pupils. It is considered that adoption of these strategies will result in school-leavers who would: i) be capable of working in a laboratory environment; ii) have a much fuller picture of the methodology of science; iii) be able to think in a logical reasoning manner and; iv) possess valuable skills with which to interact with their environment.

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LIST OF APPENDICES

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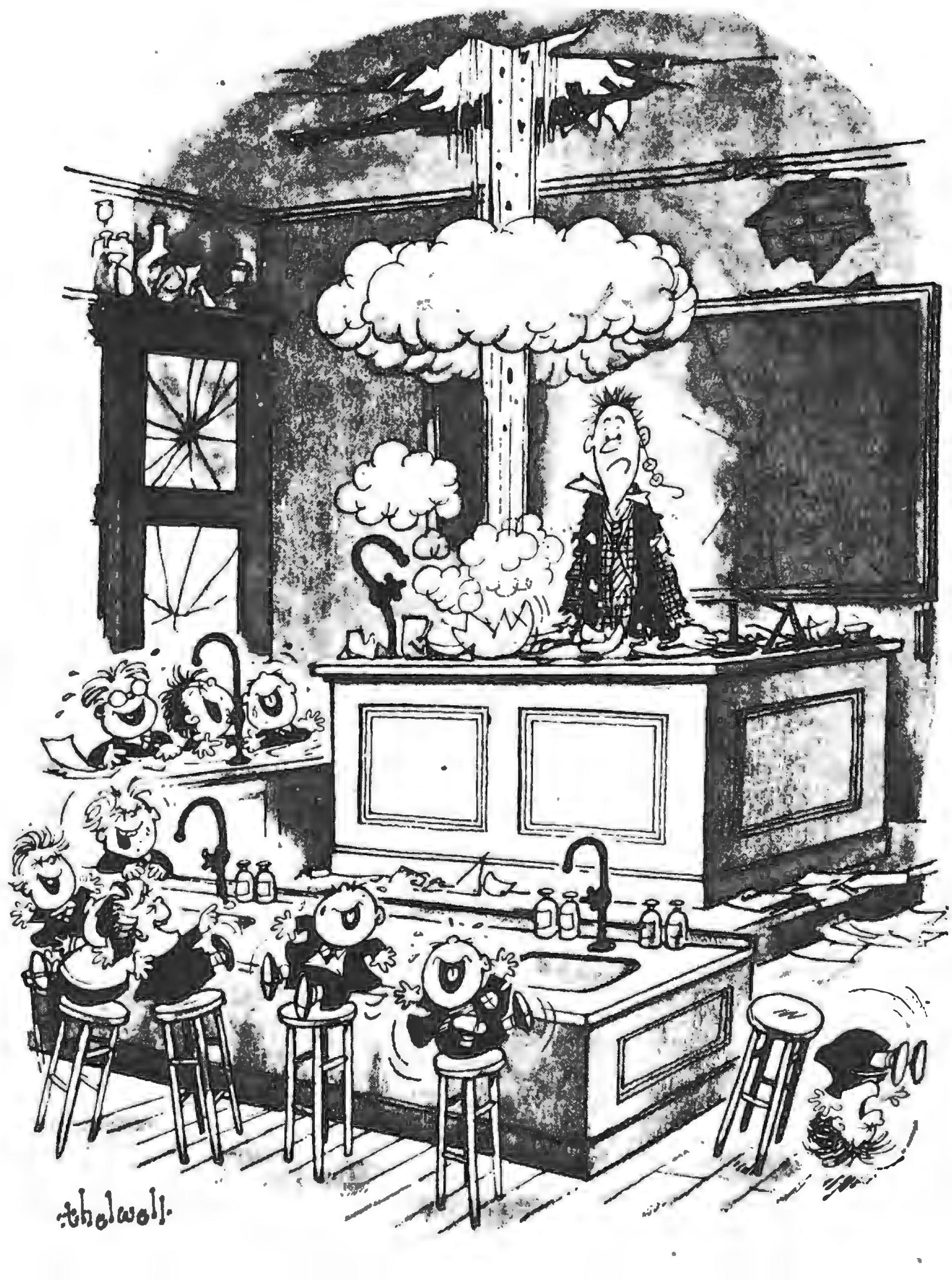
APPENDIX A

QUESTIONNAIRES USED IN STUDY

1. Teacher questionnaire
2. Student questionnaire

TEACHER QUESTIONNAIRE

SENIOR CERTIFICATE CHEMISTRY PRACTICAL WORK



QUESTIONNAIRE FOR TEACHERS

DECEMBER 1982.

SECTION A : GENERAL INFORMATION

1) Please tick as appropriate

MALE	FEMALE

2) How long have you been teaching Std 10 physical science?

years.

3) Please indicate your qualifications e.g. UDE (JS)

4) What is the size and composition of each Std 10 physical science class you teach?

	Classes			
Number of Higher Grade pupils				
Number of Standard Grade pupils				

5) Which of the two parts of physical science do you prefer to teach?

Chemistry	Physics	No Preference

6) Which of the two parts of physical science do you find more difficult to teach?

Chemistry	Physics	Equal Difficulty

2.

SECTION B: PRACTICAL WORK

1. The following is a list of typical Senior Certificate chemistry demonstrations Please complete the table by placing an 'X' in the appropriate column.

	Performed as a demonstration	Done as a pupil experiment	I chose not to do this demonstration	I am not familiar with this particular demonstration
1. Investigation of the effect of a non volatile dissolved substance on the boiling point of a liquid.				
2. Investigation of the effect of pressure on the boiling point of a liquid.				
3. Comparison of the vapour pressures of water, ethanol and ether.				
4. Investigation of the solubility of molecular and ionic solids in different solvents.				
5. Investigation of the conductivity of ionic and covalent compounds in water.				
6. Demonstration of the changes in temperature during chemical reactions.				
7. Demonstration of the common ion effect eg. sodium acetate is added to acetic acid.				
8. Demonstrate the acidic and basic character of the hydroxides of the elements of period 3.				
9. Investigation of the factors that can influence equilibrium eg. temp and concentration.				
10. Investigation of the electrical conductivity of different acids.				
11. Demonstration of the existence of reversible chemical processes.				
12. Demonstration of how successive dilutions affect the pH of an acid.				
13. Investigation into the electrolysis of a dilute solution of copper sulphate or water.				
14. Investigation of the addition of metals to solutions of other metal ions.				
15. Investigation of the oxidising and reducing properties of the elements in Period 3.				

2. The following is a list of typical Senior Certificate chemistry pupil experiments. Please complete the table by placing an 'X' in the appropriate column.

	Done as an experiment by pupils.	Performed as a demonstration	I chose not to do this experiment	I was not able to do it for some reason.
1. Investigate the relationship between the pressure and volume of a gas (Boyles Law)				
2. Investigate the relationship between the pressure and temperature of a gas.				
3. Investigate the relationship between the volume and the temperature of a gas				
4. Investigate the effect of a non volatile dissolved substance on the boiling point of a liquid.				
5. Investigate the effect of concentration and temperature on the reaction rate of $Na_2S_2O_3$ and HCl				
6. Investigate the separation of cations by the formation of insoluble salts (qualitative analysis).				
7. Preparation of a standard solution by accurate massing and dilution.				
8. Use of standard solution to standardise a strong acid (i.e. a titration)				
9. Investigate the acidic and basic character of the hydroxides of the elements of period 3.				
10. Investigate the potential difference or emf between a metal/metal ion half cell and Cu/Cu^{++} half cell.				
11. Investigate the action of H_2S on HNO_3, H_2SO_4 and $KMnO_4$				
12. Demonstrate the oxidation of Fe^{2+} to Fe^{3+}				
13. Investigate the reaction of bromine dissolved in CCl_4 with lab gas, ethene and ethyne.				
14. Prepare bromo-ethane from ethanol, KBr and H_2SO_4 (distillation).				
15. Hydrolysis of bromo-ethane with KOH				
16. Preparation of a polymer or plastic				
17. Preparation of an ester.				

SECTION C: AIMS

1. It is accepted that for each experiment or demonstration you would have had particular aims. However taking an overall view of your aims, please indicate the actual degree of importance you attached to each of the following aims. (It is recognised that the actual degree of importance you attached to an aim may differ from the ideal degree you would like to attach)

ACTUAL TEACHER AIMS	PUPIL EXPERIMENTS					TEACHER DEMONSTATIONS				
	Extremely important	Very important	Important	Fairly important	Not very important	Extremely important	Very important	Important	Fairly important	Not very important
1. To encourage accurate observation and description.										
2. To arouse and maintain interest in chemistry.										
3. To make chemical phenomena more real through actual experience.										
4. To develop specific manipulative skills eg handling of chemicals.										
5. To prepare the pupils for the practical examination or moderation.										
6. To clarify theoretical parts of the chemistry syllabus.										
7. To promote a logical, reasoning method of thought.										
8. To let pupils discover facts and arrive at new principles.										
9. To verify facts and principles already taught.										
10. To give pupils practice at seeing problems and seeking ways to solve them.										
11. To help pupils remember facts and principles.										
12.										

NOTE: If you have any other aims which you considered important when performing practicals please add them to the above list.

2. If you have any comments to make concerning the questions please do so. (eg difference between your actual aims and ideal aims).

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3. As a result of performing experiments during the past year, your pupils will have developed some of the following practical abilities. Please indicate how many of the pupils have, in your opinion, these abilities with regard to CHEMISTRY practicals.

PRACTICAL ABILITIES PUPILS WILL HAVE RELATED TO CHEMISTRY PRACTICALS	HIGHER GRADE PUPILS.					STANDARD GRADE PUPILS.				
	Most	More than Half	About Half	Less than Half	Very Few	Most	More than Half	About Half	Less than Half	Very Few
1. Ability to understand the aim of an experiment.										
2. Ability to devise or select a procedure or technique.										
3. Ability to recognize limitations and possible sources of error in procedure selected.										
4. Ability to follow and understand written and verbal instructions.										
5. Ability to select and assemble apparatus to perform a particular experiment.										
6. Ability to determine whether the apparatus is functioning correctly.										
7. Ability to use familiar apparatus and materials.										
8. Ability to make accurate observations.										
9. Ability to record accurately the experimental data.										
10. Ability to arrange/organize the data in tabular/graphical form.										
11. Ability to interpret results and draw conclusions.										
12. Ability to understand the purpose of the experiment.										
13. Ability to write a concise, effective report.										
14. Ability to use the results to make predictions for new situations.										

3. Please comment on any aspect of pupil practical work which you would like to bring to my attention.

e.g. conditions peculiar to your school, the examinable practicals, teacher laboratory manuals, time available, apparatus available, level of difficulty or complexity of practicals etc.

Thank you for your time and trouble

Paul Hobden

PAUL HOBDEN

Science Division
Faculty of Education
University of Durban-Westville.

STUDENT QUESTIONNAIRE

QUESTIONNAIRE ON SCHOOL CHEMISTRY PRACTICAL WORK DURING 1982

SECTION A : GENERAL INFORMATION

Please note all information given will be treated in the strictest confidence. No names of students or schools will be disclosed.

1. School attended during Std. 10

2. Please give your name and student number.

Name	
Student Number	

3. Please tick as appropriate

Male	
Female	

4. Please fill in your grade and symbol for Physical Science

Grade (H.G. or S.G.)	
Symbol	

5. Which of the two parts of school Physical Science did you prefer?

Physics	Chemistry	No preference

6. Which of the two parts of Physical Science did you find more difficult?

Physics	Chemistry	Equal difficulty

7. In your opinion how much chemistry practical work did you do last year?

Too much	Sufficient	Too little

8. Do you think your final written examination result in Physical Science was improved because of the practical work you did?

Improved	Undecided	No improvement

SECTION B : ORGANISATION

During 1982 you would have had an opportunity of doing some experimental work in Chemistry. The following questions are related to your recollection of how the teacher organised and conducted the Chemistry experiments.

INDICATE HOW OFTEN EACH OF THESE STATEMENTS WAS TRUE	Always True	Often True	Sometimes True	Rarely True	Never True
1. You were required to prepare for the experiment in advance.					
2. Verbal instructions for the experiment were given to you by the teacher.					
3. You were told to follow the instructions in your text book.					
4. Written instructions for the experiment were given to you by the teacher.					
5. The instructions used were clear enough for you to follow.					
6. The purpose for doing the experiment was explained to you by the teacher.					
7. You understood the purpose for doing the experiment.					
8. You were asked to prepare a written report or write up of the experiment.					
9. The group in which you worked was small enough to enable you to participate fully.					
10. You had sufficient time to complete the experiment.					
11. You never really understood what was being done - you merely followed the instructions.					
12. You were tested on your knowledge of the experiment by means of a test, written or verbal.					

SECTION C : AIMS

Teachers have specific reasons for doing chemistry experiments with you at school. They hope to influence you in a number of ways, some of which are listed below.

PLEASE INDICATE THE EXTENT OF YOUR AGREEMENT WITH THESE STATEMENTS.	Agree strongly	Agree	Undecided	Disagree	Disagree strongly
1. I was encouraged to make accurate observations and descriptions.					
2. My interest in chemistry was aroused by doing chemistry experiments.					
3. Chemical phenomena (e.g. dynamic equilibrium, redox reactions) were made more real to me through my actual experience of them.					
4. I developed specific skills in the handling of equipment and chemicals in the laboratory.					
5. I was prepared for the practical examination or moderation.					
6. I found that the theoretical parts of the syllabus were easier to understand after doing the experiments.					
7. My ability to think in a logical reasoning manner has been improved by doing experiments.					
8. I was given the opportunity to discover facts and arrive at new principles, e.g. by obtaining information from experiments, followed by explanations from books or teachers.					
9. Facts and principles already taught were verified in the laboratory.					
10. I was given the opportunity to practise seeing problems and seeking ways of solving them in the Chemistry Laboratory.					
11. The experiments helped me to remember facts and principles taught in class.					

SECTION D : SKILLS

As a result of performing experiments during last year, you will have developed some of the following abilities.

HOW WOULD YOU RATE YOURSELF WITH RESPECT TO THE FOLLOWING CHEMISTRY EXPERIMENTAL ABILITIES?	Very competent	Competent	Fairly competent	Not very competent	Not competent
1. Ability to understand the aim of an experiment.					
2. Ability to devise or select a procedure or technique i.e. what apparatus or method to choose.					
3. Ability to recognize limitations and possible sources of error in the procedure selected.					
4. Ability to follow and understand written and verbal instructions.					
5. Ability to select and assemble apparatus to perform a particular experiment.					
6. Ability to determine whether the apparatus is functioning correctly.					
7. Ability to use familiar apparatus and materials e.g. burettes, balances, acids, etc.					
8. Ability to make accurate observations e.g. of colour changes, of gases given off etc.					
9. Ability to record accurately the experimental data.					
10. Ability to arrange/organize the data in tabular/graphical form.					
11. Ability to interpret results and draw conclusions.					
12. Ability to understand the purpose of the experiment.					
13. Ability to write a concise, effective report or practical write up.					
14. Ability to use the results to make predictions for new situations.					

APPENDIX B

COVERING LETTERS USED IN POSTAL SURVEY

1. Initial letters
2. Follow-up letter

8 Westminster
55 Currie Road
Durban
4001
30th November 1982.

SENIOR CERTIFICATE PHYSICAL SCIENCE TEACHERS.

Dear Colleague

The questionnaire accompanying this letter is part of a private research project that I am carrying out into "chemistry practical work in schools under the control of the I.E.D."

The information supplied will be of value
(a) in supplementing the ongoing research effort into science teaching.
(b) as a guide to me personally in my role as a chemistry method lecturer at the University of Durban-Westville.
(c) as a help in the development of an alternative approach to school practical work.

I will be most grateful if you take the time and trouble to complete this questionnaire and return it to me in the envelope supplied. The information you provide will be treated as absolutely confidential. To ensure this, please do not sign the questionnaire unless you so desire.

Your co-operation will be greatly appreciated.

Yours sincerely

Paul Hobden

PAUL HOBDEN.

INITIAL LETTER (page 2)

Telegramadres:
Telegraphic address:
"INOND"
Navrae/Inquiries
Tel. No. 37-2351
Bylyn/Ext.

DIA 1/81

Verwysing/Reference
No. 19/57/3/44

REPUBLIEK VAN SUID-AFRIKA · REPUBLIC OF SOUTH AFRICA

DEPARTEMENT VAN BINNELANDSE AANGELEENTHEDE · DEPARTMENT OF INTERNAL AFFAIRS

DIREKTEUR VAN INDIËRONDERWYS
DIRECTOR OF INDIAN EDUCATION
Esplanadestaatskantore (Stangerstraat)
Esplanade Government Offices (Stanger Street)
H/v Victoria-oeweroord en Stangerstraat
Cor. of Victoria Embankment and Stanger Street
Privaatsak/Private Bag X54323
DURBAN
4000

1982-11-25

Mr P.A. Hobden
8 Westminster
55 Currie Road
DURBAN
4001

Sir

PERMISSION TO CONDUCT RESEARCH IN INDIAN SCHOOLS
Your letter dated 17 November 1982 has reference

1. Permission is hereby granted to you to administer the research questionnaires to the standard 10 Physical Science teachers of the 61 schools (list of names and addresses of the schools is enclosed) subject to the following conditions:

   1.1. The standard 10 Physical Science teachers of the 61 schools may be approached but are under no obligation to complete the questionnaires.

   1.2. Completion of the questionnaires is done during non-lesson time.

   1.3. The information obtained from respondents is treated confidentially and used solely for academic purposes.

   1.4. The word 'matric' be changed to 'Senior Certificate' wherever it appears.

   1.5. A copy of this letter accompanies the questionnaires which are sent to the standard 10 Physical Science teachers.

2. A list of names and addresses of schools that are offering Physical Science in standard 10 is enclosed.

-2-

3. Consideration will be given to your request to interview a sample of standard 10 Physical Science teachers provided that the following information is supplied:

   3.1. an interview schedule

   3.2. a list of schools that will constitute the sample.

Yours faithfully

DIRECTOR OF INDIAN EDUCATION

FOLLOW-UP LETTER

Division of Science Education
Faculty of Education
University of Durban-Westville
Private Bag X54001
Durban
4000
9 February 1983

The Principal

Dear Sir

During the last weeks of the 1982 school year, all senior Science teachers were requested to complete a questionnaire as part of a research project into Science practical work. It seems however that many of these questionnaires were mislaid, either in the post or in the end of year rush, or that possibly a few teachers chose not to participate in the project.

Could you please pass the enclosed copy of the questionnaire to your senior Science teacher for his consideration. If he does not wish to participate , I would be grateful for the return of the questionnaire in the envelope provided.

If the questionnaire has already been returned, please disregard this letter and convey my thanks to your teacher for his co-operation.

Yours faithfully

P Hobden

P.A. HOBDEN

APPENDIX C

LIST OF CHEMISTRY PRACTICAL WORK

1. Extract from Higher Grade syllabus (DIE 1977).

LIST OF CHEMISTRY PRACTICAL WORK

Experiments marked T may be done by the teacher or the pupil; those marked P are to be done by the pupil and those marked E may be examined in the practical tests in Std. X.

24E. Investigate the relationship (if any) between the pressure and the volume of a given mass of gas at constant temperature (Boyle's Law).

25E. Investigate the relationship between the increase in the pressure of a given mass of gas from ice-point to steam-point and the pressure of the gas at ice-point the volume being kept constant. (Pressure/temperature relationship).

26E. Investigate the relationship between the expansion of a given mass of gas from ice-point to steam-point and the volume of the gas at ice-point, the pressure being constant. (Volume /temperature relationship.)

27P. Investigate the effect of a non-volatile dissolved substance on the boiling point of a liquid

28E. Investigate
(a) the effect of concentration on the reaction rate of sodium thiosulphate and hydrochloric acid
E (b) the effect of temperature on the reaction rate of sodium thiosulphate and hydrochloric acid.
E (c) the effect of a catalyst on the reaction rate in the case of the decomposition of (a) potassium chlorate (b) hydrogen peroxide
P (d) the effect of particle size on the rate of any reaction

29E. Demonstrate the common ion effect when sodium acetate solution is added to acetic acid.

30P. Investigate the separation of cations by the formation of insoluble salts e.g. Ag^{+} , Cu^{2+} , Mg^{2+} .

31E. (a) Make an approximately 0,1M standard solution of sodium hydrogen carbonate.
(b) Use this solution to standardise an approximately 0,1M solution of a strong acid.
(c) Use this strong acid to standardise an approximately 0,1M solution of a strong base.
(d) Use this strong base to standardise an approximately 0,1M solution of a weak acid.

32P. Demonstrate the acidic and basic character of the hydroxides of the elements of period 3.

33P. Investigate the potential difference or emf between a metal/metal ion half cell and Cu/Cu^{2+} half cell.

34E. Investigate the actions of
(a) hydrogen sulphide on
(1) concentrated nitric acid
(2) dilute nitric acid
(3) concentrated sulphuric acid
(4) potassium permanganate solution and
(b) sulphurous acid on
(1) concentrated nitric acid
(2) dilute nitric acid
(3) potassium permanganate solution
(4) hydrogen sulphide
(c) Demonstrate the oxidation of Fe^{2+} to Fe^{3+}.

35P. (a) Investigate the reaction of oxygen with available hydrocarbons, i.e. combustion.
(b) Investigate the reaction of bromine dissolved in CCl_4 with laboratory gas, ethene (ethylene) and ethyne (acetylene).

36P Prepare bromo-ethane (ethylbromide) from ethanol and potassium bromide and sulphuric acid.

37E. (a) Test bromo-ethane (ethylbromide) with silver nitrate solution
(b) Hydrolyse bromo-ethane (ethylbromide) with potassium hydroxide and treat the resultant mixture with silver nitrate solution.

38E. Prepare any ester.

39P. Demonstrate the formation of a plastic e.g. by adding a few crystals of benzoyl peroxide to methyl methacrylate (heated in a beaker of water) OR by adding a solution of sodium hydroxide and hexamethylene diamine to a solution of sebacyl chloride in carbon tetrachloride.

APPENDIX D

MODERATORS GUIDE TO ASSESSMENT OF PRACTICAL WORK

1. Qualities evaluated
2. Examples of individual mark schemes

QUALITIES EVALUATED (DIE MODERATORS GUIDE)

ASSESSMENT OF PRACTICAL WORK : PHYSICAL SCIENCE

	H	S
In each of the examinable experiments laid down in the syllabus the following qualities of practical work will be evaluated and marks assigned as indicated:		
A: LABORATORY SKILLS AND ABILITIES:		
1. Choice of appropriate APPARATUS		
2. ASSEMBLES apparatus correctly and TEST for correct functioning		
3. PERFORMS experiment/investigation skilfully		
4. MEASURES accurately/OBSERVES critically		
5. RECORDS data/observation systematically		
6. ANALYSES data/INTERPRETS observation		
7. Formulates appropriate CONCLUSION/EQUATION		
SUB-TOTAL	(24)	(24)
B: SCIENTIFIC ATTITUDES:		
1. works in a methodical manner		
2. is honest in his/her observation, data, interpretation, analysis		
3. organises report/results in a neat and systematic manner		
SUB-TOTAL	(4)	(0)
C: INSIGHT INTO AND UNDERSTANDING OF EXPERIMENT:		
1. Has background KNOWLEDGE (viz concepts; principles)		
2. Can explain how apparatus FUNCTIONS		
3. Able to give reasons for PRECAUTIONS		
4. Able to DISCUSS inferences and conclusions		
SUB-TOTAL	(12)	(6)
TOTAL	(40)	(30)

EXPERIMENT 10:

INVESTIGATE THE EFFECT OF:

		H	S
10.1	CONCENTRATION ON THE REACTION RATE OF SODIUM THIOSULPHATE AND HYDROCHLORIC ACID	23	17
10.2	A CATALYST ON THE DECOMPOSITION OF POTASSIUM CHLORATE <u>OR</u> HYDROGEN PEROXIDE	17	13

10.1 EFFECT OF CONCENTRATION:

	H	S
A. SKILLS AND ABILITIES:		
1. APPARATUS: glass ware clean and dry; reactants of suitable concentration (± 2 Mol. dm^{-3} HCl; ± 0,25 Mol dm^{-3} $Na_2S_2O_3$)	1	1
2. ASSEMBLY: places solutions of varying concentration at once; labels containers; at least 3 different concentrations	2	2
3. PERFORMANCE: starts reaction and watch simultaneously; stops watch when mark on paper just disappears	2	2
4. MEASUREMENT: accuracy (vol. of solution; time interval)	1	1
5. RECORDING: variables in terms of aim; observation	2	2
6. ANALYSIS: graphs data; identifies products of reaction	3	3
7. CONCLUSION: in terms of aim; equation of reaction	3	3
	(14)	(14)
B. ATTITUDES:	(2)	(0)
C. INSIGHT AND UNDERSTANDING:		
1. KNOWLEDGE: concentration; rate of reaction	1	1
2. DISCUSSION: can positively identify products of reaction; can explain how concentration affects reaction rate; can discuss implication of conclusion for industry	6	1 1
	(7)	(3)

10.2 EFFECT OF CATALYST

	H	S
A. SKILLS AND ABILITIES:		
1. APPARATUS: Pyrex test tube or clean, wet test tube; small quantity of MnO_2	2	2
2. ASSEMBLY: test tube at angle - clamped or held in holder	1	1
3. PERFORMANCE: dexterity; test for oxygen	2	2
4. OBSERVATION: effect on glowing splint clearly observable	1	1
5. RECORDING: observation	1	1
6. INTERPRETATION: liberation of oxygen indicates rate of reaction	1	1
7. CONCLUSION: in terms of aim; equation of reaction	2	2
	(10)	(10)
B. ATTITUDES:	(2)	(0)
C. INSIGHT AND UNDERSTANDING:		
1. KNOWLEDGE: decomposition; catalyst	1	1
2. DISCUSSION: how catalyst affects reaction rate; can positively identify products of reaction	4	1 1
	(5)	(3)

EXPERIMENT 12:

12.1 MAKE AN APPROXIMATELY 0,1 $mol.dm^{-3}$ STANDARD SOLUTION OF SODIUM HYDROGEN CARBONATE.

12.2 STANDARDISE A DILUTED SOLUTION OF A
(a) STRONG ACID (HCl) OR
(b) STRONG BASE (NaOH) OR
(c) WEAK ACID $(COOH)_2$

	H	S
12.1 PREPARE A STANDARD SOLUTION		
A. SKILLS AND ABILITIES:		
1. APPARATUS: clean volumetric flask; accurate mass meter	1	1
2. ASSEMBLY: check and adjust mass meter	1	1
3. PERFORMANCE: mass by difference; uses distilled water; ensures $NaHCO_3$ completely dissolves and solution is homogeneous; handiness in carrying out procedures; use of mass meter	5	5
4. MEASUREMENT: accuracy in finding - mass and volume	2	2
5. RECORDING: all mass readings systematically	1	1
6. ANALYSIS: calculates concentration of $NaHCO_3$; accuracy of result ($\pm$ 0,1 $mol\ dm^{-3}$)	2	2
	(12)	(12)
B. ATTITUDES:	(2)	(0)
C. INSIGHT AND UNDERSTANDING		
1. KNOWLEDGE: Mole; standard solution	1	1
2. PRECAUTIONS: explains need for precautions taken	1	1
3. DISCUSSION: calculation of required mass of $NaHCO_3$	2	
calculation of concentration of $NaHCO_3$	2	1
	(6)	(3)
12.2 TITRATION		
A. SKILLS AND ABILITIES:		
1. APPARATUS: appropriate indicator	1	1
2. ASSEMBLY: cleans burette and checks for leaks; washes burette with solution	2	2
3. PERFORMANCE: fixed volume in flask; handling of burette; handling of flask;	3	3
4. MEASUREMENT: trial run; at least 3 accurate readings	2	2
5. RECORDING: tabulates data	1	1
6. ANALYSIS: calculates concentration	1	1
7. CONCLUSION: accuracy of result; equation of reaction	2	2
	(12)	(12)
B. ATTITUDES:	(2)	(0)
C. INSIGHT AND UNDERSTANDING:		
A. KNOWLEDGE: strong/weak acid/base; neutralisation	1	1
B. FUNCTION: of indicator (including reason for choice)	1	
C. PRECAUTIONS: explains reasons	2	2
D. DISCUSSION: calculation of concentration from first principles	2	
	(6)	(3)
	(40)	(30)

EXPERIMENT 13:

3.1 INVESTIGATE THE ACTIONS OF (a) HYDROGEN SULPHIDE OR (b) SULPHUR IV OXIDE/SULPHUROUS ACID ON

1. CONCENTRATED NITRIC ACID
2. DILUTE NITRIC ACID
3. (a) CONCENTRATED SULPHURIC ACID/ (b) HYDROGEN SULPHIDE
4. POTASSIUM PERMANGANATE SOLUTION

		H	S
A.	SKILLS AND ABILITIES:		
1.	APPARATUS: clean test tubes in rack (dry for HNO_3(conc)	1	1
2.	ASSEMBLY: appropriate quantity of solutions in each test tube; labels test tubes; acidifies $KMnO_4$	2	2
3.	PERFORMANCE: controls flow of gas; uses clean and dry delivery tube	1	1
4.	OBSERVATION: notes colour change, odour; precipitates; change in temp. (4 × 1)	4	4
5.	RECORDING: tabulates observation, interpretation and products of reaction (4 × 1)	4	4
6.	ANALYSIS: conducts tests to positively identify products	4	4
7.	CONCLUSION: equation for each reaction (4×1)	4	4
		(20)	(20)
B.	ATTITUDES:	(2)	(0)
C.	INSIGHT AND UNDERSTANDING:		
1.	KNOWLEDGE: oxidation/reduction; conc/dilute solution; ion	2	2
2.	FUNCTION: Kipp's Apparatus; Fume cupboard	1	
3.	PRECAUTION: use of H_2S; why delivery tube clean	1	
4.	DISCUSSION: shows how any ONE equation is balanced; how oxidant/reductant is identified; how oxidation/reduction reaction is identified	4	1
		(8)	(3)

13.2 DEMONSTRATE THE OXIDATION OF Fe^{2+} to Fe^{3+}

		H	S
A.	SKILLS AND ABILITIES:		
1.	DEMONSTRATION: ; Tests $FeSO_4$ for Fe^{+2} ion oxidises Fe^{2+}; suitable oxidant; Tests for Fe^{3+} ion; checks colour of ion against controls	4	4
	OBSERVATION: colour of Fe^{2+} and Fe^{3+} ion	1	1
	EQUATION: for Fe^{2+} to Fe^{3+} using oxidant	1	1
		(6)	(6)
B.	ATTITUDE:	(1)	(0)
C.	INSIGHT AND UNDERSTANDING:		
1.	KNOWLEDGE: oxidant/reductant	1	1
2.	DISCUSSION: explains colour change; names 2 other oxidants	2	
		(3)	(1)
		(40)	(30)

APPENDIX E

GUIDE TO PRACTICAL WORK

1. Foreword to guide (DIE 1981)
2. Examples of individual experiment instructions

FOREWORD

In the school situation PRACTICAL WORK is generally understood to be DOING ACTIVITIES rather than KNOWING QUALITIES. It is associated with working with the hands rather than the head.
This narrow concept of practical work may be true for those subjects in the school curriculum concerned mainly with the development of basic skills. In Physical Science practical work has a more general purpose.

The following general AIMS of practical work have been identified by the JMB in their list of 'Minimum Practical work' to be done by a pupil studying physical science:

1. to help pupils understand the fundamental role played by experiment and observation in establishing and extending the body of scientific knowledge;

2. to facilitate the learning and understanding of facts and principles;

3. to give pupils opportunities of making simple "discoveries" of their own;

4. to provide experience of elementary measuring techniques, and acquaintance with some of the measuring instruments in common use;

5. to give practice in the recording and treatment of observations the drawing of appropriate conclusions and the presentation of of results.

The following list of specific objectives may be identified.

1. ability to choose appropriate apparatus for the performance of a given experiment;

2. skill in assembling apparatus to perform a given experiment.

3. ability in carrying out the experiment in a scientific manner

   3.1 manual dexterity in use of apparatus.
   3.2 precautions taken in use of apparatus.
   3.3 skill in using measuring instruments.

4. skill in observing (critical observation)

5. ability to record data/observation in a meaningful manner.

6. ability to analyse data,

7. ability to interpret observation.

8. ability to devise an experiment (practical procedure) to solve a problem.

ASSESSMENT OF PRACTICAL WORK:

Science is both a body of knowledge and a process. Hence evaluation of a persons proficiency in science implies that both the knowledge component and process component be assessed. Assessments of the process component is best done on a continual basis and by the teacher. The following statement by Schools Council of Great Britain may be applied to the teacher as an assessor of practical work:

> "it is accepted that the teacher is likely to know more about his pupils than an external examiner.....He can also put his own pupils in an order of merit more accurately than any examination. What he cannot do is to be sure that he is accurately assessing the standards of his own pupils in relation to those of other pupils in other schools"

The latter requires a system of external moderation.

EXPERIMENT 31 (b)

AIM: To standardise a diluted solution of a strong acid.

APPARATUS:
1. burette and burette stand
2. three 250 cm^3 conical flasks
3. plastic wash bottle
4. 2 test tubes with test tube stands
5. two 200 cm^3 beakers
6. 2 x 10 cm^3 or 15 cm^3 pipette

DISCUSSION:

The following reaction occurs at end point:

$$NaHCO_3 + HCl \rightarrow CO_2 + Na\,Cl + H_2O$$

The formula for determining the concentration of the acid is:

$$\frac{Ca \times Va}{Cb \times Vb} = \frac{Na}{Nb}$$

where Ca = concentration of acid

Va = volume of acid

Na = no. of moles of acid in balanced equation.

The indicator used is methyl orange, because at end point there is a sharp change of pH in the range 3 to 5, which is the range in which the indicator changes colour.

colour: red in acid
yellow in base

METHOD

Rinse the burette with distilled water and thenwith the prepared H Cl solution. Clamp the burette to a burette stand after filling with the HCl solution. Wash the pipette with distilled water and then with the $NaHCO_3$ solution. Pipette exactly 10 cm^3 of the $NaHCO_3$ solution into each of the four conical flasks.
Fill each of two test tubes to about 1/3 level with the $NaHCO_3$ and HCl solutions. Add a few drops of methyl orange indicator to each of the test tubes and observe the colour in each. To determine the colour at end point, hold the two test tubes side by side and hold towards a source of bright light.
Place one of the flasks containing the $NaHCO_3$ solution below the burette and add approximately 3 drops of the indicator into the flask. Carefully run out the HCl from the burette into the flask. Simultaneously swirl the contents of the flask with your free hand while doing this. Use the wash bottle to wash the sides of the flask occasionally. (This procedure does not affect the results because we are interested in chemically equivalent amounts)

EXPERIMENT 34 (a)

AIM: To investigate the effect of hydrogen sulphide gas on certain solutions viz. Nitric acid (conc. and dilute) Sulphuric acid (conc); Potassium Permanganate.

DISCUSSION:

1. Hydrogen sulphide gas is prepared by the reaction of Iron (11) sulphide and Hydrochloric acid (6 mol. dm^{-3}).

2. For a sustained and controlled evolution of the gas Kipp's apparatus is used for its generation. Small chunks of Iron (11) sulphide is placed in the middle bulb of the apparatus (prevent any small particles from falling to the bottom vessel by using a piece of perforated rubber or plastic). The acid is poured through the upper bulb of Kipp's apparatus until sufficient quantity just covers the Iron (11) sulphide.

   The following reaction occurs:

   $$Fe\,S + 2HCl \longrightarrow Fe\,Cl_2 + H_2S$$

   If the system is closed H_2S gas builds up in the middle bulb until the pressure forces the HCl up the stem into the upper bulb thus bringing the reaction to a stop. On opening the tap, gas escapes from the middle bulb and allows the HCl to enter this bulb to once again activate the reaction. The evolution of H_2S gas is thus controlled.

3. Hydrogen sulphide gas is highly poisonous. The generation and use of the gas must be done in a fume extraction chamber and the laboratory must be properly ventilated.

4. Hydrogen sulphide reacts with lead acetate as follows:

   $$Pb\,(CH_3COO)_2 + H_2S \quad PbS + 2CH_3COOH$$

   Lead sulphide is a black solid. This reaction is used as a positive test for the presence of H_2S.

PROCEDURE

1. Suitable quantities of the required solutions are placed in clean test-tubes and appropriately labelled.

   N.B. conc. acids must be placed in dry test-tubes.

2. The gas is bubbled through the solution via a clean dry delivery tube.

3. Any changes in the solution must be noted and where products are obtained these must be positively identified by using suitable tests.

e.g. 3.1 SO_2 (g) decolourises $KMnO_4$ solution

3.2 NO (g) turns orange colour of Potassium dichromate to green or green colour of $FeSO_4$ to reddish brown.

3.3 Barium chloride test identifies the presence of sulphate ions.

4. Equation for the reactions are obtained from observation and consequent positive identification of the products.

FOLLOW-UP:

Using theoretical techniques it may be established that the reaction are all oxidation-reduction and that H_2S is a strong reducing agent.

NOTE:

If HNO_3 (conc.) produces sulphur when reacted with H_2S then the solution is not sufficiently concentrated. Try warming the solution of HNO_3 in a test-tube before passing H_2S.

APPENDIX F

PUPIL PRACTICAL NOTEBOOKS

1. Examples of teacher instructions
2. Examples of pupil reports

Aim: To investigate the effect of concentration on the reaction rate of sodium thiosulphate and hydrochloric acid

Apparatus:

5 X 100cm^3 conical flasks

1 X 500cm^3 conical flask

1 X 10cm^3 measuring cylinder

1 X 250cm^3 measuring cylinder

2 Mol. dm^{-3} HCl.

Stop watch.

Method.

1. Prepare a sodium of approx. 10g sodium thiosulphate in 250cm^3 of distilled water.
2. Measure 50, 40, 30, 20 and 10cm^3 of the solution into each ofthe flasks.
3. Add distilled water to bring the volumes to 50cm^3.
4. Make a cross on the centre of a white sheet of paper.
5. Place the flask containing 50cm^3 of the original solution over the cross.
6. Add 5cm^3 of the acid into the flask and simultaneously start a stopwatch.
7. Shake the flask with a swirling ~~motion and place it over the cross.~~
8. Look at the pencil cross through the flask from a point vertically above the mark. Stop the stop-watch immediately the milkiness of the liquid makes the pencil mark invisible. Note the time.
9. Repeat the above procedure for the remaining flasks.
10. Taking concentration as the volume of the original solution used, plot a graph of concentration against time (ie. time elapsed when the pencil mark becomes invisible)

Questions:

1. Are the concentrations in all the flasks the same?
2. Describe your observations in each of the flask.
3. Was any gas given off during the reaction? If so, what gas?
4. Are there any ions present in the product solution?
5. If so, how would you test for them?
6. Write down a balanced equation for any reaction taking place.
7. What form does the graph take?
8. What relationship between the concentration and the reaction rate can you deduce from the graph?
9. How does the reaction rate change with change in concentration?
10. Explain your answer in (9) in terms of the molecular collision theory.

EXPERIMENT 13

Aim: To investigate the oxidation of Fe^{2+} to Fe^{3+}

Apparatus: test tubes; 4 x 50 cm^3 beakers; $FeSO_4$; $FeCl_3$; $KMnO_4$; NaOH.

Method

1. Prepare fresh solutions of (A) $FeSO_4$
   (B) $FeCl_3$
   (C) NaOH
   (D) $KMnO_4$ (acidify with H_2SO_4)
2. Pour about 2 cm^3 of the $FeSO_4$ solution into a test tube. Add a few drops of NaOH solution.
3. Pour about 2 cm^3 of $FeCl_3$ solution into another test tube. Add a few drops of NaOH solution.
4. Pour about 2 cm^3 of the $FeSO_4$ solution into a test tube and add, drop by drop, a dilute solution of $KMno_4$ (acidified with H_2SO_4) until a faint pink colour is observed.
5. Transfer about 1 cm^3 of the $FeSO_4$ solution (after adding $KMno_4$) into another test tube and add a few drops of NaOH solution.

Questions

1. What purpose does the test tube of $FeCl_3$ serve in this experiment?
2. What do you observe when
   (i) NaOH is added to $FeSO_4$ solution.
   (ii) NaOH is added to $FeCl_3$ solution.
   (iii) $KMno_4$ solution (acidified) is added to $FeSO_4$ solution?
3. Explain with the aid of equations your observations in (2) above.
4. Why is it advisable to use a freshly prepared solution of $FeSO_4$?
5. Does the Fe^{2+} ion in $FeSO_4$ undergo oxidation on addition of an acidified solution of $KMno_4$? Justify your answer.
6. Write (i) a balanced molecular equation
   (ii) a balanced ionic equation for the reaction taking place in (5) above.
7. Identify the oxidizing agent and reducing agent in the above reaction.
8. Two girls carried out this experiment. Both added an acidified solution of $KMnO_4$ to asolution of$FeSO_4$. On adding NaOH solution one girl found a green precipitate while the other found a brick- red precipitate. Explain this difference.

PUPIL REPORT EXAMPLE 1

EXPERIMENT 8

90%

AIM. To investigate the effect of a catalyst on the reaction rate in the case of the decomposition of Potassium Chlorate.

APPARATUS Test-tube, retort stand, splint, bunsen burner.

CHEMICALS. Potassium chlorate, manganese (iv) oxide.

ASSEMBLING APPARATUS:

Clamp a hard glass test-tube in an upright position in a retort stand (Do not use a wooden stand) Set up another retort stand with test tube and place next to first one. Keep a few wood splints close on hand for testing gas.

PROCEDURE

1. Fill each test-tube to about a quarter of its length with Potassium chlorate.
2. Heat the first test-tube strongly until the $KClO_3$ melts. Move the bunsen flame over the sides of the test-tube. This ensures that the $KClO_3$ at the sides and at the top melts
3. Hold a glowing splint for short intervals of time at the mouth of the test-tube lower the glowing splint into the test-tube if necessary
4. Now heat the second test-tube until the $KClO_3$ just melts Remove the flame and add a pinch of manganese (iv) oxide using a spatula Test with glowing splint as before.

RECORDING + ANALYSIS OF RESULTS.

REACTION	TEST	OBSERVATION	INFERENCE.
$KClO_3$ + heat	glowing splinter	splinter continued to glow brightly.	During reaction; Oxygen was liberated - caused splinter to glow more brightly.
$KClO_3$ + Heat + MnO_2	glowing splinter.	splinter burst into flames	the reaction was speeded because the concentration of oxygen had increased + catalyst speeds up reaction.

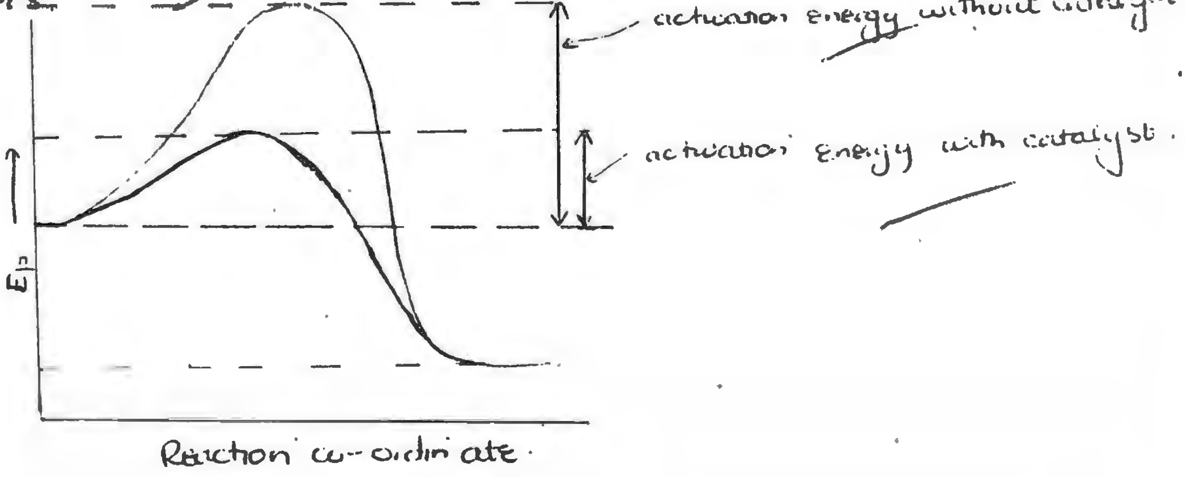
QUESTIONS

Write down a balanced equation for the reaction.

$$2KClO_3 \xrightarrow[MnO_2]{\Delta} 2KCl + 3O_2.$$

Explain the effect of a catalyst on the rate of reaction

the addition of a positive catalyst causes the energy hill to lowered. The amt. of energy required for reaction to proceed is lowered rate increases.



PUPIL REPORT EXAMPLE 2

Expt. 18

Aim. To demonstrate the oxidation of Fe^{2+} to Fe^{3+}

CHEMICALS
(1) ferrous sulphate ($FeSO_4$)
(2) ferric chloride ($FeCl_3$)
(3) sodium hydroxide ($NaOH$)
(4) hydrogen peroxide (H_2O_2)

APPARATUS small beakers, spatulas, medicine droppers, test-tubes

REPORT (1) A fresh soln of each of the fllg. was prepared in beakers
(a) $FeSO_4$
(b) $FeCl_3$
(c) $NaOH$

(2) Some $FeSO_4$ soln was placed in a test-tube and a few drops of $NaOH$ added. Observations were recorded.
(3) Some $FeCl_3$ soln. was placed in a test-tube and a few drops of $NaOH$ added. Observations were recorded
(4) To some of the mixture prepared in step 2, a few drops of H_2O_2 was added. Observations were recorded.

RESULTS

REACTANTS	OBSERVATIONS	EQUATIONS
$NaOH + FeSO_4$	a dirty green precipitate forms in the test tube	$2NaOH + FeSO_4 \rightarrow Fe(OH)_2 + Na_2SO_4$
$FeCl_3 + NaOH$.	a Brick red precipitate in the test-tube	$FeCl_3 + 3NaOH \rightarrow 3NaCl + Fe(OH)_2$
$FeSO_4 + H_2O_2 + NaOH$	Soln. turned Brick red	$FeSO_4 + H_2O_2 + NaOH \rightarrow Fe_2(SO_4)_3 + Na_2SO_4 + H_2O + O_2$

ANSWERS TO QUESTIONS.

(1) It serves as a control.

(2) (i) a dirty green precipitate is formed

(ii) a brick red precipitate is formed.

(iii) a brick red precipitate is formed when a few drops of NaOH are added.

3. (i) $FeSO_4 + 2NaOH \rightarrow Na_2SO_4 + Fe(OH)_2$

(ii) $FeCl_3 + 3NaOH \rightarrow 3NaCl + Fe(OH)_3$

4. a solution of $FeSO_4$ which has prepared and left, exposed to air for some time, oxidises the $FeSO_4$ to $Fe_2(SO_4)_3$

5. Yes: the brick red precipitate formed is that of $Fe(OH)_3$ - the oxidation number of Fe in this compound is (+3)

6. refer to no. 3.

7. Oxidising agent - H_2O_2

Reducing agent - $FeSO_4$

8. The girl who obtained a green precipitate used a freshly prepared solution of $FeSO_4$. The other girl used a stale solution which probably had already been oxidised to $Fe_2(SO_4)_3$.

APPENDIX G

THE MID RANK METHOD

1. Mid rank method of obtaining a rank order

Mid-rank method of ranking items.

The ranking of the aims will be used to illustrate the value of this particular method. For each reply, the aim was allocated a rank in a ranking whereby each member of an equally ranked group was given that rank which was the average of all the ranks that the members of the group would have possessed if they were not tied. An example will make this clear.

AIM	1	2	3	4	5	6	7	8	9	10
RESPONSE BY TEACHER	5	4	4	4	3	4	4	4	4	4
ORDER	1	5,5	5,5	5,5	10	5,5	5,5	5,5	5,5	5,5

Given ten aims, using the means to obtain the rank, the mean values must fall between 1 and 5 if five categories of response are allowed e.g. very important = 5 ; not important
= 1, whereas the mid rank method will have values ranging from 1 to 10 (the maximum range possible is equal to the number of items being ranked). In the example it can be seen that the aim 5 which the respondent considered definitely less important than the others is given a rank of 10 emphasising the distinction the respondent has made. It can be seen that this method assigns the aim a rank depending on the importance of the others. The greater the number in the group of tied items, the lower will be the common rank.

Then for each item the mean of the ranks assigned to it by each respondent is calculated. This mean is referred to as the 'mean rank'. It has been calculated after each respondent's reply has been transformed using the mid rank method. It is only at this stage that a rank order of importance is calculated based on the mean ranks. This gives a consistent method for obtaining an overall ranking indicating the consensus of opinion. The range of the mean ranks will become less when there is poor agreement amongst the respondents ie. they will tend towards the middle of the order. In this way it is possible to show where items are bunched in importance and where they stand out.

[adapted from Thompson (1975, p.18) and based on Rank Correlation Statistics as developed by Kendall(1962).]