AN EVALUATION OF PRACTICAL WORK IN SCHOOL CHEMISTRY COURSES UP TO O-GRADE

An Evaluation of Practical Work in School Chemistry Courses up to O-Grade

by

Dennis J. Gunning

A thesis in part fulfilment of the requirements for the degree of Master of Science of the University of Glasgow.

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SUMMARY

It is now 12 years since the Alternative Syllabus in Chemistry was first introduced into Scottish schools. This syllabus was radically different from its predecessor in its approach to the role of practical work. The "new" syllabus stressed the importance of having the pupils involved in learning by discovery and exploration.

This research is concerned with an appraisal of the practical work in the "new" syllabus. The aims of the research were to carry out a survey to establish how many experiments were being done and by what methods, to investigate the objectives which teachers had in mind when setting experimental work, and to see whether these objectives were being achieved by the pupils. Finally, an attempt was made to devise a method of assessing practical work without the need for a "practical examination". These aims were restricted to the practical work being done in Scottish schools as part of the O-grade chemistry course.

The general survey of practical work was done by questionnaire; a similar method was used to look at teachers' and pupils' opinions of the objectives and their achievement. Assessment was attempted by the use of a specially designed objective test.

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Glossary of Terms Used

O-Grade Examination	This examination is normally taken by pupils who have completed four years in the Secondary school. The examination is set by and controlled by the Scottish Certificate of Education Examinations Board (S.C.E.E.B.).
H-Grade Examination	This examination is taken by pupils who have completed at least five years in the Secondary school. The examination is set and controlled by the S.C.E.E.B..
SI,SII,SIII etc	These abbreviations are used to designate the year of study in the Secondary school. The O-Grade examination is thus normally taken at the end of SIV.

ABSTRACT

It is now 12 years since the Alternative Syllabus in Chemistry was first introduced into Scottish schools. This syllabus was radically different from its predecessor in its approach to the role of practical work. The "new" syllabus stressed the importance of having the pupils involved in learning by discovery and exploration.

This research is concerned with an appraisal of the practical work in the "new" syllabus. The aims of the research were to carry out a survey to establish how many experiments were being done and by what methods, to investigate the objectives which teachers had in mind when setting experimental work, and to see whether these objectives were being achieved by the pupils. Finally, an attempt was made to devise a method of assessing practical work without the need for a "practical examination". These aims were restricted to the practical work being done in Scottish schools as part of the O-grade chemistry course.

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Chapter 1

INTRODUCTION

Chapter 1 - Introduction

Before 1962, the O-grade chemistry syllabus which was taught in Scotland demanded of the pupils that they recall information such as the method of preparation and properties of common laboratory gases. This syllabus, whose content and teaching method had changed little in years, contained practical work of a kind which lent itself to demonstration at the teacher's bench. There were few experiments which were carried out by the pupils.

Although some teachers had expressed dissatisfaction with the syllabus, no concerted effort was made to change it until 1960. In that year, the CHEM Study course and texts[1] were published in the United States and these acted as a stimulus to groups of teachers in Great Britain. Within a few years, the Alternative Syllabus in chemistry was published by the Scottish Education Department[2], followed in England by the Nuffield course[3]. In both of these courses, the aim was to move from a teacher-centred course to one which allowed the pupils to discover for themselves the relationships within chemistry. Both courses stressed the importance of the understanding of basic concepts, with correspondingly less need for the ability to regurgitate factual information.

In Scotland, the Traditional ("old") syllabus and the Alternative ("new") syllabus were operated together from 1962 until 1971, with separate O-grade examinations taking place at the end of the course. During that period, the number of schools presenting pupils in the Alternative syllabus increased greatly, until by 1971 all Scottish secondary schools were offerring that course. In that year, the Traditional syllabus was abandoned and the title "Alternative" was dropped. In fact, the Alternative syllabus had not been untouched during those years: a revision occurred in 1969[4] to take account of changes in SI and II science, to clarify the depth of treatment in SV and to lighten the quantity of material covered in SIII and IV. The nature of the course and its method of learning by controlled discovery was retained.

Since a number of courses and methods are now available in SI and II, the most recent being the Integrated Science Course[5], the general course for O-grade chemistry can be considered to be made up of the material for the "second cycle" in the S.C.E.E.B. syllabus. This is the work normally taught in SIII and IV and it is divided into sections as follows.

Section G - Atomic Structure

Section H - Chemical Combination

Section I - Activity and the Electrochemical Series

Section J - Acids, Bases and Salts

Section K - Sulphuric Acid

Section L - Fuels and Related Substances

Section M - Ammonia and Nitric Acid

Section N - Foodstuffs and Related Substances

Section O - Macromolecules

A total of 104 experiments are suggested in the syllabus as being relevant to the work of these sections.

The order of the sections shown above is also the teaching order in schools, with two main exceptions -

a) Many schools teach Section M before Section L. In this way, nitric acid is dealt with after sulphuric acid, and the sections loosely concerned with organic chemistry are dealt with consecutively.

b) A small number of schools use a "reversed" syllabus. This involves the teaching of the organic sections in SIII and the more theoretical sections H,I and J in SIV. This reversed syllabus was investigated by A.H.Johnstone et al[6] as a method of overcoming difficulties experienced by the pupils in some parts of the course.

The general aims of the revised (1969) course are stated in the syllabus published by the S.C.E.E.B.[4]. These are that pupils should be provided with -

1. Some knowledge of the empirical world around him.
2. Something of the vocabulary and grammar of science.
3. A training in objective observation.
4. Experience of problem solving in experimental situations.
5. Experiences in thinking scientifically.
6. Exposure to the culture which is science.
7. Some appreciation of the part which chemistry has to play in world economy.

Although some of these objectives are vague, it is clear that those numbered 3,4 and 5 can best be achived by allowing pupils to carry out experiments for themselves. The consequences of this pupil-centred approach for teachers and administrators were -

1. On a national scale, much more pupil experimental work was involved. Even allowing for the fact that many of the experiments could be performed using simple apparatus, this would mean that the cost of running an O-grade chemistry course would increase.

2. The teaching approach should change from a demonstration and chalk-and-talk format to one of discovery and discussion.
3. Because of the greater time needed to allow discovery methods to be effective, the method of recording theory and practical work might have to swing away from the traditional and time-consuming "written notes in a notebook" method.

It might be expected, therefore, that the success of the new syllabus would depend largely on the attitudes of teachers to it and, in particular, on their willingness to change or adapt their teaching methods to accommodate the objectives of the new syllabus.

Bearing this in mind, this research has set out to answer the following questions.

1. How much experimental work is being done in schools as part of the O-grade chemistry course, what methods are being used and how effective does the teacher think the practical work is ?
2. What objectives does a teacher have in mind when he decides to set practical work ?
3. What does the pupil achieve as a result of doing practical work ?
4. Can practical work be assessed without the need for a traditional "practical" examination ?

CHAPTER 2

A Survey of the Practical Work in the Scottish O-Grade Syllabus

Chapter 2 - A Survey of the Practical Work in the Scottish O-Grade Syllabus.

Aims

The aims of this survey were as follows -

1. To find out how much practical work was being done in Scottish schools as part of the O-grade chemistry course.
2. To examine the methods used by teachers when setting this practical work.
3. To obtain the teachers' subjective judgement as to how useful they found this practical work to be.
4. To examine the effect of factors such as time allocation, class size etc. on the amount of practical work done and the methods used.
5. To examine the extent to which each experiment recommended in the syllabus was being carried out and the methods being used to perform the experiment.

Experimental Design

In order to conduct this survey, a sample of 140 Scottish secondary schools was chosen. This number represents approximately 35% of the total number of schools presenting O-grade chemistry pupils. The list of schools available was examined and it was seen that it was made up of 69% state schools, 18% Roman Catholic schools and 13% independant or grant-aided schools. The sample was then selected in such a way as to reflect the relative numbers of each type of school. (The sample selected contained 70% state schools, 18% Roman Catholic schools and 12% independant or grant-aided schools.) The sample was taken from all areas of Scotland.

Each school was sent a questionnaire (see Appendix 2.1) which contained a list of the 104 suggested experiments in the S.C.E.E.B. syllabus. Each school was asked to provide background information of the following kind -

1. Name of school (optional)
2. Number of periods per week devoted to chemistry
3. Length of school period
4. Number of pupils in O-grade chemistry classes
5. Average size of the O-grade teaching section
6. Method of recording practical work

The school was also asked, for each experiment listed, to tick one box under each of the headings shown on the following page.

a) Is the experiment - done regularly (3A)
- was done, but now abandoned (3B)
- never done (3C)

b) Method used - pupil performs experiment (4A)
- stations technique (4B)
- teacher demonstration (4C)
- assissted demonstration (4D)

c) Effectiveness - the experiment is useful (5A)
- the experiment is of little use (5B)
- the experiment is fairly useful (5C)

The numbers in brackets are the codes given to each column to assist in statistical analysis.

"Stations technique" involves the setting up around the laboratory of a number of different experiments which the pupil works through one by one.

"Assisted demonstration" means that the experiment is performed by the teacher, with some active assistance from pupils.

The teacher was asked to judge "effectiveness" or "usefulness" on the basis of how well the experiment aided the pupils' understanding of the topic under discussion.

Space was provided in the questionnaire for teachers to make comments or to add extra experiments which they thought useful.

Response to the Questionnaire

Questionnaires were returned by 101 schools. This was 72% of those who recieved the questionnaire. Statistical analysis was therefore based on approximately 26% of the total number of schools presenting O-grade chemistry pupils.

Analysis was carried out by computer ; the computer programme is shown in Appendix 2.2

Returns from 80 of the sample schools were obtained quickly, and, after two months, a reminder was sent to the remaining 60 schools, of which 21 then submitted their completed questionnaires.

Results of the Analysis

The data analysed and the results quoted refer to the position of practical work in school chemistry departments in session 1972-73.

The results will be quoted and discussed in sections corresponding to the headings in the questionnaire.

a) Background Information   The average size of a chemistry teaching section was 19.12 pupils. (Standard deviation = 3.05). Although this would seem to be a satisfactory figure from safety considerations it was noted that 23% of the sample had average class sizes of greater than 20 pupils.

The average class size might also be considered on a regional basis as follows -

Strathclyde region (excluding Glasgow)	-	average	class	size	20.3
Glasgow city	-	"	"	"	17.3
Stewartry and Galloway	-	"	"	"	19.7
Borders	-	"	"	"	18.0
Edinburgh and the Lothians	-	"	"	"	19.1
Fife	-	"	"	"	19.9
Stirling and East Central Scotland	-	"	"	"	20.2
Dundee and Tayside	-	"	"	"	18.0
Highlands, Islands and North-east	-	"	"	"	18.5

The average time devoted to chemistry was 183.43 minutes per week. 83% of the sampled schools had time allocations of between 160 and 240 minutes per week (equivalent to between 4 and 6 forty-minute periods). The distribution of time allocations is shown in Figure 2.1. No school was attempting to cover the syllabus in less than 140 minutes per week (equivalent to 4 thirty-five-minute periods). The greatest allocation in the sample was 280 minutes (7 forty-minute periods).

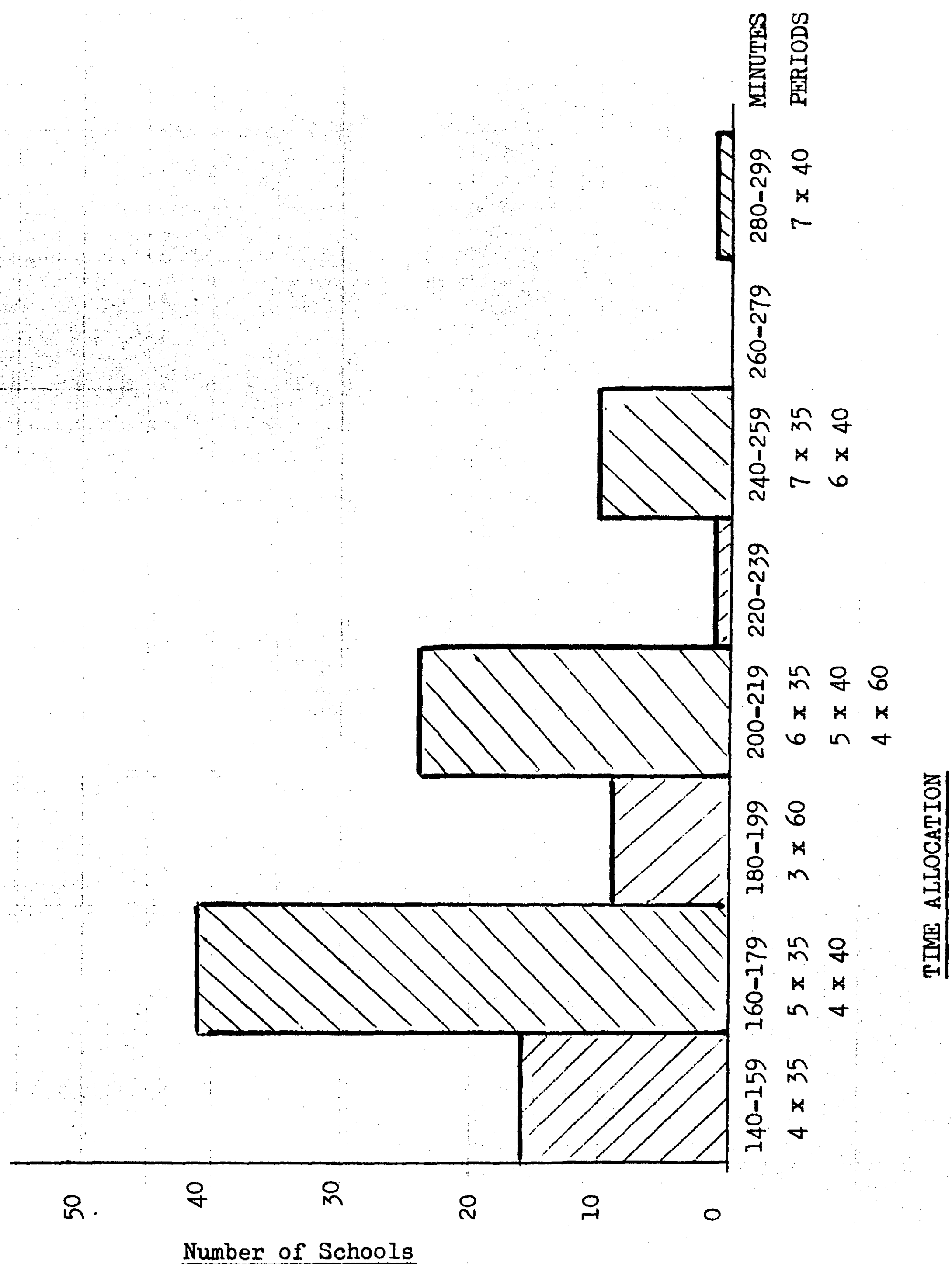
Recording of Practical Work - The percentage of schools who were using each method was as follows -

Method A (practical work not formally recorded, but theory written up in notebook)	11%
Method B (practical work recorded in worksheets)	19%
Method C (practical work recorded in notebook as a laboratory report)	57%
Method D (other methods)	14%

The popularity of Method C, probably coupled with printed notes on the routine course work, might reflect on the volume of work to be covered in the O-grade chemistry syllabus.

Although workshbets were widely in use in SI and II as part of the Integrated Science Course, their use was not found to be very popular for SIII and IV pupils. This might reflect the subjective view of teachers - that the use of worksheets encouraged the "spoon-feeding" of pupils.

Figure 2.1 Distribution of Time Allocations.



It was found that the method used for recording practical work did not correlate with the time allocation or the average class size. However the teacher was asked only to state his numerical time allocation, but was not asked to comment on whether or not he thought that this time allocation was adequate. C.Wood, in his survey of H-grade practical work[7], found that the teachers' opinion of the adequacy of his time allocation correlated more strongly with his choice of recording method than did the time allocation itself.

b) Response to the Experimental Section of the Questionnaire. The overall results are shown in table 2.1.

The Pearson correlation coefficient (r) was computed in order to establish the presence of relationships between the columns and the background information. The correlation coefficients are shown in table 2.2. In each case, a test of significance was carried out ; only correlation coefficients which were significant at the 10% level or better were considered in the subsequent discussion. Cross corrlations within the same column (e.g. column 3A with 3B) were not discussed, since it was thought obvious that these must be related negatively. (The more ticks in column 3A, the fewer there must be in column 3B and 3C - because teachers were asked to tick only one of these columns for each experiment.)

Each column will now be considered and the relevant correlations and totals discussed.

Performing of Experiments (Column 3 of the Questionnaire) . From the overall results, it was seen that schools were, on average, performing 84 of the 104 suggested experiments in the S.C.E.E.B. syllabus[4]. The distribution of the number of experiments performed per school is shown in figure 2.2. On average, each school had tried three experiments, and had abandoned them, and had never done 15 of the experiments. The figure of 84 experiments showed that a considerable amount of practical work was being done in SIII and IV. Furthermore, no correlation was found between the number of experiments done and either the time allocation or the average class size. This lack of correlation might suggest that a teacher's selectivity of experiments was based on other factors, of which one might be his attitude to practical work. Correlation was strong between column 3A (experiments done regularly) and columns 4A (pupil experiment) and 5A (experiment useful). These could be interpreted as showing that a teacher who finds practical work to be useful tends to carry out many experiments, and to have them done by the pupils. Analysis was also carried out to see if the omission of experiments could be accounted for ; this is discussed later (page 16).

TABLE 2.1 Overall Response to the Questionnaire

Column in Questionnaire		Total (see note 1)	Mean (see note 2)	Standard Deviation
3A	Experiment done regularly	8,487	84.0	11.4
3B	Was done,now abandoned	340	3.4	3.3
3C	Experiment never done	1,500	14.9	9.7
4A	Done by pupils	5,569	55.1	15.2
4B	Stations technique	260	2.6	7.4
4C	Demonstration	2,296	22.7	11.4
4D	Assisted demonstration	486	4.8	7.1
5A	Experiment useful	6,956	68.9	18.1
5B	Experiment of little use	580	5.7	7.8
5C	Experiment fairly useful	1,271	12.6	11.8

Note 1 - The number of occasions on which a tick was placed in a particular column was summed for all 101 schools and 104 experiments to obtain the total response to each column.

Note 2 - The mean number of ticks for each column was computed. For instance, this showed that the mean number of experiments done per school was 84.0 .

TABLE 2.2 Correlation Coefficients (Pearson's r)

The figure shown is the value of r (Pearson's correlation coefficient) The significance of each correlation is shown in brackets ; no significant correlation (i.e. one with poorer than 10% significance) is indicated by the word "none".

	COLUMN						
	4A	4B	4C	4D	5A	5B	5C
3A done regularly	0.56 (0.1%)	0.22 (5%)	0.03 none	0.07 none	0.64 (0.1%)	-0.25 none	-0.13 none
3B was done, not now	-0.10 none	-0.16 none	-0.09 none	0.10 none	-0.35 (0.1%)	0.58 (0.1%)	0.22 (5%)
3C never done	-0.52 (0.1%)	-0.18 (10%)	-0.03 none	-0.12 none	-0.55 (0.1%)	0.11 none	0.08 none
4A done by pupils					0.36 (0.1%)	-0.04 none	-0.16 none
4B stations					0.26 (1%)	-0.10 none	-0.15 none
4C demonstration					-0.08 none	0.02 none	0.18 (10%)
4D assissted dem.					0.04 none	-0.06 none	0.10 none
Time Allocation	0.11 none	-0.03 none	-0.20 (10%)	0.06 none	0.06 none	-0.07 none	-0.10 none
Average Class Size	-0.09 none	0.11 none	0.10 none	-0.07 none	0.04 none	-0.14 none	-0.05 none

As already stated, cross correlations within the same column were not considered in the discussion, and are not therefore shown above.

In view of the fact that many schools were teaching O-grade chemistry on a fairly small time allocation, it was decided to investigate whether the number of experiments performed was distributed evenly throughout the two years of the course. To do this, the number of experiments in each section of the syllabus was counted and the number of these experiments performed by the average school was calculated. The results have been drawn as an histogram in figure 2.3. The height of the column shows the average number of schools performing the experiments in that syllabus section. Section G is omitted because it contains no recommended practical work.

It was seen from figure 2.3 that the number of schools performing experiments in a given section of the syllabus was higher in those sections which were normally taught in SIII (sections H to K), and that the number of schools declined noticeably at the end of the syllabus (section O). This section contains practical work which is interesting to the pupils and does not require special apparatus ; the lack of experimental work being done must therefore be due to a general rushing of the work in this final section because of the impending Scottish Certificate of Education examinations.

Using the same method as desribed for the investigation above, the average number of schools performing experiments in each sub-section of the syllabus was calculated. The results are shown in figure 2.4. The syllabus sub-sections which pupils were reported[8] to have found difficult are marked in figure 2.4 by an arrow. It can be seen from figure 2.4 that these subsections did not differ significantly in the number of experiments being done. (The exceptions were noted to be sub-section O1 - which has been discussed above - and sub-section H9.) In fact, as the figure 2.4 shows, the majority of the troublesome subsections included an above-average amount of performed practical work. It should be remembered, however, that these figures indicated only the degree of performance of the suggested experiments in the syllabus, but did not offer a comment on the actual number of these experiments in the syllabus.

When examining the list of experiments, it was found that several significant correlation coefficients had been computed. These were -

Column 3B (was done, not now) with
- Column 5A (useful) r= -0.35
- Column 5B (of little use) r= 0.58
- Column 5C (fairly useful) r= 0.22

Figure 2.3 Average Number of Schools Performing Experiments in Each Section of the Syllabus

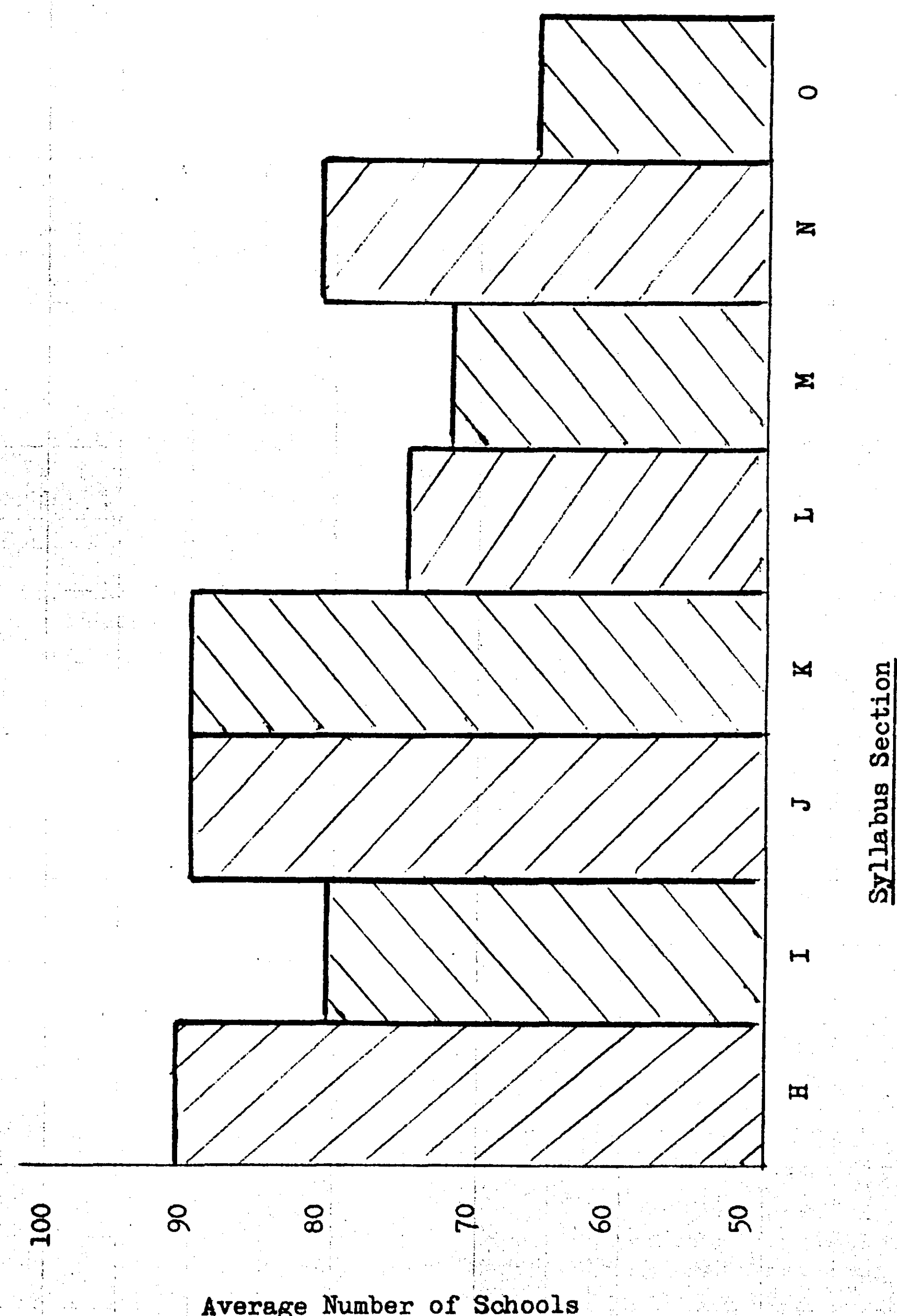
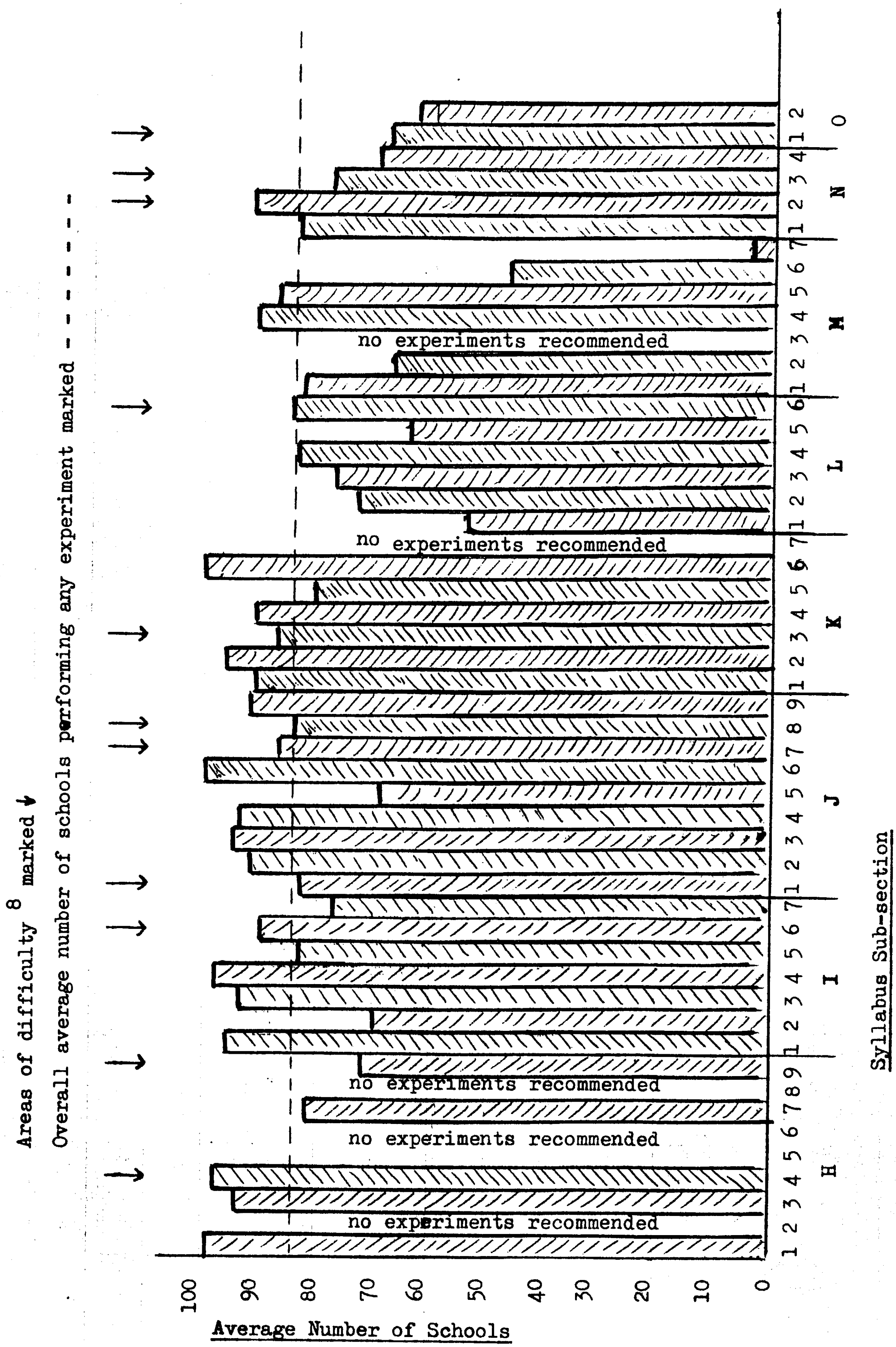


Figure 2.4 Average Number of Schools Performing Experiments in Each Sub-section of the Syllabus



Column 3C (never done) with Column 5A (useful) r= -0;55
The latter (above) correlation was ignored in the discussion, because many teachers who ticked column 3C then left all other columns blank (thus reducing the total number of ticks in column 5A). It was also noted, however, that of the teachers who did not follow this practice, not all of them ticked columns 5B (of little use) or 5C (fairly useful) for an experiment which they stated they had never done ; thus columns 5B and 5C did not correlate significantly with column 3C (never done).

The experiments in the given list which were commonly being left out of the course were seen to fall into two categories -

Category 1. These were experiments for which many teachers had ticked column 3B (was done, now abandoned) or column 3C (never done). In view of the correlation of column 3B with "lack of usefulness" (columns 5B and 5C), it is suggested that these experiments were being omitted because teachers found them not to be useful. (Teachers who ticked column 3C for these experiments might be interpreting "never done" as meaning that it was never done in the presence of a class, although it may have been tried out during a lesson preparation.)

The experiments in this category include -

Experiment 11 - section I2 - Experimental verification of the masses of reactants and products in displacement reactions.

Experiment 56 - section L3 - Gas chromatographic separation of a hydrocarbon mixture such as lighter fuel.

In the latter case, it is suggested that teachers may be experiencing difficulty with the commonly-used apparatus, which uses town gas as a carrier. An alternative apparatus which can be used in areas which have been converted to natural gas and which can easily be built by a school laboratory technician has been designed by the Scottish Science Equipment Research Centre (S.S.E.R.C.)[9].

Experiment 67 - section M2 - Sparking a nitrogen / hydrogen mixture over liquid paraffin.

Experiment 68 - section M2 - Sparking ammonia over liquid paraffin.

It is possible that teachers do not find these experiments to be useful in establishing the principles behind the Haber process. In particular, experiemnt 67, which is negative in its result, was being done by only 22% of the sampled schools.

Category 2 . These were experiments for which many teachers had ticked column 3C (never done) but very few had ticked column 3B (was done, now abandoned). Since column 3C did not show any correlation with "lack of usefulness" (columns 5B and 5C), it could be suggested that these experiments were being omitted for other reasons. These are discussed below.

Experiments in this category included -

Experiment 18 - section I7 - Relative efficiency of galvanising and tinning

It was thought likely that teachers considered this experiment to be a part of the more general experiment 19 (corrosion in gels containing indicators).

Experiment 59 - section L5 - Ignition temperature of fractions from the distillation of crude oil.

It was noted that the distillation itself was widely performed (by 84% of schools). It might be that although a general mention of flashpoint or ease of evaporation of the fractions was done, the actual measurement of ignition temperature, which is difficult to determine without the correct apparatus, was being omitted.

Experiment 75 - section M6 - Preparation of fertilisers.

This experiment repeats practical work which will have already been covered earlier in the syllabus (section J8 - titration techniques)

Experiment 76 - section M7 - Culture solutions.

This experiment is strongly "biological" in nature. The note in the syllabus on this experiment may be enough to discourage most teachers. " The help of the biology department should be obtained here ...... They (culture solutions) are long-term experiments and are not always effective in unskilled hands."

Experiment 80 - section N1 - Presence of starch and reducing sugar in plants.

This experiment may already have been done in SII as part of section 8 of the Integrated Science Course.

Experiment 98 - section N4 - Digestion of protein by pepsin.

This experiment occurs towards the end of the syllabus ; its content is similar to that of experiment 99 (Hydrolysis of protein and detection of the products by chromatography) which is much more widely carried out. Experiment 98 may therefore be omitted as part of the pruning at the end of the course. It is also noted that the most commonly used textbook, " Chemistry Takes Shape - Book 4 " [10], gives details of hydrolysis of protein by acid but not by pepsin. It is the writer's experience,however,that the results obtained by the use of pepsin are often far superior to those obtained by the use of acid.

Experiment 102 - section O1 - Action of soda-lime on nylon.

This may already have been done as part of experiemnt 97 (heating of proteins with soda-lime) which was done by all schools in the sample.

Experimental Method (Column 4 of the Questionnaire)

As shown on page 2.1, the average number of experiments performed by each method was -

Column 4A (done by pupils)	55 experiments	(81)
Column 4B (stations technique)	3 experiments	(1)
Column 4C (demonstration by teacher)	23 experiments	(20)
Column 4D (assissted demonstration)	5 experiments	(2)

The figures in brackets show the number of occasions in the syllabus when each method is recommended. (The totals are different because not all experiments are done by the average school.) If percentages are calculated, it is seen that the syllabus recommends that 79% of all practical work be done by pupils. In the average school, 68% of all practical work is done by pupils. Before commenting further, it should be noted that the recommended method in the syllabus was determined only by the merits of the experiment ; it did not, and could not, take account of the factors peculiar to each school such as time allocation, lack of equipment etc.. Indeed, a significant correlation was found between column 4C (teacher demonstrations) and time allocation (r= -0.20 at 10%) showing that the more time a teacher had, the fewer demonstrations he used.

The distribution of the number of experiments performed by the pupils (columns 4A and 4B) is shown in figure 2.5. The percentage of the total practical work done by pupils is shown in figure 2.6. It was noted that 80% of the sample of schools were performing fewer pupil experiments than was recommended in the syllabus.

Having established that most schools performed more experiments by demonstration than is recommended, an investigation was carried out to see if this excess was spread evenly over the course, or was concentrated in any one section. The actual number of schools performing an average experiment in any section of the syllabus was found by dividing the total number of demonstrations (columns 4C and 4D) done by the number of experiments in that section.

$$\text{i.e. actual number of schools} = \frac{\text{total number of demonstrations DONE}}{\text{total number of experiments in section}}$$

The theoretical number of schools performing an average experiment by demonstration was then calculated in a similar manner - i.e.

$$\text{theoretical number of schools} = \frac{\text{total no. of demonstrations RECOMMENDED}}{\text{total number of experiments in section}}$$

The figures represent an average value for all experiments in each section. The difference between the actual and theoretical number of schools indicated whether too many demonstrations were being done (a positive value) or whether more pupil experiments were being done than was recommended in the syllabus (a negative value). Results are shown below

Figure 2.5 Distribution of the Number of Experiments Performed by the Pupils

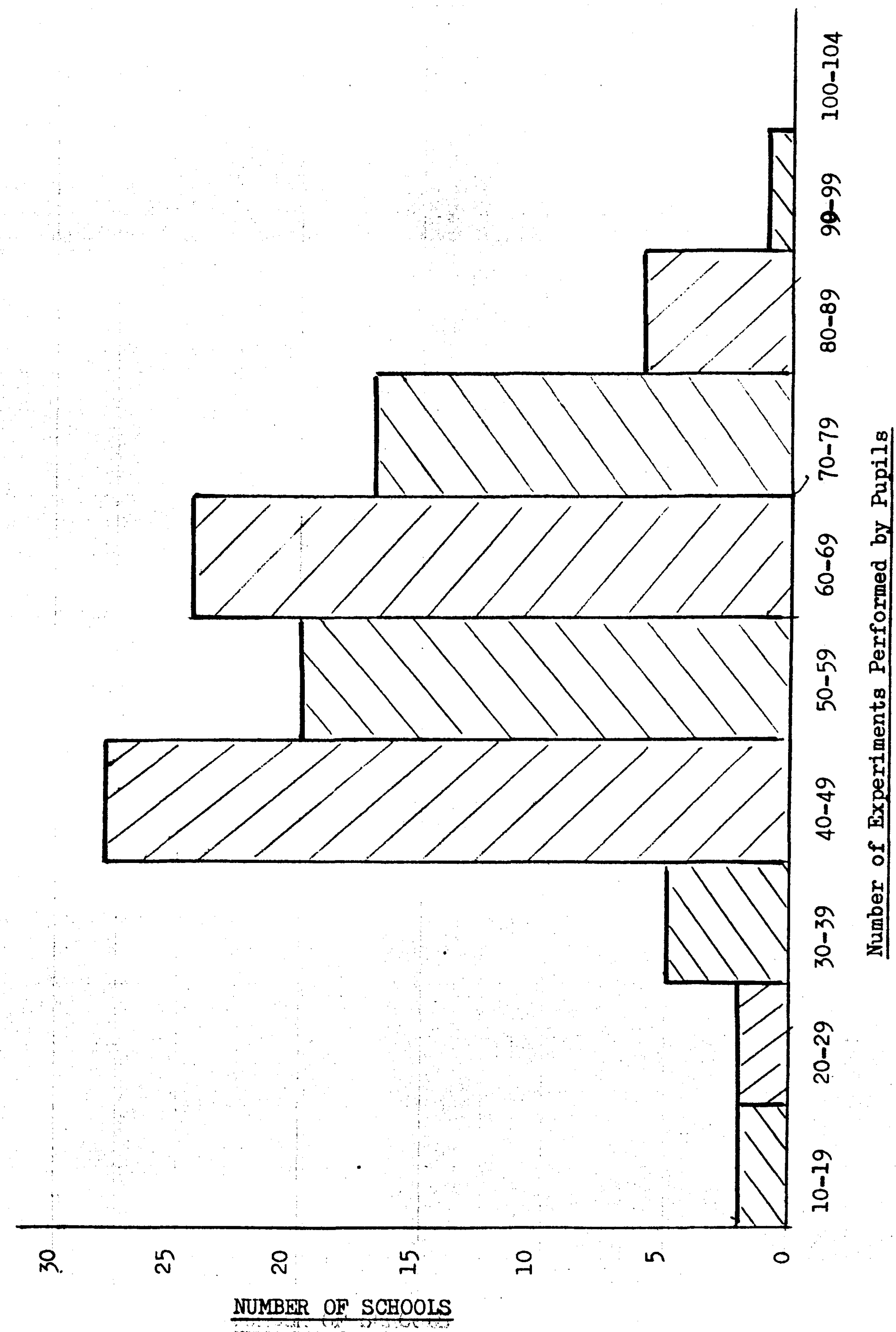


Figure 2.6 Distribution of Percentage of Total Experimental Work Done by Pupils

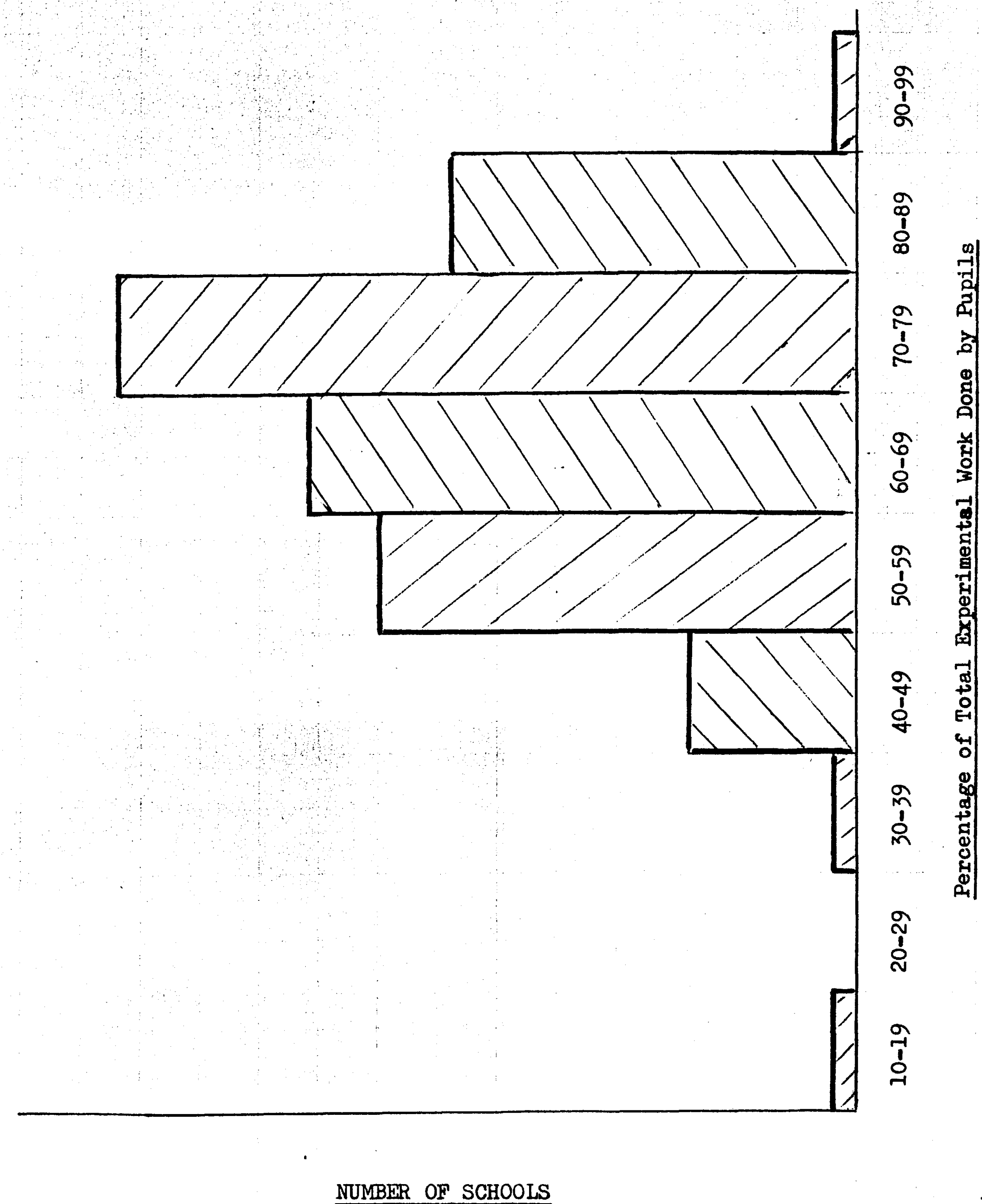


table 2.3 below.

Table 2.3

SYLLABUS SECTION	H	I	J	K	L	M	N	O
ACTUAL NO. OF SCHOOLS	25	27	15	40	48	60	26	30
THEORETICAL NO. OF SCHOOLS	29	14	0	15	25	54	22	0
DIFFERENCE	-4	+13	+15	+25	+23	+ 6	+ 4	+30

The results showed that more experimental work was being done in section H than was recommended. This was perhaps to be expected because it follows section G, which contains no practical work. Teacchers may have felt that the pupils should be encouraged and interested by allowing them to perform as many experiments as possible in section H. Section O, on the other hand, could be suffering from being the last section in the syllabus. The demonstration of more experiments than normal might have been one way in which a teacher could cover this section more quickly.

It could be concluded from the above results that no steady increase in the number of demonstrations could be seen as the end of the syllabus approached. The gain in time from the extra demonstrations in section O would be small, because this is a fairly short section. Section N, which is the penultimate section, is long and contains many pupil experiments. It might be expected that it too would show signs of end-of-course demonstrations ; this was not seen from the results above.

The methods used for individual experiments will now be discussed. In the case of certain experiments, it was noted that a large number of schools were performing them by a method different from that recommended in the syllabus. There were two groups of experiments -

a) Those recommended as 'pupil experiments' but which were widely carried out as demonstrations (by 50% or more of the sample schools). The actual percentage of schools in the sample which carried out each experiment by demonstration is shown in brackets.

These experiments were -

Experiment 47 - section K6 - properties of concentrated sulphuric acid. (53%)

Experiment 53 - section L3 - burning of methane and testing of the products of combustion. (55%).

Safety considerations, especially in the former case, may account for the demonstration of these experiments.

Experiment 48 - section L1 - Building of models of diamond and graphite. (76%)

Experiment 54 - section L3 - Building of models of isomeric alkanes. (51%)

Teachers might feel that it was sufficient to show pupils the models. Alternatively, schools might not have enough models to allow pupils to build the structures. The latter point might account for the greater number of schools demonstrating the experiment 48 - which requires a larger number of models. C.Wood has reported[7] a similar response in experiments involving model-building in the H-grade syllabus. The demonstration of such models is to be regretted because, in the writer's experience, these experiments are much more meaningful to the pupils when they have built the models for themselves.

Experiment 66 - section M2 - Solubility of ammonia (76%)

This might seem surprising for such a simple experiments It might be because many teachers were still using the"fountain experiment" to demonstrate the solubility. This method was also suitable for showing the solubility of sulphur dioxide, and it was noted that 47% of the sample performed this experiment (38 - section K2) by demonstration.

Experiment 104 - section O2 - Water-repellant properties of silicones (76%)

Again, teachers might have felt that it was sufficient to show samples of silicones - especially if these were in short supply in the school.

Experiment 20 - section I7 - Anodising (56%)

At first sight, it was difficult to account for this experiment being demonstrated. No expensive equipment was needed, and a satisfactory "recipe" was found in the recognised textbook.[11] After discussion with teachers, two explanations arose - (i) Some teachers were using a commercially-available kit and (ii) some found the results of the pupil experiment to be so poor that they resorted to demonstration.

b) Those experiments recommended as demonstrations but which were widely carried out by the pupils. (The number of schools using demonstrations is shown in brackets.)

Experiment 83 - section N1 - Combustion of glucose (40%)

Experiment 90 - section N2 - Hydrolysis of esters (28%)

In both cases, it is difficult to see why demonstration was recommended in the syllabus, especially if both were intended to be done on a test-tube scale.

It should also be noted that the syllabus contained only one experiment (6 - section H4) for which a stations technique was recommended. Only 4% of schools were using this method for that experiment. Indeed, this method did not seem to be popular at all - 59% of the sample did not use this method for any of the 104 experiments. At the other extreme, one principal teacher commented on the questionnaire that he found this technique to be very useful in that although it was time-consuming in the setting up and testing of the group of experiments it allowed particularly efficient use of the time which the pupil spent in the laboratory. This teacher used stations techniques to carry out 63 of the experiments.

<u>Usefulness of the Experiments</u> (Column 5 of the Questionnaire)

The overall results were -

Column 5A (experiment useful) .... 69 (78% of total)
Column 5B (experiment of little use)... 6 (7%)
Column 5C (experiment fairly useful) .. 13 (15%)

Certain significant correlations were found between usefulness and experimental method. These were -

Column 5A (useful)	with	Column 4A (pupil experiment)	r=0.36 at 0.1%
		Column 4B (stations)	r=0.26 at 1%
Column 5C (fairly useful)	with	Column 4C (demonstrations)	r=0.18 at 10%

These correlations taken together might suggest that teachers find, in subjective judgement, that experiments carried out by pupils are more useful than those done by demonstration.

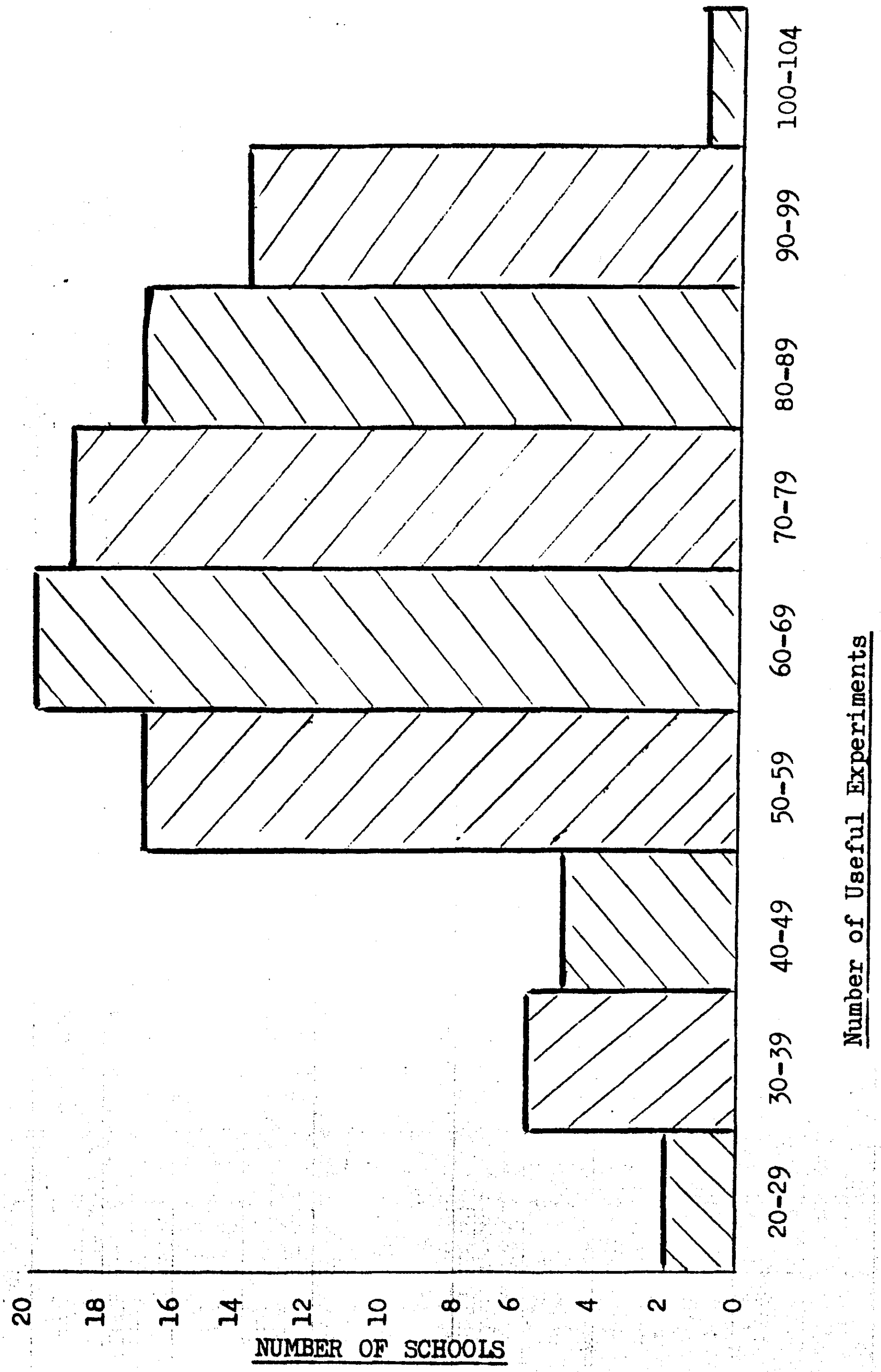
The distribution of the number of experiments thought to be useful by each school is shown in figure 2.7. It was noted that the distribution was shifted to the left compared to that for the number of experiments performed regularly (figure 2.2). Almost all schools in the sample had reservations about the usefulness of some of the experiments which they regularly performed. If the sum of columns 5B and 5C were taken as a measure of teachers' reservations, then it was found that 40% of the schools had reservations about 20 or more of the recommended experiments.

In the case of four experiments in particular, it was noticed that although many schools performed them, few thought them to be useful. These experiments were -

Experiment 7 - section H7 - Determination of the composition of a compound by experiment.

Experiment 28 - section J6 - Neutralisation using conductivity.

Figure 2.7 Distribution of the Number of Useful Experiments



Experiment 52 - section L2 - Preparation of water gas.
Experiment 58 - section L5 - Examination of a bunsen flame.

Teachers might be persevering with the former two because (i) they include groundwork which is needed later in the course and (ii) they are fairly common O-grade examination topics. Neither reason can be applied to the latter two, and it is difficult to see why many teachers who find them not to be useful should continue to do them .

Summary of Chapter 2

It would appear from the results of this survey that the state of practical work in school chemistry was fairly healthy. The size of teaching sections were reasonable (using 20 pupils as a criterion) and the time allocation seemed to be adequate in all cases.

The quantity of practical work being done was substantial, and teachers found most of it to be useful. The only reservation would be that more experiments could be being done by the pupils rather than by demonstration.

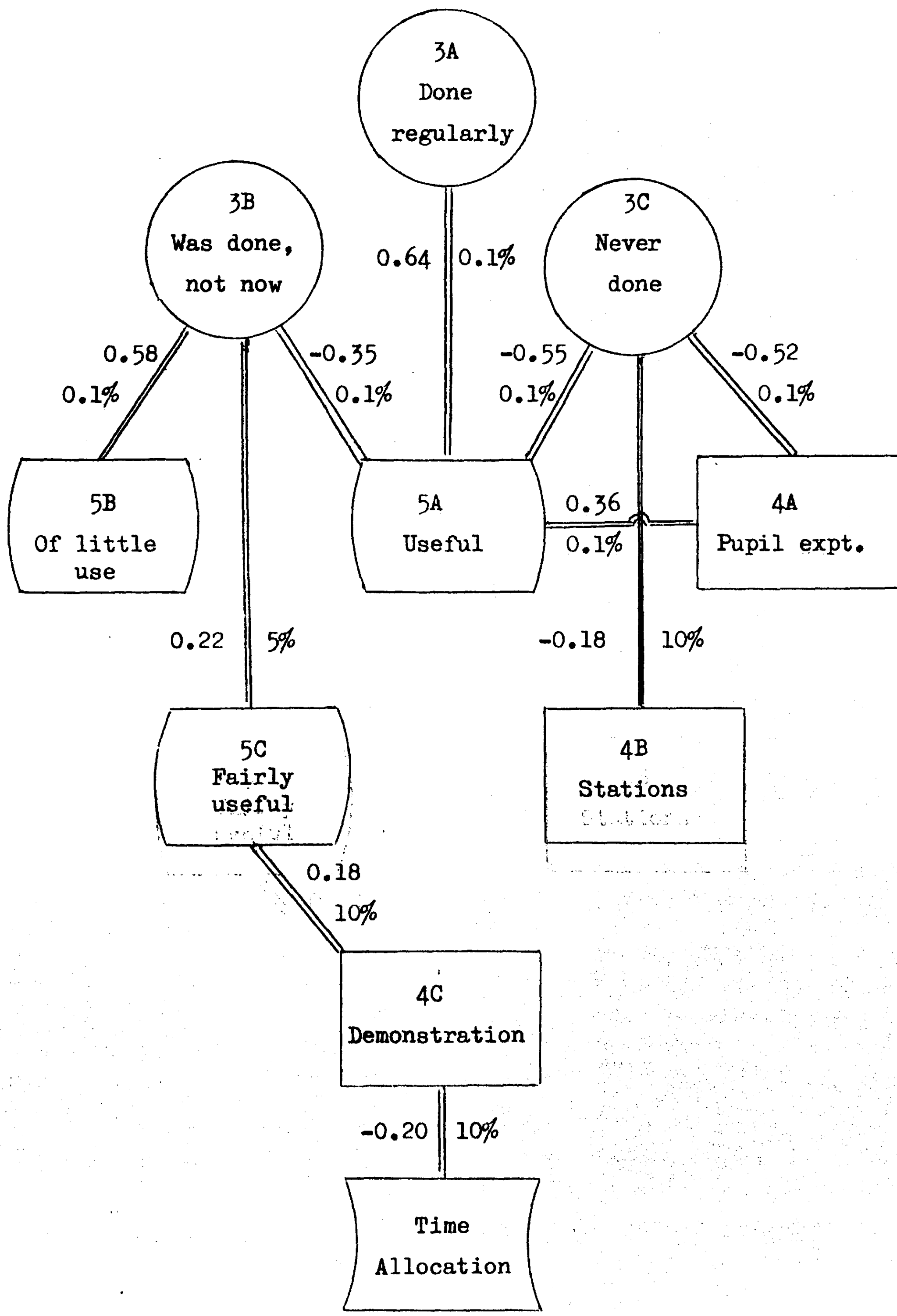
The significant correlations which were found are summarised in figure 2.8.

Figure 2.8 Summary of Correlations

Only those correlations which are significant at 10% or better are shown.

The value of r and its significance are shown in each case.

Each box in the diagram contains the column number and heading as in the questionnaire.



University of Glasgow

Research in Chemical Education

AN EVALUATION OF PRACTICAL WORK IN SCHOOL CHEMISTRY COURSES

Questionnaire on the practical work done as part of the 'O' grade syllabus

Introduction Please fill in the information in the space provided.

1. Name of school (optional) ....
2. No. of periods per week devoted to chemistry ....
3. Length of school period ....
4. No. of pupils taking 'O' grade course in 1972/73 ....
5. Average size of chemistry teaching section ....

Notes on Questionnaire

Column 1 - gives the code of the relevant section in S.C.E.E.B. syllabus.

Column 2 - code number for statistical work.

Column 3 - please tick the relevant space according to whether the particular experiment is done regularly, used to be done but now abandoned, or has never been done in your school.

Column 4 - please tick the relevant space according to the method by which the experiment is usually done. (Assisted dem. - involves pupil participation in an experiment performed at the teacher's bench. Stations - involves a series of experiments which the pupils work through, each group doing a different experiment.)

Column 5 - please tick the space which most closely describes your attitude to the experiment - according to its use as an aid to the understanding of the particular topic.

Column 6 - please mention here any other practical work which you normally do during each section. If there is insufficient space to do this, or if there are any other experiments which you regularly perform, please enter them at the end of the list of experiments.

Recording of Practical Work

Please tick opposite the method used in your school to record practical work

a. Practical work not formally recorded, but theory written in notebook ☐

b. Practical work recorded in worksheets ☐

c. Practical work recorded in pupils' notebook (lab. report) ☐

d. Other method - please describe. ☐

Col.1	Col.2		Col.3			Col.4				Col.5			
'0' grade section	Expt. no.	Description of Experiment	Performed			Method				Usefulness			
			regularly	was done, but now abandoned	never done	pupil	stations	demonstration	assisted dem.	useful	of little use	fairly useful	p

	Expt. no.	Description of Experiment	Performed	Method	Usefulness
I 1	01	Experiments to discover materials which are non-conductors or conductors of electricity			
	02	Electrolysis of melts.			
	03	Electrolysis of solutions.			
H 3	04	Inspection of coloured salts.			
	05	Migration of coloured ions.			
H 4	06	Mobility of ions.			
H 7	07	Determination of composition of compounds.			
H 9	08	Experimental verification of calculations.			
11	09	Action of metals on oxygen, water and acids.			
12	10	Displacement of metals.			
	11	Quantitative displacement of metals.			
	12	Displacement showing electron transfer.			
13	13	Reduction of metal oxides.			
14	14	Simple experiments on electrode potential.			
15	15	Conduction of pure water.			
16	16	Tests for iron II, iron III, and iodine.			
	17	Cells involving redox reactions.			
17	18	Comparison of galvanising and tinning.			

	Expt. no.	Description of Experiment	Performed	Method	Usefulness
	19	Corrosion in gels containing indicators.			
	20	Anodising.			
	21	Electroplating.			
	22	Corrosive action of salt solution.			
J 1	23	Acidic and basic oxides - prep. and tests.			
J 2	24	Electrolysis of acids.			
J 3	25	Action of acids on metals, oxides and carbonates.			
J 4	26	Measurement of pH of various solutions.			
	27	Conductivity of strong and weak acids.			
J 5	28	Precipitation of hydroxides.			
J 6	29	Conductivity to follow a neutralisation.			
	30	Heats of neutralisation.			
J 7	31	Small scale preparation of salts.			
J 8	32	Volumetric titrations.			
J 9	33	Electrolysis of dilute sulphuric acid.			
	34	Electrolysis of sodium halides.			
K 1	35	Burning of sulphur in air.			
	36	Heating of iron pyrites in air.			
K 1	37	Bromine / iodine as tests for SO_2			
K 2	38	Properties of sulphur dioxide.			

	Expt. no.	Description of Experiment	Performed	Method	Usefulness
K 3	39	Test for sulphate.			
K	40	Action of SO_2 on bromine, iodine.			
	41	Action of SO_2 on Fe^{3+} (aq).			
	42	Reducing action of SO_3^{2-} (aq) using cells.			
	43	Sulphurous acid as a bleach.			
	44	Action of dilute acids on sulphites.			
K 4	45	Preparation of sulphur trioxide.			
K 5	46	Preparation of sulphuric acid from SO_3.			
K 6	47	Properties of concentrated sulphuric acid.			
L 1	48	Construction of models of diamond and graphite.			
L 2	49	Burning carbon - test for carbon dioxide.			
	50	Combustion of carbon monoxide.			
	51	Carbon monoxide as a reducing agent.			
	52	Preparation of water gas.			
L 3	53	Burning of methane - test for products.			
	54	Construction of models of alkanes.			
	55	Reaction of alkane with bromine.			
	56	Gas chromatographic separation of a gas mixture.			
L 4	57	Fractional distillation of crude oil			

	Expt. no.	Description of Experiment	Performed	Method	Usefulness
L 5	58	Examination of bunsen flame			
L 5	59	Ignition temperature of crude oil fractions			
L 6	60	Test for unsaturation.			
	61	Catalytic crackjig of medicinal paraffin.			
	62	Preparation of addition polymers.			
	63	Properties of addition polymers.			
M 1	64	Sparking air.			
	65	Action of alkalis on ammonium salts.			
	66	Solubility of ammonia.			
	67	Sparking nitrogen / hydrogen over paraffin.			
	68	Sparking ammonia over paraffin.			
M 4	69	Burning ammonia.			
	70	Ammonia passed over hot copper II oxide.			
	71	Catalytic oxidation of ammonia.			
	72	Brown ring test for nitrates.			
M 5	73	Preparation of nitrates by neutralisation.			
	74	Action of nitric acid on metals.			
M 6	75	Preparation of fertilisers.			
M 7	76	Culture solution experiments.			
N 1	77	Colloidal nature of starch solution.			

	Expt. no.	Description of Experiment	Performed	Method	Usefulness
	78	Test for reducing sugar.			
	79	Test for starch.			
N 1	80	Detection of starch and reducing sugars in plants			
	81	Detection of above in foodstuffs.			
	82	Hydrolysis of starch.			
	83	Combustion of glucose.			
	84	Air-flour (or custard) explosion.			
	85	Hydrolysis of sucrose.			
N 2	86	Fermentation of glucose.			
	87	Properties of ethanol.			
	88	Properties of ethanoic acid.			
	89	Preparation of esters.			
	90	Hydrolysis of esters.			
N 3	91	Combustion of fats.			
	92	Testing olive oil for unsaturation.			
	93	Formation of soap.			
	94	Soap as an emulsifier.			
	95	Effect of soap and detergents on hard water.			
N 4	96	Basic nature of ammonia and simple amines.			
	97	Heating proteins with soda-lime.			

	Expt. no.	Description of Experiment	Performed	Method	Usefulness
	98	Digestion of a protein using pepsin.			
	99	Hydrolysis of proteins (chromatography)			
0 1	100	Preparation of condensation polymers.			
	101	Action of heat on nylon.			
	102	Action of soda-lime on nylon.			
	103	Burning polymers.			
0 -	104	Properties of silicones.			

APPENDIX 2.2 Computer Programme Used for Analysis of Response

```
LEVEL 1JUL67                          OS ALGOL F                          DATE  AUG 27 1973

                                    SOURCE PROGRAM                                 PAGE 001
 SC      SOURCE STATEMENT

00000    'BEGIN''COMMENT' PROGRAM ON 'H' & 'O' GRADE SURVEYS, IN ALGOL 1900,
                        MODIFIED TO I.B.M. CARD PUNCHES;
00000         'COMMENT' INPUT/OUTPUT PROCEDURES;
00000     'REAL' 'PROCEDURE' READ;
00001         'BEGIN' 'REAL' R;
00002               INREAL(0,R);
00003               READ := R
00003         'END';
00004     'PROCEDURE' NEWPAG;
00005     'BEGIN' 'INTEGER' Q,R;
00006        SYSACT(1,11,Q);
00007        'IF' Q = 1 'THEN' 'BEGIN' SYSACT(1,3,R);
00008                                 'IF'R=64'THEN'R:=62;
00009                                 SYSACT(1,14,64-R)
00009                                ;SYSACT(1,2,15);
00011                          'END'
00011                   'ELSE' 'BEGIN' SYSACT(1,6,132);
00012                                 SYSACT(1,8,64);
00013                                 SYSACT(1,12,1)
00013                          'END'
00013     'END';
00014     'PROCEDURE' NEWLIN(N);
00015     'VALUE' N;
00016     'INTEGER' N;
00017       'BEGIN'
00017           'INTEGER'K,R;
00018           SYSACT(1,3,R);
00019           'IF'R+N>=60&N\=100'THEN''BEGIN'
00019               'IF'R=64'THEN'R:=62;
00020               SYSACT(1,14,64-R);
00021               SYSACT(1,2,15);
00022                             'END'
00022           'ELSE''BEGIN'
00022           'IF'N=100'THEN''BEGIN'
00022                             SYSACT(1,14,1);
00023                             SYSACT(1,2,15);
00024                         'END'
```

```
          'ELSE' 'BEGIN'
          SYSACT(1,14,N);
          SYSACT(1,2,15);
                 'END';
                'END';
      'END';
    'PROCEDURE' SPACE(N);
    'VALUE' N;
    'INTEGER' N;
    'BEGIN' 'INTEGER' R;
       SYSACT(1,1,R);
       SYSACT(1,2,N+R)
    'END';
    'PROCEDURE' WRITFT(ST);
    'STRING' ST;
        OUTSTRING(1,ST);
    'PROCEDURE' PRINT(X,F1,F2);
        'VALUE' X,F1,F2;
    'INTEGER' F1,F2;
    'REAL' X;
    'BEGIN' 'INTEGER' A,B,Y,Z,NOSP,I,COUNT,CO,FC,R;
        'BOOLEAN' NEG;
        'REAL' CA;
        A := ENTIER(ABS(X));
        B := ENTIER((ABS(X)-A)*10**F2+0.5);
        'IF' B > 10**F2-1 'THEN'
        'BEGIN' A := A+1;
           B := 0
        'END';
        NEG := X < 0;
        CA := A;
        COUNT := 0;
   AGAIN : COUNT := COUNT+1;
        CA := CA/10;
        'IF' CA >= 1 'THEN' 'GOTO' AGAIN;
        NOSP := 'IF' NEG 'THEN' F1-COUNT-1 'ELSE' F1-COUNT;
        'IF' NOSP = 0 'THEN' 'GOTO' SKIP;
        'IF' NOSP < 0 'THEN'
```

```
        'BEGIN' SYSACT(1,14,2);
           OUTSTRING(1,'('FORMAT ERROR  ')');
           OUTREAL(1,X);
           SYSACT(1,14,2);
           'GOTO' END
        'END';
        SYSACT(1,1,R);
        SYSACT(1,2,NOSP+R);
  SKIP : 'IF' NEG 'THEN' OUTSTRING(1,'('-')');
        'FOR' I := 1 'STEP' 1 'UNTIL' COUNT 'DO'
        'BEGIN' CO := COUNT-I;
              Y := A '/' ENTIER(10**CO);
           OUTSYMBOL(1,'('0123456789')',Y+1);
              A := A - (Y*10**CO);
        'END';
        'IF' F2 \= 0 'THEN' OUTSTRING(1,'('.')');
        'FOR' I := 1 'STEP' 1 'UNTIL' F2 'DO'
        'BEGIN' FC := F2-I;
              Z := B '/' ENTIER(10**FC);
           OUTSYMBOL(1,'('0123456789')',Z+1);
              B := B - (Z*10**FC);
        'END';
     END :
     'END' PROCEDURE PRINT;
        'COMMENT' END OF INPUT/OUTPUT PROCEDURES;

     'PROCEDURE' CRDTXT;
      'BEGIN' 'INTEGER' I,J;
   TRY AGAIN : INSYMBOL(0,'('*')',I);
        'IF' I = 1 'THEN'
        'BEGIN'
      NEXTSYM : INSYMBOL
       (0,'('*ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789+-,.=()@%<>?&_')',J);
        'IF' J = 1 'THEN' 'GOTO' OUT;
        OUTSYMBOL
       (1,'('*ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789+-,.=()@%<>?&_')',J);
        'GOTO' NEXTSYM
        'END'
```

```
00083       'ELSE' 'GOTO' TRYAGAIN;
00084      OUT :
00084       'END' PROCEDURE CRDTXT;
00085      'PROCEDURE'SORT(COL,LISTC,CYCLON);
00086        'VALUE' COL,CYCLON;
00087        'INTEGER' COL,CYCLON;
00088      'INTEGER''ARRAY'LISTC;
00089        'BEGIN' 'INTEGER' M,N,P,Q,ROW,POS,MIN;
00090           'FOR' P := 1 'STEP' 1 'UNTIL'CYCLON-1 'DO'
00090           'BEGIN' MIN := 100000;
00091              'FOR' Q := P+1 'STEP' 1 'UNTIL' CYCLON 'DO'
00091              'IF' LISTC(/Q,COL/) < MIN 'THEN'
00091              'BEGIN' MIN := LISTC(/Q,COL/);
00092                 POS := Q
00092              'END';
00093              'IF' LISTC(/POS,COL/) < LISTC(/P,COL/) 'THEN'
00093              'BEGIN' 'FOR' M := 1 'STEP' 1 'UNTIL' 17 'DO'
00093                 'BEGIN' ROW := LISTC(/POS,M/);
00094                    LISTC(/POS,M/) := LISTC(/P,M/);
00095                    LISTC(/P,M/) := ROW
00095                 'END'
00095              'END'
00095           'END'
00095        'END'
00095      SEMICOLON;
00096      'PROCEDURE' GRAPH( CYCLON, LISTF ,COL);
00097      'VALUE'CYCLON ,COL;
00098      'INTEGER'CYCLON ,COL;
00099      'INTEGER''ARRAY'LISTF;
00100      'BEGIN'
00100         'INTEGER' I,J, K,GRADE,MAXBAR;
00101         'REAL' SCALE;
00102         'INTEGER''ARRAY' ME,YOU(/1:10/);
00103      NEWPAG;
00104      NEWLIN(1);
00105       NEWLIN(1);
00106        'FOR' I:=1'STEP'1'UNTIL'10'DO'
00106        ME(/I/):=0;
00107        'FOR' I:=1'STEP'1'UNTIL'CYCLON'DO'
```

```
00107        'BEGIN'
00107            GRADE:=LISTF(/I,COL/);
00108        'IF'COL=2'THEN''BEGIN'
00108                'FOR'J:=20'STEP'10'UNTIL'110'DO'
00108            'IF'GRADE>=J-10&GRADE<J'THEN'ME(/(J-10)'/'10/):=
00108                                        ME(/(J-10)'/'10/)+1;
00109            'IF'GRADE>=100'THEN'ME(/10/):=ME(/10/)+1;
00110          'END'
00110         'ELSE''IF'COL=1'THEN''BEGIN'
00110            'FOR'J:=100'STEP'30'UNTIL'400'DO'
00110            'IF'GRADE>=J-30&GRADE<J'THEN'ME(/(J-100)'/'30/):=
00110                                                              ME(/(J-100)'/'30/)+1;
00111            'IF'GRADE=400'THEN'ME(/10/):=ME(/10/)+1;
00112            'END';
00113        'END';
00114        MAXBAR:=ME(/1/);
00115        'FOR'I:=2'STEP'1'UNTIL'10'DO'
00115        'IF' MAXBAR<ME(/I/) 'THEN' MAXBAR:=ME(/I/);
00116        SCALE :=100/MAXBAR;
00117        'FOR' I:=1'STEP'1'UNTIL'10'DO'
00117        'BEGIN'
00117            YOU(/I/):=ME(/I/)*SCALE;
00118            'FOR'J:=1'STEP'1'UNTIL'5'DO'
00118            'BEGIN'
00118                'IF' J=3 'THEN'
00118                                    'BEGIN'
00118                                        PRINT( ME(/I/),8,0);
00119                                        SPACE(2);
00120                                    'END'
00120                                'ELSE'
00120                        'IF' J=5 'THEN'
00120                                            'BEGIN'
00120                         'IF'COL=2'THEN'PRINT(10+10*I,7,0)
00120                        'ELSE''IF'COL=1'THEN'
00120                                  PRINT(100+30*I,7,0);
00121                                          OUTSYMBOL(1,'('=')',1);
00122                                        SPACE(2);
00123                                            'END'
```

```
00123                               'ELSE' SPACE(10);
00124              'FOR' K:= 1'STEP'1'UNTIL'YOU(/I/)'DO'
00124              OUTSYMBOL(1,'('+')',1);
00125          NEWLIN(100);
00126             'END'
00126         'END';
00127          SPACE(10);
00128      'FOR' I:=1'STEP'1'UNTIL'10'DO'
00128          'BEGIN'
00128              'FOR'J:=1'STEP'1'UNTIL'9'DO'
00128              OUTSYMBOL(1,'('⊥')',1);
00129              OUTSYMBOL(1,'('!')',1);
00130          'END';
00131          NEWLIN(100);
00132          SPACE(12);
00133      'FOR' I:=1'STEP'1'UNTIL'10'DO'
00133          PRINT(10*I*MAXBAR/CYCLON,7,2);
00134   'END' OF GRAPH PROCEDURE;
00135   'PROCEDURE'
00135           GRAFITI(LIST,COL,COLUMN,CYCLON,STARTX,STARTY,ENDX,ENDY);
00136   'VALUE'    COL,COLUMN,CYCLON,STARTX,STARTY,ENDX,ENDY;
00137   'INTEGER' COL,COLUMN,CYCLON,STARTX,STARTY,ENDX,ENDY;
00138   'INTEGER''ARRAY'LIST;
00139   'BEGIN'
00139      'INTEGER'LIMITA,LIMITB;
00140   LIMITA:=28;
00141      LIMITB:=105;
00142      'BEGIN'
00142          'INTEGER'I,J,K,INC I,INC J;
00143          'INTEGER''ARRAY'X(/1:LIMITA/),Y(/1:LIMITB/),
00143                              GRAFT(/1:LIMITA+1,1:LIMITB+1/);
00144          INC I:=(ENDX-STARTX)'/'(LIMITA+1)+1;
00145          INC J:=(ENDY-STARTY)'/'(LIMITB+1)+1;
00146          'FOR'I:=1'STEP'1'UNTIL'LIMITA'DO'
00146          X(/I/):=0+STARTX+I*INC I;
00147          'FOR'J:=1'STEP'1'UNTIL'LIMITB'DO'
00147          Y(/J/):=0+STARTY+J*INC J;
00148          'FOR'I:=1'STEP'1'UNTIL'LIMITA+1'DO'
00148          'FOR'J:=1'STEP'1'UNTIL'LIMITB+1'DO'
```

```
00148          GRAFT(/I,J/):=0;
00149          'FOR'K:=1'STEP'1'UNTIL'CYCLON'DO'
00149          'BEGIN'
00149          'INTEGER'XI,YJ;
00150          XI:=LIST(/K,COL/);
00151          YJ:=LIST(/K,COLUMN/);
00152              'FOR'I:=1'STEP'1'UNTIL'LIMITA'DO'
00152          'BEGIN'
00152              'IF'XI<X(/I/)'THEN''GOTO'FOUNDX;
00153          'END';
00154          I:=LIMITA+1;
00155            FOUNDX:
00155                  'FOR'J:=1'STEP'1'UNTIL'LIMITB'DO'
00155    'BEGIN'
00155          'IF'YJ<Y(/J/)'THEN''GOTO'FOUNDY;
00156    'END';
00157          J:=LIMITB+1;
00158            FOUNDY:
00158              GRAFT(/I,J/):=GRAFT(/I,J/)+1;
00159          'END';
00160          NEWPAG;
00161      'FOR'I:=LIMITA+1'STEP'-1'UNTIL'1'DO'
00161      'BEGIN'
00161          'IF'I=5'THEN'
00161              'BEGIN'
00161                  PRINT(X(/I/),8,0);
00162                  SPACE(1);
00163                  OUTSYMBOL(1,'('-')',1);
00164                  'FOR'J:=1'STEP'1'UNTIL'LIMITB+1'DO'
00164                  'IF'GRAFT(/I,J/)>9'THEN'OUTSYMBOL(1,'('&')',1)
00164                  'ELSE''IF'GRAFT(/I,J/)=0'THEN'SPACE(1)
00164                  'ELSE''IF'GRAFT(/I,J/)>0'THEN'PRINT(GRAFT(/I,J/),1,0);
00165                  NEWLIN(1);
00166              'END'
00166              'ELSE''IF'I\=LIMITA+1'THEN'
00166              'BEGIN'
00166                  PRINT(X(/I/),8,0);
00167                  SPACE(1);
```

```
00168                   OUTSYMBOL(1,'('-')',1);
00169                   'FOR'J:=1'STEP'1'UNTIL'LIMITB+1'DO'
00169              'BEGIN'
00169                   'IF'GRAFT(/I,J/)>9'THEN'OUTSYMBOL(1,'('&')',1)
00169                   'ELSE''IF'GRAFT(/I,J/)=0'THEN'SPACE(1)
00169                   'ELSE''IF'GRAFT(/I,J/)>0'THEN'PRINT(GRAFT(/I,J/),1,0);
00170              'END';
00171              NEWLIN(100);
00172                   SPACE(9);
00173                   OUTSYMBOL(1,'('*')',1);
00174              NEWLIN(100);
00175              'END'
00175              'ELSE'
00175              'BEGIN'
00175                   SPACE(9);
00176                   OUTSYMBOL(1,'('*')',1);
00177                   'FOR'J:=1'STEP'1'UNTIL'LIMITB+1'DO'
00177              'BEGIN'
00177                   'IF'GRAFT(/I,J/)>9'THEN'OUTSYMBOL(1,'('&')',1)
00177                   'ELSE''IF'GRAFT(/I,J/)=0'THEN'SPACE(1)
00177                   'ELSE''IF'GRAFT(/I,J/)>0'THEN'PRINT(GRAFT(/I,J/),1,0);
00178              'END';
00179              NEWLIN(100);
00180      SPACE(9);
00181              OUTSYMBOL(1,'('*')',1);
00182              NEWLIN(100);
00183              'END'
00183      'END';
00184    SPACE(10);
00185                   'FOR'J:=1'STEP'1'UNTIL'LIMITB+1'DO'
00185      'BEGIN'
00185          'IF'J'/'10*10=J'THEN'OUTSYMBOL(1,'('I')',1)
00185          'ELSE'OUTSYMBOL(1,'('⊥')',1);
00186      'END';
00187      NEWLIN(100);
00188      SPACE(10);
00189      'FOR'J:=10'STEP'10'UNTIL'LIMITB'/'10*10'DO'
00189      PRINT(Y(/J/),10,0);
00190      NEWLIN(100);
```

```
00191         WRITET('('                                & = NO, GREATER THAN 9')');
00192                 'END';
00193      'END';
00194      'INTEGER''PROCEDURE'SIGMA(A,M,N,P,Q);
00195         'VALUE'      M,N,P,Q;
00196         'INTEGER'    M,N,P,Q;
00197         'INTEGER' 'ARRAY' A;
00198         'BEGIN'
00198             'INTEGER' SUM,I;
00199             SUM:=0;
00200             'IF' Q= 1 'THEN' 'GOTO' NONZERO;
00201             'FOR'I:=1'STEP'1'UNTIL' M'DO'
00201             SUM:=SUM+A(/I,N/);
00202             'GOTO'EXIT;
00203          NONZERO:
00203             'FOR'I:=1'STEP'1'UNTIL' M'DO'
00203             'BEGIN'
00203             'IF' A(/I,P/)>0'THEN'
00203             SUM:=SUM+A(/I,N/);
00204             'END';
00205          EXIT:
00205             SIGMA:=SUM;
00206          'END';
00207      'PROCEDURE'RPBI(A,M,N,P);
00208         'VALUE'     M,N,P;
00209         'INTEGER'   M,N,P;
00210         'INTEGER' 'ARRAY' A;
00211         'BEGIN'
00211             'INTEGER' I;
00212             'REAL'K,J,R,T;
00213             NEWLIN(9);
00214             L:=0;
00215             K:=SIGMA(A,M,P,P,1);
00216             J:=SIGMA(A,M,N,P,0);
00217             'FOR'I:=1'STEP'1'UNTIL'M'DO'
00217             L:=L+(A(/I,N/)-J/M)**2;
00218             'IF'SQRT(L/M)=0'THEN''GOTO'OOPS;
00219             WRITET('('  SD = ')');
00220             PRINT(SQRT(L/M),4,4);
```

```
        NEWLIN(2);
        'IF'M=K!K=0'THEN''GOTO'OOPS;
        R:=(SIGMA(A,M,N,P,1)/K-J/M)/SQRT(L/M)*SQRT(K/(M-K));
        'IF'R=1'THEN''GOTO'OOPS;
        T:=R*SQRT((M-2)/(1-R*R));
        T:=ABS(T);
        WRITET('('R (POINT BISERIAL CORRFLATION COEFFT.' =')');
        PRINT(R,4,4);
        NEWLIN(1);
        WRITET('('                                   T =')');
        PRINT(T,4,4);
        NEWLIN(1);
        'IF'T< 1.29          'THEN'WRITET('('NO SIGNIFICANT CORRELATION
                                                                    ')');
        'IF'T>=1.29&T<1.67'THEN'WRITET('('CORRELATION SIGNIFICANT
                   AT THE 20% LEVEL')');
        'IF'T>=1.67&T<2.00'THEN'WRITET('('CORRELATION SIGNIFICANT
                   AT THE 10% LEVEL')');
        'IF'T>=2.00&T<2.39'THEN'WRITET('('CORRELATION SIGNIFICANT
                   AT THE  5% LEVEL')');
        'IF'T>=2.39&T<2.66'THEN'WRITET('('CORRELATION SIGNIFICANT
                   AT THE  2% LEVEL')');
        'IF'T>=2.66&T<3.46'THEN'WRITET('('CORRELATION SIGNIFICANT
                   AT THE  1% LEVEL')');
        'IF'T>=3.46          'THEN'WRITET('('CORRELATION SIGNIFICANT
                   AT THE 0.1% LEVEL')');
      OOPS:
     'END';
 'PROCEDURE' CORRAL(A,B,X,Y);
    'VALUE'   B,X,Y;
    'INTEGER' B,X,Y;
    'INTEGER' 'ARRAY' A;
    'BEGIN'
        'INTEGER' I;
        'REAL' J,K,L,M,N,R,T,SD X,SD Y;
        NEWLIN(10);
        L:=M:=N:=0;
```

```
        J:=SIGMA(A,B,X,0,0)/B;
        K:=SIGMA(A,B,Y,0,0)/B;
        'FOR'I:=1'STEP'1'UNTIL'B'DO'
        'BEGIN'
            L:=L+A(/I,X/)*A(/I,Y/);
            M:=M+(A(/I,X/)-J)**2;
            N:=N+(A(/I,Y/)-K)**2;
       'END';
        SD X:=SQRT(M/B);
        SD Y:=SQRT(N/B);
        WRITFT('(' SD X = ')');
        PRINT(SD X,4,4);
        WRITET('(' SD Y = ')');
        PRINT(SD Y,4,4);
        NEWLIN(1);
        'IF'SD X=0!SD Y=0'THEN''GOTO' TUT TUT;
        R:=(L-B*J*K)/(B*SD X*SD Y);
        'IF'R=1'THEN''GOTO' TUT TUT;
        T:=R*SQRT((B-2)/(1-R*R));
        T:=ABS(T);
        WRITET('(' PEARSON'S R = ')');
        PRINT(R,4,4);
        NEWLIN(1);
        WRITET('('                                   T =')');
        PRINT(T,4,4);
        NEWLIN(1);
        'IF'T< 1.29        'THEN'WRITET('('NO SIGNIFICANT CORRELATION
                                                                      ')');
        'IF'T>=1.29&T<1.67'THEN'WRITET('('CORRELATION SIGNIFICANT
                    AT THE 20% LEVEL')');
        'IF'T>=1.67&T<2.00'THEN'WRITET('('CORRELATION SIGNIFICANT
                    AT THE 10% LEVEL')');
        'IF'T>=2.00&T<2.39'THEN'WRITET('('CORRELATION SIGNIFICANT
                    AT THE  5% LEVEL')');
        'IF'T>=2.39&T<2.66'THEN'WRITET('('CORRELATION SIGNIFICANT
                    AT THE  2% LEVEL')');
        'IF'T>=2.66&T<3.46'THEN'WRTTET('('CORRELATION SIGNIFICANT
                    AT THE  1% LEVEL')');
        'IF'T>=3.46        'THEN'WRITET('('CORRELATION SIGNIFICANT
                    AT THE 0.1% LEVEL ')');
        TUT TUT:
      'END';
```

```
00281
00281   'INTEGER'SCHOOL,CARD,TOTPER,LABPER,LENPER,TIMALL,REQPER,REQLAB,SIZ,
00281           AVSIZ,A,B,C,D,E,I,J,K,L,NE,X,Y,Z,TIM,NOTES,COUNT,CYCLE,CENT;
00282   'INTEGER'SUBTIM,SUBSIZ,SUBAVE,CARDS,ENOS;
00283   SYSACT(0,10,1);
00284   NEWPAG;
00285   SUBTIM:=SUBAVE:=SUBSIZ:=CYCLE:=COUNT:=Z:=0;
00286   NE    :=READ;
00287
00287   CARDS:=NE'/'7+1;
00288   'COMMENT' NE IS THE NO. OF EXPTS. CONCERNED,I.E. 104 OR 62. THIS THE
00288           ONLY CARD THAT NEEDS TO BE CHANGED IN ORDER TO MAKE THE
00288           PROGRAM WORK  FOR 'O' GRADE OR 'H' GRADE SURVEY DATA THUS THE
00288           FIRST CARD OF ANY DATA MUST BE NE ;
00288   ENOS:=READ;
00289   'COMMENT' ENOS IS THE ESTIMATED NO. OF SCHOOLS BEING READ IN;
00289   'BEGIN'
00289
00289     'INTEGER''ARRAY'DATA(/1:NE,1:4/),SUM(/1:35/),TOTEXP(/1:NE,0:11/),
00289                     LIST(/1:ENOS,0:25/),UNIEXP(/1:NE,0:11/),
00289                     SUMUNI(/1:NE,1:5,0:11/);
00290     'FOR'I:=1'STEP'1'UNTIL'35'DO'
00290     SUM(/I/):=0;
00291     'FOR'I:=1'STEP'1'UNTIL'NE'DO'
00291     'FOR'J:=0'STEP'1'UNTIL'11'DO'
00291   'BEGIN'
00291     UNIEXP(/I,J/):=TOTEXP(/I,J/):=0;
00292   'END';
00293   'FOR'I:=1'STEP'1'UNTIL'NE'DO'
00293   'FOR'J:=1'STEP'1'UNTIL' 5'DO'
00293   'FOR'K:=0'STEP'1'UNTIL'11'DO'
00293   SUMUNI(/I,J,K/):=0;
00294   'FOR'I:=1'STEP'1'UNTIL'ENOS'DO'
00294     'FOR'J:=0'STEP'1'UNTIL'25'DO'
00294     LIST(/I,J/):=-2;
00295
00295
00295   NEXTSCHOOL :
00295   SCHOOL:=READ;
00296   'COMMENT' = NO. OR NAME OF SCHOOL;
00296   [illegible]
```

```
00297
00297   'COMMENT' THIS LAST STATEMENT IS TO GET OUT OF A LOOP .IT DOES NOT MEAN
00297            THAT THE PROGRAM IS AN INFINITE LOOP, BUT THAT THE COMPUTER
00297            WILL LOOK FOR DATA BEYOND THAT SUPPLIED, PROBABLY RESULTING
00297            IN PROGRAM FAILURE. THUS THE LAST CARD IN ANY DATA SET MUST
00297            BE -1;
00297
00297   CARD:=READ;'COMMENT'CARD NO. GOES FROM 1 TO 10 FOR 'H',& 1 TO 16 FOR'O'
00298                          GRADE FORM;
00298   HOPEFULL:
00298   COUNT:=COUNT+1;
00299   'COMMENT' = NO. OF SURVEY FORMS READ;
00299   NOTES:=READ;'COMMENT'WHETHER PRINTED NOTES ARE USED, 1=YES,0=NO;
00300   TOTPER:=READ;'COMMENT'NO. OF PERIODS (PER) /WEEK OF CHEMISTRY;
00301   LABPER:=READ;'COMMENT'NO. OF LAB. PERIODS/WEEK;
00302   LENPER:=READ;'COMMENT'LENGTH OF SCHOOL PERIOD;
00303   TIMALL:=READ;'COMMENT'TIME ALLOWANCE ADEQUATE?,1=YES,2=NO;
00304   REQPER:=READ;'COMMENT'REQUIRED NO. OF PERIODSELSE 0 IF TIME ALLOWED 1;
00305   REQLAB:=READ;'COMMENT'REQUIRED LAB. PERIODS OR 0 IF TIMALL=1;
00306   SIZ    :=READ;'COMMENT' SIZE OF YEAR;
00307   AVSIZ  :=READ;'COMMENT' SIZE OF SECTION;
00308   A      :=READ;'COMMENT'METHOD A OF RECORDING PRACTICAL WORK 0,1, OR 2;
00309   B:=READ;'COMMENT'METHOD B OF RECORDING PRACTICAL WORK, 0,1, OR 2;
00310   C:=READ;'COMMENT'METHOD C OF RECORDING PRACTICAL WORK, 0,1, OR 2;
00311   D      :=READ;'COMMENT'METHOD D OF RECORDING PRACTICAL WORK 0,1, OR 2;
00312   E:=READ;'COMMENT'METHOD E OF RECORDING PRACTICAL WORK, 1,0, OR 2;
00313
00313   'COMMENT'NOTIICE THAT NOTES,LABPER,TIMALL,REQPER,REQLAB,& E, & THE 2'S
00313           OF THE RECORDING METHODS  ONLY APPLY TO THE 'H' GRADE FORM;
00313
00313   'FOR'I:=1'STEP'1'UNTIL'CARDS'DO'
00313   'BEGIN'
00313
00313   'COMMENT' THE FOLLOWING BLOCK READS IN THE DATA FROM THE MAIN SURVEY
00313           FORM BODY, PROVIDING THAT THE FIRST NO. ON EACH DATA CARD IS
00313            THE SCHOOL NO. AND THE 2ND. IS AN INCREMENT OF THE PREVIOUS
00313            CARD NO.. THE LATTER CONDITION MEANS THAT, ALTHOUGH THE DATA
00313            SETS FOR EACH SCHOOL CAN BE IN ANY ORDER, THE CARDS
00313           WITHIN EACH SET MUST BE ORDERED, OTHERWISE THE DATA WILL BE
00313            IGNORED ;
```

```
      'IF'NE=7*(I-1)'THEN''GOTO'NO CARD;
     X := READ;
     Y := READ;
      'IF'X=SCHOOL&Y=I+1
     'THEN' 'BEGIN'
      'IF'I=CARDS'THEN'
      'BEGIN'
           'FOR'J:=7*(I-1)+1'STEP'1'UNTIL'NE'DO'
                'FOR' L := 1 'STEP' 1 'UNTIL' 4 'DO'
                DATA(/J,L/) := READ
      'END'
       'ELSE'
      'BEGIN'
           'FOR' J := 7*I-6 'STEP' 1 'UNTIL' 7*I 'DO'
                'FOR' L := 1 'STEP' 1 'UNTIL' 4 'DO'
                DATA(/J,L/) := READ;
      'END'
           'END'
     'ELSE' 'BEGIN'
                'INTEGER'IGNORE,TOUGH;
                WRITET('('ERROR, SCHOOL NUMBER INCOMPATIBLE ')');
                PRINT(SCHOOL,3,0);
                WRITET('(' CARD NO. ')');
                PRINT(Y,2,0);
           WRITET('('  COUNT = ')');
           PRINT(COUNT,4,0);
NEWLIN(1);
                K:=I;
       AGAIN:
                'IF'K\=I'THEN'
                         'BEGIN'
                              X:=READ;
                              Y:=READ;
                         'END';
                'IF'X\=SCHOOL & Y=1'THEN''GOTO'HOPEFULL;
                'FOR'J:=7*K-6'STEP'1'UNTIL'7*K'DO'
                'FOR'L:=1'STEP'1'UNTIL'4'DO'
                IGNORE:=READ;
                K:=K+1;
```

```
00332           'IF'NE=7*(K-1)'THEN''GOTO'NEXTSCHOOL
00332           'ELSE'
00332               'IF'K=CARDS'THEN'
00332                   'BEGIN'
00332                       'FOR'J:=7*(K-1)+1'STEP'1'UNTIL'NE'DO'
00332                       'FOR'L:=1'STEP'1'UNTIL'4'DO'
00332                       IGNORE:=READ;
00333                   'END'
00333           'ELSE'
00333               'IF'K<CARDS'THEN''GOTO'AGAIN;
00334               TOUGH:=TOUGH+1;
00335               'IF'TOUGH=10'THEN''GOTO'OUT;
00336               'GOTO'NEXTSCHOOL;
00337             'END';
00338     'END';
00339     NO CARD:
00339     'FOR'I:=14'STEP'1'UNTIL'24'DO'
00339     SUM(/I/):=0;
00340
00340     'COMMENT''THE NEXT THREE BLOCKS CHECKS THE RESPONSE TO EACH EXPERIMENT
00340              'SUMS' THE NO. OF TICKS IN EACH COLUMN FOR EACH SCHOOL,AND
00340              'TOT'ALS THE RESPONSES TO EACH  'EXP'ERIMENT FOR ALL SCHOOLS.
00340              IT ALSO CHECKS FOR ERRORS IN DATA PREPARATION ( TO A LIMITED
00340              EXTENT );
00340
00340     'FOR'I:=1'STEP'1'UNTIL'NE'DO'
00340     'BEGIN'
00340        'IF'DATA(/I,2/)=1
00340        'THEN'
00340            'BEGIN'
00340               SUM(/14/):=SUM(/14/)+1;
00341               TOTEXP(/I,1/):=TOTEXP(/I,1/)+1;
00342            'END'
00342           'ELSE''IF'DATA(/I,2/)=2
00342        'THEN'
00342            'BEGIN'
00342               SUM(/15/):=SUM(/15/)+1;
00343               TOTEXP(/I,2/):=TOTEXP(/I,2/)+1;
00344            'END'
00344           'ELSE''IF'DATA(/I,2/)=3
00344        'THEN'
```

```
00344           'BEGIN'
00344              SUM(/16/):=SUM(/16/)+1;
00345              TOTEXP(/I,3/):=TOTEXP(/I,3/)+1;
00346           'END'
00346          'ELSE''IF'DATA(/I,2/)=4
00346       'THEN'
00346           'BEGIN'
00346              SUM(/17/):=SUM(/17/)+1;
00347              TOTEXP(/I,4/):=TOTEXP(/I,4/)+1;
00348           'END'
00348          'ELSE''IF'DATA(/I,2/)>4!DATA(/I,2/)<0
00348       'THEN'
00348           'BEGIN'
00348              WRITET('('ERROR2,WRONG DATUM; SCHOOL NUMBER IS')');
00349              PRINT(SCHOOL,4,0);
00350              WRITET('(' CODE NO. = ')');
00351              PRINT(DATA(/I,1/),3,0);
00352              WRITET('(' COUNT = ')');
00353              PRINT(COUNT,4,0);
00354              NEWLIN(1);
00355              'GOTO'NEXTSCHOOL;
00356                'END';
00357       'IF'DATA(/I,3/)=1
00357       'THEN'
00357           'BEGIN'
00357              SUM(/18/):=SUM(/18/)+1;
00358              TOTEXP(/I,5/):=TOTEXP(/I,5/)+1;
00359           'END'
00359          'ELSE''IF'DATA(/I,3/)=2
00359       'THEN'
00359           'BEGIN'
00359              SUM(/19/):=SUM(/19/)+1;
00360              TOTEXP(/I,6/):=TOTEXP(/I,6/)+1;
00361           'END'
00361          'ELSE''IF'DATA(/I,3/)=3
00361       'THEN'
00361           'BEGIN'
00361              SUM(/20/):=SUM(/20/)+1;
00362              TOTEXP(/I,7/):=TOTEXP(/I,7/)+1;
00363           'END'
```

```
    'ELSE''IF'DATA(/I,3/)=4
'THEN'
     'BEGIN'
        SUM(/21/):=SUM(/21/)+1;
        TOTEXP(/I,8/):=TOTEXP(/I,8/)+1;
     'END'
    'ELSE''IF'DATA(/I,3/)>4!DATA(/I,3/)<0
'THEN'
     'BEGIN'
         WRITET('('ERRORS,WRONG DATUM; SCHOOL NUMBER IS ')');
        PRINT(SCHOOL,4,0);
        WRITET('(' CODE NO. = ')');
        PRINT(DATA(/I,1/),3,0);
        WRITET('(' COUNT = ')');
        PRINT(COUNT,4,0);
        NEWLIN(1);
        'GOTO'NEXTSCHOOL;
          'END';
'IF'DATA(/I,4/)=1
'THEN'
     'BEGIN'
        SUM(/22/):=SUM(/22/)+1;
        TOTEXP(/I,9/):=TOTEXP(/I,9/)+1;
     'END'
    'ELSE''IF'DATA(/I,4/)=2
'THEN'
     'BEGIN'
        SUM(/23/):=SUM(/23/)+1;
        TOTEXP(/I,10/):=TOTEXP(/I,10/)+1;
     'END'
    'ELSE''IF'DATA(/I,4/)=3
'THEN'
     'BEGIN'
        SUM(/24/):=SUM(/24/)+1;
        TOTEXP(/I,11/):=TOTEXP(/I,11/)+1;
     'END'
    'ELSE''IF'DATA(/I,4/)>4!DATA(/I,4/)<0
'THEN'
```

```
        'BEGIN'
           WRITET('('ERROR4,WRONG DATUM; SCHOOL NUMBER IS')');
           PRINT(SCHOOL,4,0);
           WRITET('(' CODE NO. = ')');
           PRINT(DATA(/I,1/),3,0);
           WRITET('(' COUNT = ')');
           PRINT(COUNT,4,0);
           NEWLIN(1);
           'GOTO'NEXTSCHOOL;
        'END'
SEMICOLON;
   TOTEXP(/I,0/):=DATA(/I,1/);
SUMUNI(/I,1,0/):=TOTEXP(/I,0/);
'FOR'J:=1'STEP'1'UNTIL'11'DO'
'BEGIN'
   'IF'A>0'THEN'SUMUNI(/I,1,J/):=SUMUNI(/I,1,J/)+TOTEXP(/I,J/)-
                                                        UNIEXP(/I,J/);
   'IF'B>0'THEN'SUMUNI(/I,2,J/):=SUMUNI(/I,2,J/)+TOTEXP(/I,J/)-
                                                        UNIEXP(/I,J/);
   'IF'C>0'THEN'SUMUNI(/I,3,J/):=SUMUNI(/I,3,J/)+TOTEXP(/I,J/)-
                                                        UNIEXP(/I,J/);
   'IF'D>0'THEN'SUMUNI(/I,4,J/):=SUMUNI(/I,4,J/)+TOTEXP(/I,J/)-
                                                        UNIEXP(/I,J/);
   'IF'E>0'THEN'SUMUNI(/I,5,J/):=SUMUNI(/I,5,J/)+TOTEXP(/I,J/)-
                                                        UNIEXP(/I,J/);
   UNIEXP(/I,J/):=TOTEXP(/I,J/);
'END';
            'END';

'COMMENT'HAVING REACHED THIS FAR WITHOUT FINDING ANY OBVIOUS ERRORS THE
         PROGRAM NOW GOES ON TO WORK ON THE DATA. IT THEN STORES ITS
         FINDINGS IN A LIST, AWAITING INSTRUCTIONS AS TO FORM OF OUTPUT
SEMICOLON;

TIM:=TOTPER*LENPER;
SUM(/1/) := SUM(/1/) + TIM;
'IF'TIM=0'THEN'SUBTIM:=SUBTIM+1;
SUM(/2/):=SUM(/2/)+SIZ;
'IF'SIZ=0'THEN'SUBSIZ:=SUBSIZ+1;
```

```
SUM(/3/):=SUM(/3/)+AVSIZ;
'IF'AVSIZ=0'THEN'SUBAVE:=SUBAVE+1;
'IF'A>1'THEN'SUM(/5/):=SUM(/5/)+1'ELSE'SUM(/4/):=SUM(/4/)+A;
'IF'B>1'THEN'SUM(/7/):=SUM(/7/)+1'ELSE'SUM(/6/):=SUM(/6/)+B;
'IF'C>1'THEN'SUM(/9/):=SUM(/9/)+1'ELSE'SUM(/8/):=SUM(/8/)+C;
'IF'D>1'THEN'SUM(/11/):=SUM(/11/)+1'ELSE'SUM(/10/):=SUM(/10/)+D;
'IF'E>1'THEN'SUM(/13/):=SUM(/13/)+1'ELSE'SUM(/12/):=SUM(/12/)+E;
'FOR'I:=25'STEP'1'UNTIL'35'DO'
SUM(/I/):=SUM(/I/)+SUM(/I-11/);
Z:=0;
'FOR'I:=22'STEP'1'UNTIL'24'DO'
Z:=Z+SUM(/I/);
CYCLE:=CYCLE+1;
LIST(/CYCLE,0/):=SCHOOL;
LIST(/CYCLE,1/):=TIM;
LIST(/CYCLE,2/):=SUM(/14/);
LIST(/CYCLE,3/):=AVSIZ;
LIST(/CYCLE,4/):=A;
LIST(/CYCLE,5/):=B;
LIST(/CYCLE,6/):=C;
LIST(/CYCLE,7/):=D;
LIST(/CYCLE,8/):=E;
'FOR'I:=9'STEP'1'UNTIL'18'DO'
LIST(/CYCLE,I/):=SUM(/I+6/);
LIST(/CYCLE,19/):=NOTES;
LIST(/CYCLE,20/):=Z;
LIST(/CYCLE,21/):=TIMALL;
LIST(/CYCLE,22/):=REQPER;
LIST(/CYCLE,23/):=REQLAB;
LIST(/CYCLE,24/):=LABPER*LENPER;
LIST(/CYCLE,25/):='IF'LIST(/CYCLE,24/)≠LIST(/CYCLE,1/)'THEN'0'ELSE'1;
'GOTO' NEXTSCHOOL;
OUT :
'FOR'I:=1'STEP'1'UNTIL'18'DO'
'FOR'J:=1'STEP'1'UNTIL'18'DO'
'BEGIN'
   'IF'I<=J'THEN''GOTO'EQUALITY;
   CORRAL(LIST,CYCLE,I,J);
   NEWLIN(1);
   'IF'I=1'THEN' WRITET('('  TIME(MINS.)/WEEK SPENT ON CHEMISTRY')')
```

```
'ELSE'
'IF'I=2'THEN' WRITET('('  TOTAL NO. OF EXPTS. DONE')')
'ELSE'
'IF'I=3'THEN' WRITET('('  AVERAGE SIZE OF CHEMISTRY SECTION')')
'ELSE'
'IF'I>3&I<9'THEN' 'BEGIN'
    WRITET('('  RECORDING METHOD')');
    OUTSYMBOL(1,'('(')',1);
    OUTSYMBOL(1,'('***ABCDE')',I);
    OUTSYMBOL(1,'(')')',1);
'END'
'ELSE'
'BEGIN'
    WRITET('('  COLUMN ')');
    OUTSYMBOL(1,'('********3334444555')',I);
    OUTSYMBOL(1,'('********BCDABCDABC')',I);
'END';
WRITET('(' WITH ')');
'IF'J=1'THEN' WRITET('('  TIME(MINS.)/WEEK SPENT ON CHEMISTRY')')
'ELSE'
'IF'J=2'THEN' WRITET('('  TOTAL NO. OF EXPTS. DONE')')
'ELSE'
'IF'J=3'THEN' WRITET('('  AVERAGE SIZE OF CHEMISTRY SECTION')')
'ELSE'
'IF'J>3&J<9'THEN' 'BEGIN'
    WRITET('('  RECORDING METHOD')');
    OUTSYMBOL(1,'('(')',1);
    OUTSYMBOL(1,'('***ABCDE')',J);
    OUTSYMBOL(1,'(')')',1);
'END'
'ELSE'
'BEGIN'
    WRITET('('  COLUMN ')');
    OUTSYMBOL(1,'('********3334444555')',J);
    OUTSYMBOL(1,'('********BCDABCDABC')',J);
WRITET('(' CORRELATION WITH TIME ALLOCATION')');
'END';
EQUALITY:
'END';
NEWPAG;
WRITET('(' TOTAL NO. OF SCHOOLS DEALT WITH = ')');
```

```
PRINT(CYCLE,4,Ø);
NEWLIN(2);
WRITET('(' AVERAGE REQUIRED PERIODS = ')');
K:=SIGMA(LIST,CYCLE,21,Ø,Ø);
'IF'CYCLE-K=Ø'THEN'WRITET('(' Ø.ØØ')')
  'ELSE'
PRINT(SIGMA(LIST,CYCLE,22,Ø,Ø)/(CYCLE-K),4,4);
NEWLIN(2);
;WRITET('(' NO. OF SCHOOLS WITH LAB. PERIODS DIFFERENT FROM TOTAL =')');
PRINT(SIGMA(LIST,CYCLE,25,Ø,Ø),4,Ø);
NEWLIN(2);
WRITET('(' NO. OF SCHOOLS WITH ADEQUATE TIME = ')');
PRINT(K,4,Ø);
'FOR'I:=1'STEP'1'UNTIL'18'DO'
'BEGIN'
   'IF'I'/'2*2=I'THEN'NEWPAG;
   RPBI(LIST,CYCLE,I,19);
   NEWLIN(1);
   'IF'I=1'THEN' WRITET('('  TIME(MINS.)/WEEK SPENT ON CHEMISTRY')')
   'ELSE'
   'IF'I=2'THEN' WRITET('('  TOTAL NO. OF EXPTS. DONE')')
   'ELSE'
   'IF'I=3'THEN' WRITET('('  AVERAGE SIZE OF CHEMISTRY SECTION')')
   'ELSE'
   'IF'I>3&I<9'THEN' 'BEGIN'
       WRITET('('  RECORDING METHOD')');
       OUTSYMBOL(1,'('(')',1);
       OUTSYMBOL(1,'('***ABCDE')',I);
       OUTSYMBOL(1,'(')')',1);
   'END'
   'ELSE'
   'BEGIN'
       WRITET('('  COLUMN ')');
       OUTSYMBOL(1,'('********333444555')',I);
       OUTSYMBOL(1,'('********BCDABCDABC')',I);
   'END';
   WRITET('(' CORRELATION WITH EXTENSIVE PRINTED NOTES')');
   RPBI(LIST,CYCLE,I,21);
   NEWLIN(1);
   'IF'I=1'THEN' WRITET('('  TIME(MINS.)/WEEK SPENT ON CHEMISTRY')')
   'ELSE'
```

```
'IF'I=2'THEN' WRITET('('  TOTAL NO. OF EXPTS. DONE')')
'ELSE'
'IF'I=3'THEN' WRITET('('  AVERAGE SIZE OF CHEMISTRY SECTION')')
'ELSE'
'IF'I>3&I<9'THEN' 'BEGIN'
    WRITET('('  RECORDING METHOD')');
    OUTSYMBOL(1,'('(')',1);
    OUTSYMBOL(1,'('***ABCDF')',I);
    OUTSYMBOL(1,'(')')',1);
'END'
'ELSE'
'BEGIN'
    WRITET('('  COLUMN ')');
    OUTSYMBOL(1,'('********333444555')',I);
    OUTSYMBOL(1,'('********BCDABCDABC')',I);
'END';
WRITET('(' CORRELATION WITH TIME ALLOCATION')');
'END';
'FOR'I:=1'STEP'1'UNTIL'NE'DO'
'BEGIN'
NEWLIN(10);
WRITET('(' EXPT. NO. ')');
PRINT(SUMUNI(/I,1,0/),4,0);
NEWLIN(2);
SPACE(20);
'FOR'J:=1'STEP'1'UNTIL'11'DO'
'BEGIN'
    SPACE(5);
    OUTSYMBOL(1,'('33333444555')',J);
    OUTSYMBOL(1,'('ABCDABCDABC')',J);
'END';
'FOR'J:=1'STEP'1'UNTIL' 5'DO'
'BEGIN'
    NEWLIN(1);
    SPACE(10);
    OUTSYMBOL(1,'('ABCDE')',J);
    SPACE( 9);
```

```
            'FOR'K:=1'STEP'1'UNTIL'11'DO'
            PRINT(SUMUNI(/I,J,K/),7,0);
        'END';
'END';
PASTIT:
NEWFAG;
WRITET('('AVERAGE TIME = ')');
PRINT( SUM(/1/)/(CYCLE-SUBTIM),3,2);
WRITET('(' MINS.')');
WRITET('('                          SUBTIME = ')');
PRINT(SUBTIM,3,0);
WRITET('('   S.D. = ')');
'BEGIN''REAL'A,B,C,D,X,Y,Z,J;
A:=B:=C:=D:=0.0;
J:=SUM(/1/)/(CYCLE-SUBTIM);
Z:=SUM(/3/)/(CYCLE-SUBAVE);
Y:=SUM(/25/)/CYCLE;
X:=SUM(/29/)/CYCLE;
'FOR'I:=1'STEP'1'UNTIL'CYCLE'DO'
'BEGIN'
   A:=A+(LIST(/I,1/)-J)**2;
   B:=B+(LIST(/I,3/)-Z)**2;
   C:=C+(LIST(/I,2/)-Y)**2;
   D:=D+(LIST(/I,12/)-X)**2;
'END';
PRINT(SQRT(A/CYCLE),4,4);
NEWLIN(2);
WRITET('(' AVERAGE YEAR =')');
PRINT( SUM(/2/)/(CYCLE-SUBSIZ),4,2);
WRITET('('                          SUBSIZE = ')');
PRINT(SUBSIZ,3,0);
NEWLIN(2);
WRITET('('AVERAGE SIZE OF CHEMISTRY SECTION = ')');
PRINT( SUM(/3/)/(CYCLE-SUBAVE),4,2);
```

```
WRITET('('                              SUBAVE  = ')');
PRINT(SUBAVE,3,0);
WRITET('(' S.D. = ')');
PRINT(SQRT(B/CYCLE),4,4);
NEWLIN(2);
WRITET('(' TOTALS FOR RECORDING METHODS, A - E')');
NEWLIN(1);SPACE(4);
WRITET('(' NO. TICKED ONCE     NO. TICKED TWICE     TOTAL TICKS  ')');
'FOR'I:=4'STEP'2'UNTIL'12'DO'
'BEGIN'
NEWLIN(1);
   OUTSYMBOL(1,'('SSSASBSCSDSES')',I);
   PRINT(SUM(/I/),15,0);
   PRINT(SUM(/I+1/),19,0);
   PRINT(SUM(/I/)+2*SUM(/I+1/),15,0);
'END';
'FOR'I:=25'STEP'1'UNTIL'35'DO'
'BEGIN'
   NEWLIN(3);
   SPACE(1) ;
   CROTXT;
   PRINT(SUM(/I/),6,0);
   'IF'I=25'THEN''BEGIN'
        WRITET('('  MEAN = ')');
        PRINT(Y,4,4);
        WRITET('('  S.D. =')');
        PRINT(SQRT( C/CYCLE),4,4);
            'END'
   'ELSE''IF'I=29'THEN''BEGIN'
        WRITET('('  MEAN = ')');
        PRINT(X,4,4);
        WRITET('('  S.D. =')');
        PRINT(SQRT( D/CYCLE),4,4);
            'END';
            'END';
'END';
```

```
NEWPAG;
WRITET('(' TOTEXP FOLLOES(?)'PD')');
    NEWLIN(1);
'FOR'I:=1'STEP'1'UNTIL'NE'DO'
'BEGIN'
    'FOR'J:=0'STEP'1'UNTIL'11'DO'
    PRINT(TOTEXP(/I,J/),4,0);
    NEWLIN(1);
'END';
HISTIT:
GRAPH(CYCLE,LIST,2);
WRITET('(' DISTRIBUTION OF TOTAL NO. OF EXPTS. DONE ')');
GRAPH(CYCLE,LIST,1);
WRITET('(' DISTRIBUTION OF TIME/WEEK(MINS.) ')');
GRAFITI(LIST,1,2,CYCLE,1000,360,104);
      NEWPAG;
      NEWLIN(2);
WRITET('(' DGRAPH OF TIME AGAINST NO. OF EXPTS. DONE ')');
      NEWLIN(2);
'FOR'I:=1'STEP'1'UNTIL'CYCLE'DO'
'BEGIN'
    'FOR'J:=0'STEP'1'UNTIL'25'DO'
      PRINT(LIST(/I,J/),4,0);
    NEWLIN(1);
'END';
'END'
```

Appendix 2.3 List of Responses per Experiment

Expt. No.	3A	3B	3C	4A	4B	4C	4D	5A	5B	5C
	COLUMN IN QUESTIONNAIRE									
1	96	1	4	81	8	2	6	89	1	7
2	99	2	0	23	1	58	19	95	1	4
3	100	1	0	90	4	6	0	97	1	1
4	93	1	5	60	4	24	6	63	12	22
5	96	3	2	55	2	37	5	83	3	13
6	97	1	1	55	4	31	7	73	2	17
7	82	6	12	73	6	2	4	52	13	23
8	71	7	21	67	4	2	2	41	11	28
9	97	1	2	74	5	9	7	87	1	4
10	101	0	0	94	2	2	2	90	1	8
11	29	14	56	33	1	3	1	19	25	12
12	84	2	14	52	5	24	3	70	5	9
13	93	2	5	84	3	6	2	77	3	11
14	98	1	2	69	5	16	9	70	4	24
15	83	4	12	39	2	38	5	56	7	19
16	88	1	11	77	3	6	2	72	3	13
17	92	o	7	59	8	19	6	69	4	15
18	42	1	55	23	3	12	5	38	8	5
19	94	2	5	65	5	19	7	83	6	7
20	86	4	11	37	2	36	13	60	7	24
21	86	2	13	56	2	25	3	70	6	12
22	65	2	33	41	3	20	2	51	9	11
23	83	6	11	55	8	15	7	63	7	20
24	91	2	7	66	4	15	5	79	2	9
25	97	2	2	93	3	0	2	90	2	4
26	96	2	2	89	5	3	1	82	5	12
27	96	0	5	66	4	18	8	84	5	8
28	69	3	42	60	4	5	2	42	13	21
29	100	0	1	87	2	7	4	84	4	10
30	100	0	1	90	6	2	2	77	5	15
31	87	3	8	82	5	0	0	65	6	18
32	84	5	9	85	2	1	0	60	10	22
33	93	1	7	51	3	32	6	70	5	15
34	89	4	6	57	6	22	6	77	3	10
35	96	2	2	70	1	21	5	81	6	8
36	93	4	2	77	1	14	4	79	6	12
37	85	1	15	68	1	15	2	75	4	9
38	97	1	1	50	2	29	19	85	1	8
39	100	0	0	90	1	8	1	89	3	8
40	95	0	5	72	5	13	4	83	7	7
41	87	1	10	63	5	13	5	73	5	10
42	88	2	9	48	3	31	5	68	5	15
43	68	4	25	36	1	31	2	46	11	18
44	88	1	11	70	3	12	3	65	6	18
45	91	7	1	2	0	82	9	81	3	8
46	81	6	9	1	1	76	6	73	6	9
47	100	0	0	46	1	37	16	94	1	3
48	55	8	34	13	1	35	9	47	3	16
49	92	1	7	76	1	13	1	78	3	9
50	69	5	24	13	1	51	5	57	5	11
51	67	4	26	8	1	52	5	55	3	13
52	63	10	25	42	1	24	2	41	27	10

Expt. No.	3A	3B	3C	4A	4B	4C	4D	5A	5B	5C
	COLUMN IN QUESTIONNAIRE									
53	73	6	18	32	1	34	7	66	2	8
54	91	1	8	49	0	30	13	80	1	10
55	93	0	6	54	3	33	4	73	5	15
56	51	13	36	2	1	45	8	37	8	18
57	84	7	9	44	0	30	13	73	5	11
58	71	11	19	51	1	21	4	43	14	20
59	57	7	35	22	1	29	7	45	8	17
60	101	0	0	93	2	6	0	98	0	1
61	96	1	3	67	0	21	8	84	o	11
62	79	3	16	50	5	18	10	61	5	16
63	59	2	37	42	3	12	4	46	3	16
64	83	7	11	1	0	79	4	62	9	15
65	98	1	2	90	1	61	11	79	3	15
66	96	2	2	22	1	65	9	78	3	13
67	22	13	64	1	0	22	3	13	23	8
68	50	12	38	0	0	47	4	28	15	15
69	90	3	7	10	1	70	9	65	8	19
70	84	12	5	13	1	63	13	61	9	20
71	93	5	3	4	1	79	11	83	2	9
72	95	3	3	68	2	25	0	70	7	19
73	74	4	21	71	1	3	1	55	8	16
74	99	0	1	77	3	18	1	86	4	10
75	47	9	42	45	2	2	1	25	14	20
76	4	4	92	1	0	4	1	4	11	5
77	77	1	20	38	3	30	5	53	7	21
78	100	0	0	95	2	2	1	97	0	2
79	100	0	0	96	2	2	0	96	0	3
80	54	5	40	46	3	6	2	49	5	10
81	80	1	18	73	4	2	2	75	1	9
82	98	0	2	90	3	4	1	88	1	7
83	86	4	9	51	1	32	3	75	5	8
84	72	9	19	6	0	65	7	54	8	17
85	91	1	7	80	3	7	2	80	4	7
86	99	0	0	41	2	45	11	90	1	4
87	98	0	1	74	2	13	6	88	0	5
88	95	1	3	74	2	14	4	86	1	4
89	95	1	3	84	5	6	0	90	2	4
90	73	4	19	52	3	21	1	57	9	13
91	53	7	33	23	1	28	4	41	8	13
92	76	3	19	66	2	9	1	65	3	11
93	89	7	4	78	2	7	6	74	3	13
94	87	1	11	69	2	15	2	76	3	9
95	88	2	10	69	3	12	4	72	5	12
96	82	0	17	62	1	17	2	65	4	19
97	100	0	0	91	3	5	0	78	3	17
98	34	6	58	23	2	8	5	52	3	17
99	63	9	29	28	2	28	8	52	3	17
100	95	0	4	62	2	25	4	76	2	10
101	63	1	35	51	1	10	0	46	4	17
102	57	2	40	49	0	6	0	46	6	12
103	57	5	36	45	4	7	0	42	12	13
104	63	1	34	13	2	36	11	51	2	13

The list includes responses from 101 schools.

+ Total ?

Appendix 2.4 List of Responses per School

SCHOOL CODE	COLUMN IN QUESTIONNAIRE									
	3A	3B	3C	4A	4B	4C	4D	5A	5B	5C
001	94-	3-	7-	86-	0-	7-	4-	93-	5-	0
003	95-	5-	5-	67-	7-	14-	11-	91-	5-	2
006	90	6	7	48	1	35	6	62	11	27
011	92	3	8	57	1	35	0	72	4	17
012	78	4	22	52	8	11	7	65	8	11
013	94	2	7	79	0	17	0	89	4	3
014	87	4	13	49	0	36	2	86	5	6
015	94	1	8	75	0	19	0	83	0	12
022	71	0	25	52	0	19	0	32	1	38
023	51	6	45	10	0	47	0	56	23	23
024	95	2	7	47	0	47	1	82	4	9
025	59	5	39	41	2	18	0	48	0	12
029	70	4	25	42	0	3	28	55	1	5
038	54	13	32	41	i	15	2	46	9	5
043	102	0	2	91	0	13	0	50	0	0
045	94	4	5	77	4	17	0	65	6	26
050	88	7	9	76	0	14	0	79	0	10
054	94	0	10	65	0	35	0	64	1	30
060	93	4	4	52	0	40	1	91	1	0
073	78	16	5	40	0	36	18	61	8	25
087	87	1	14	62	2	23	0	61	17	7
091	81	10	12	40	0	40	0	73	28	1
096	89	1	12	74	0	12	3	85	1	14
097	97	2	5	50	19	22	6	92	0	5
100	84	8	12	62	0	18	11	61	12	28
101	55	6	23	42	0	15	0	31	14	10
103	95	3	6	67	0	24	3	68	7	20
104	86	2	9	40	16	8	22	82	1	0
105	75	3	26	45	0	28	0	70	0	3
107	72	0	31	48	0	24	1	66	1	3
108	82	3	19	45	7	24	8	58	14	24
109	81	1	17	40	0	40	0	51	1	15
111	67	1	16	48	0	16	3	56	2	9
112	80	12	12	70	0	17	2	39	42	9
119	81	6	17	52	4	24	4	74	0	7
123	92	2	10	75	0	18	0	94	1	0
125	97	3	4	65	0	35	0	94	5	2
128	96	2	6	82	2	13	0	86	0	9
132	71	4	29	54	0	17	0	50	18	3
135	79	2	20	47	10	20	3	52	12	15
137	95	1	8	80	0	16	0	92	2	2
141	93	8	3	69	0	19	13	74	5	22
142	96	0	8	71	0	21	4	77	5	18
143	95	2	4	49	1	40	5	53	16	33
154	102	0	2	86	2	14	0	99	0	3
155	88	3	13	64	0	19	7	90	0	0
157	86	5	13	78	0	3	4	67	1	16
159	93	2	6	44	7	40	0	87	4	0
160	80	0	21	46	1	34	1	38	0	36
161	72	12	20	59	5	7	1	47	25	31
164	82	3	19	52	3	15	12	89	2	13

SCHOOL CODE	COLUMN IN QUESTIONNAIRE									
	3A	3B	3C	34A	4B	4C	4D	5A	5B	5C
166	76	0	24	47	0	29	0	74	0	0
174	93	4	6	70	1	14	12	88	8	3
179	79	4	21	43	0	33	3	66	0	11
180	84	2	18	61	2	21	0	76	3	2
182	100	2	2	66	0	31	3	90	0	9
184	89	3	12	46	1	42	0	87	0	1
185	87	1	12	61	0	29	0	68	9	26
188	75	5	23	40	4	31	0	64	1	5
190	66	12	26	49	0	21	1	48	23	30
199	75	4	25	61	0	0	14	76	4	0
203	70	11	23	42	3	25	0	67	22	14
204	91	3	10	47	0	42	3	24	10	58
206	78	3	21	60	1	10	8	70	1	8
210	75	7	22	66	1	4	10	63	23	18
212	64	6	33	45	1	15	4	50	6	11
227	95	0	9	63	1	28	3	89	2	3
229	97	4	2	52	3	8	34	54	4	41
231	81	2	19	52	7	22	0	75	0	4
234	70	8	26	32	0	32	6	32	2	21
235	89	0	9	58	1	30	0	88	0	1
236	82	6	16	52	1	26	4	53	3	27
238	98	1	5	66	6	22	5	76	2	21
243	84	2	16	66	0	22	0	69	8	9
244	89	5	10	74	0	17	0	56	2	27
247	92	3	8	70	0	9	14	50	22	31
248	65	1	38	32	0	27	6	52	8	12
250	74	2	28	55	0	16	1	71	0	3
253	78	2	24	53	0	19	7	75	2	1
254	94	0	10	13	63	18	0	94	0	0
258	80	0	0	29	0	47	4	68	0	12
259	81	10	13	78	0	13	0	59	15	20
262	64	6	33	36	0	17	10	32	0	29
264	93	0	11	72	0	21	0	56	6	27
279	80	3	19	46	0	16	17	69	4	7
280	85	4	15	40	0	16	29	83	4	9
284	85	0	19	43	0	41	0	67	0	20
285	101	1	2	53	11	37	1	93	2	4
302	95	0	9	53	3	12	0	71	12	20
305	86	5	13	44	0	43	7	40	24	29
307	81	2	20	58	0	20	2	72	7	0
311	79	0	23	52	1	9	16	73	0	3
314	74	3	26	40	0	37	0	53	0	21
316	100	0	1	66	7	21	2	100	0	1
318	82	1	17	62	0	21	0	74	6	2
319	66	1	35	38	0	22	6	29	0	37
320	82	0	22	36	2	43	1	61	0	21
322	103	0	0	40	28	6	30	97	0	6
321	87	0	17	49	0	37	1	82	0	3
406	91	4	9	68	2	8	13	84	3	2
407	99	0	5	81	0	15	3	93	1	6

Each school's response concerns 104 experiments

CHAPTER 3

The Objectives of Practical Work

Chapter 3 - The Objectives of Practical Work

Aims

The aims of this section of the research were -

1. To discover what objectives a teacher had in mind when he decided to carry out practical work and what importance he placed on each objective.
2. To establish the order of importance of objectives from the teachers' point of view so that it can later be compared to the pupils' sense of achievement of these objectives. (See chapter 4).
3. To establish objectives which can be used to develop a method of assessment of practical ability. (See chapter 5).

Experimental Design

It was decided that the investigation of objectives should be carried out on two levels.

a) Objectives were studied which related to the O-grade practical work as a whole.

b) Objectives were studied which related to each of four specific experiments in the O-grade course. These experiments were -

Experiment 6 - section H4 - Mobility of ions
Experiment 30 - section J6 - Heats of neutralisation
Experiment 47 - section K6 - Properties of concentrated sulphuric acid
Experiment 89 - section N2 - Preparation of esters.

These experiments were selected because it was felt that they were, as a group, representative of the types of practical work in the course as a whole. They included 'measurement' and 'observation', 'organic', 'inorganic' and 'physical' chemistry, and were normally fairly well-spread through the course in terms of time of teaching.

The method of investigation on two levels was chosen because -

a) General objectives were needed, as mentioned above, to carry out a comparison with the pupils' response and to develop a method of assessment of practical ability.

b) Such consideration of objectives as is done by teachers is normally done on a general level. It was felt that it would be interesting to see teachers' reaction to a request for objectives for a single experiment. It was hoped that the response might give an indication of how much thought a teacher gave to the question of why he chooses to do any single experiment.

The most convenient method of investigation would have been to write to teachers and ask them to compile a list of objectives for the two levels. This method was not used for the following reasons.

1. The compilation of such a list would have been demanding of the teachers' non-teaching time. This might have led, understandably, to a poor response.
2. It might have proved difficult to classify the suggested objectives into a workable list for analysis.
3. It was felt that many teachers were perhaps not well acquainted with objective-writing, and might therefore have experienced difficulty in compiling a comprehensive list.

Interview Technique

It was decided, in view of the points listed above, that a questionnaire containing a list of possible objectives would be issued. However, it was felt that the list should be wide-ranging and that its contents should reflect the opinions of practising teachers. To achieve this end, a number of Principal Teachers of Chemistry were interviewed individually; these interviews took place in June of 1973. The 11 Principal Teachers were asked to suggest possible objectives, both general and specific (for the four chosen experiments), and these were noted. The completed notes were processed in order to compile a concise list of objectives and this list was then used to make up the full questionnaire (see Appendix 3.1) which was sent to 125 schools. These schools comprised the 101 which had returned the first questionnaire plus, in error, 24 schools which had not recieved the first questionnaire.

Contents of the Questionnaire

The questionnaire contained a list of 10 objectives and 5 advantages (for the teacher) relating to the whole course, and a list of possible objectives for each of the four experiments described previously. In every case, the list was made up on the basis of the suggestions made during the interviews. Where possible, objectives which had been suggested which, although belonging to different domains[12], were similar in material, were combined in order to simplify the questionnaire.

For example, the suggested objectives -
" Pupils should know the reasons for carrying out safety procedures in the laboratory " (Cognitive domain)
" Pupils should appreciate the need for cleanliness and tidiness in the laboratory " (Affective domain)
" Pupils should acquire skills in the safe-handling of hazardous material " (Psychomotor domain) -
were combined into the general objective -
" Pupils should be able to work safely and tidily in the laboratory".

Although it was realised that some technical accuracy was lost in this combination of objectives, it did result in the questionnaire being kept to a reasonable size and it would not therefore be too demanding of a teacher's time.

Those who recieved the questionnaire were asked to indicate for each objective whether they thought it to be important, fairly important, or not important. "Importance" was to be judged on the basis of - " Did the objective describe behaviour which it is important that the pupil should be able to demonstrate at the end of the O-grade course (or at the end of one of the four specific experiments) as a result of having done practical work."

Teachers were also asked to add any objectives which were not already on the list but which they thought to be important.

Response to the Questionnaire

Questionnaires were returned by 107 schools (85%). Returns from 75 schools were obtained quickly ; after a delay of two months, a reminder was sent to the remaining 50 schools, of which 32 then submitted their completed questionnaire. The analysis of the responses to this questionnaire was therefore based on approximately 27% of all Scottish schools presenting O-grade chemistry pupils. The response reflected the opinion of teachers in the first term of session 1973-74.

Treatment of Results

The responses which teachers made to the list of objectives were graded by applying a scoring system as follows -

A tick in each of the three possible columns was given points -

An 'important' tick was given .... +1 point

A 'fairly important' tick was given .... 0 point

A 'not important' tick was given .... -1 point

It was realised that such a scoring system had disadvantages, in particular because it implied that a constant numerical ratio could be assigned. Although a more complex response system could have been used - for instance, teachers could have been asked to grade objectives on a 5-point scale - the scoring system above was used because -

1. It allowed the teachers' questionnaire to remain simple - demanding only a subjective judgement. This would keep to a minimum the time needed to fill up the questionnaire.

2. It was thought that the use of a 5-point scale in the questionnaire would also have implied a numerical relationship. Teachers' response to such a scale would probably have been concentrated on the

middle rankings (e.g. on a 5-4-3-2-1 scale, very few 5 and 1 scores would be recieved) thus effectively reducing the 5-point scale to a 3-point scale such as that which was used for analysis.

3. It was thought desirable that the system of response used in the similar questionnaire which was later sent to pupils should be identical to that used by teachers. The pupils questionnaire contained statements related to the teachers' objectives, and it was hoped that a comparison could be made between teachers' and pupils' responses. A more complicated form of questionnaire than that used might have proved too difficult to answer for many average O-grade pupils.

4. Provided all responses were treated consistently both in teachers and pupils' questionnaires, a comparison could be made by the use of the 3-point scoring system.

5. When taken over the 107 schools, such a scoring system would allow comparison of the importance which teachers placed on an objective. A large difference in the scores of two objectives could reasonably be attributed to the teachers' belief that one objective was more imprtant than the other.

Results of the Analysis

The complete list of objectives suggested by the 11 Principal Teachers who were interviewed is shown in Appendix 3.2.

After processing, these objectives were included in the questionnaire (see Appendix 3.1) which, on return, was scored as described on page 26. The scores for all 107 schools were combined to produce an "order of importance " for the list of objectives.

1. Objectives for the O-Grade Practical Course The order of importance is shown in table 3.1. The average score for each objective is shown in brackets.

Although all objectives scored as "fairly important" or better, some comments might be made on the order.

(i) It was perhaps surprising to find that the " acquisition of skills in the handling of apparatus and chemicals " was ranked so poorly. Indeed it could be argued that the ability to " work safely and tidily in the laboratory " and the ability to " carry out written and oral instructions " could only be fully attained by a pupil who had already acquired skills in the handling of apparatus and chemicals. It might be, however, that teachers interpreted the word "skill" as implying a high level of competence, and that they did not consider a high level of competence to be important.

(ii) The ranking of the ability to " design an experiment to investigate a problem " was thought to be realistic, bearing in mind the level of

Table 3.1 Order of Importance of Objectives

RANK	AVERAGE SCORE	NUMBER IN QUESTIONNAIRE	OBJECTIVE (Pupils should ....)
1.	0.8	4	Be able to draw conclusions from experimental results.
3.	0.7	1	Develop an interest and enjoyment in chemistry
3.	0.7	2	Appreciate that chemical theory describes real observable behaviour
3.	0.7	8	Be able to work safely and tidily in the laboratory
5.	0.6	7	Be able to carry out written and oral instructions.
6.	0.5	9	Be able to record observations and results
7.	0.4	6	Acquire skills in the handling of apparatus and chemicals.
8.	0.2	5	Develop a sense of curiosity
9½	0.1	3	Be able to design an experiment to investigate a problem
9½	0.1	10	Appreciate that there are limitations in accuracy involved in practical work.

ability and maturity of the average O-grade pupil.

The order will be discussed again later (page 35) when the results of the pupils' questionnaire are given.

The extra objectives which were suggested by teachers are listed in table 3.2. The number of teachers who added each particular objective is shown in brackets. The two most popular of these were included in the questionnaire which was sent to pupils.

2. Advantages to the Teacher of Practical Work Using the same scoring system, the order shown in table 3.3 was obtained.

It was thought surprising that the advantage " allows for small-group teaching " ranked so poorly. Although small-group teaching as used in primary schools is not common in secondary schools, the teacher of chemistry is of necessity in the position of having to split the class into working groups (which may have only one or two pupils in them). When practical work is being done, the teacher can discuss the subject under study with small numbers of pupils at atime. In the writer's experience a pupil who would not admit to having difficulties during class work will often reveal them, voluntarily or inadvertently, during a discussion with his group. Furthermore, the teacher has the freedom to decide on the composition of the working groups, and can encourage pupils of different abilities and temperaments to cooperate with each other.

It was noted that many teachers violently disagreed with the statement that " practical work requires less preparation than a 'chalk-and-talk' lesson ". Many teachers stated so by adding comments as well as by ticking the " not important " column.

The extra advantages for the teacher which were suggested are listed in table 3.4 ; the number of teachers contributing each advantage are shown in brackets.

3. Further Analysis An investigation was carried out to discover if the importance which a teacher placed on an objective was reflected in the number of experiments which he carried out. To do this, the schools which had completed both questionnaires were selected. They were then classified into groups according to the number of experiments done regularly. These groups were -

Group A - schools performing fewer than 69 experiments
Group B - schools performing 70 - 79 experiments
Group C - schools performing 80 - 89 experiments
Group D - schools performing more than 90 experiments.

Each objective was then scored as before, but each group was done separately ; thus four average " importance " values were found for each objective - allowing comparisons to be made between groups of schools which carried out different numbers of experiments.

Table 3.2 Extra Objectives Suggested by Teachers

Number of teachers suggesting each is shown in brackets.

PUPILS SHOULD -

(4) Be able to cooperate with others in a working group.

(3) Improve their behaviour and self-discipline

(2) Appreciate the application of chemistry to everyday life

(2) Apprecaite that chemistry is an experimental science.

(1) Be willing to persevere to obtain results.

(1) Become aware of his own abilities.

(1) Appreciate that experiments might involve unsophisticated apparatus.

(1) Develop initiative.

(1) Realise the importance of negative results.

(1) Recognise and be able to scrutinise and critcise ideas from others

(1) Develop a becoming humility.

Table 3.3 Advantages for the Teacher

RANK	AVERAGE SCORE	NUMBER IN QUESTIONNAIRE	ADVANTAGE (Practical work....)
1	0.7	4	Maintains pupil interest in a lesson
2	0.6	2	Allows for reinforcement of ideas and concepts from a less theoretical angle.
3	0.4	3	Allows for variety in teaching method and approach.
4.	0.1	1	Allows for small-group teaching.
5.	-0.9	5	Requires less preparation than a chalk-and-talk lesson.

Table 3.4 Extra Advantages Suggested by Teachers

The number of teachers suggesting each is shown in brackets.
PRACTICAL WORK -

(2) Enables a teacher to gain insight into a pupil's character.

(2) Enables pupils to participate in the subject.

(2) Emphasises the idea of what a chemist's job would be like.

(1) Gives greater job satisfaction to the teacher.

(1) Improves pupil-teacher relationships.

(1) Enables pupils to help each ohter over difficulties.

(1) Slows down the rate of teaching of the syllabus.

(1) Provides teachers with a source of new interest (when an experiment doesn't work.)

(1) Maintains a Rousseau-type discipline.

The results are shown in figure 3.1.

In most cases, no strong trends were seen ; small differences in scores were not considered to be significant because of the reservations concerning the scoring system. The following points were noted-

a) In the case of objectives 5 (pupils should develop a sense of curiosity) and 10 (pupils should be able to design an experiment to investigate a problem), schools which considered these to be important (average score greater than 0.0) tended to be those which carried out many experiments (more than 80).

b) The objective 6 (pupils should acquire skills in the handling of apparatus and chemicals) showed no trend over the range of schools. It might have been expected that this objective would be thought most important by schools where many experiments were done.

c) The schools which did not consider the advantage 4 (practical work maintains pupil interest in a lesson) to be important were those schools performing fewer than 60 experiments. A similar result was seen for advantage 1 (practical work allows for small-group teaching.)

A similar investigation was carried out to discover if the "importance" of the objectives was related to the number of experiments carried out by the pupils. The method was similar to that just described ; the groups were made up as follows -

Group A - schools where pupils do fewer than 50 experiments

Group B - schools where pupils do 50 -59 experiments

Group C - schools where pupils do 60 - 69 experiments

Group D - schools where pupils do more than 69 experiments.

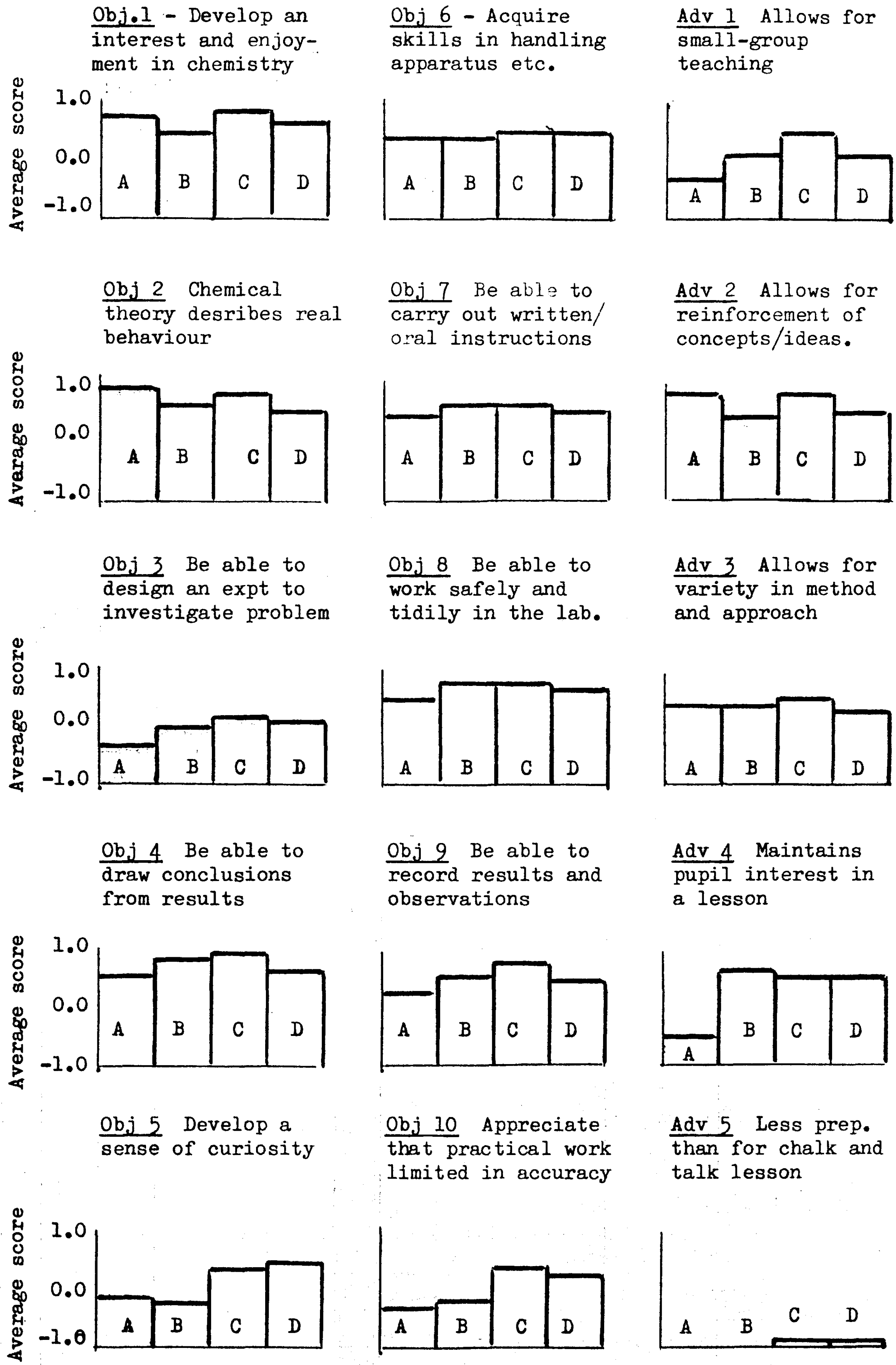
The groups were different from those on page 28 because the distribution of experiments performed by the pupils was different from that for the total number of experiments performed.

The results are shown in figure 3.2.

Again, in most cases, no strong trends were evident ; small differences in scores were again not considered to be significant because of the reservations regarding the scoring system.

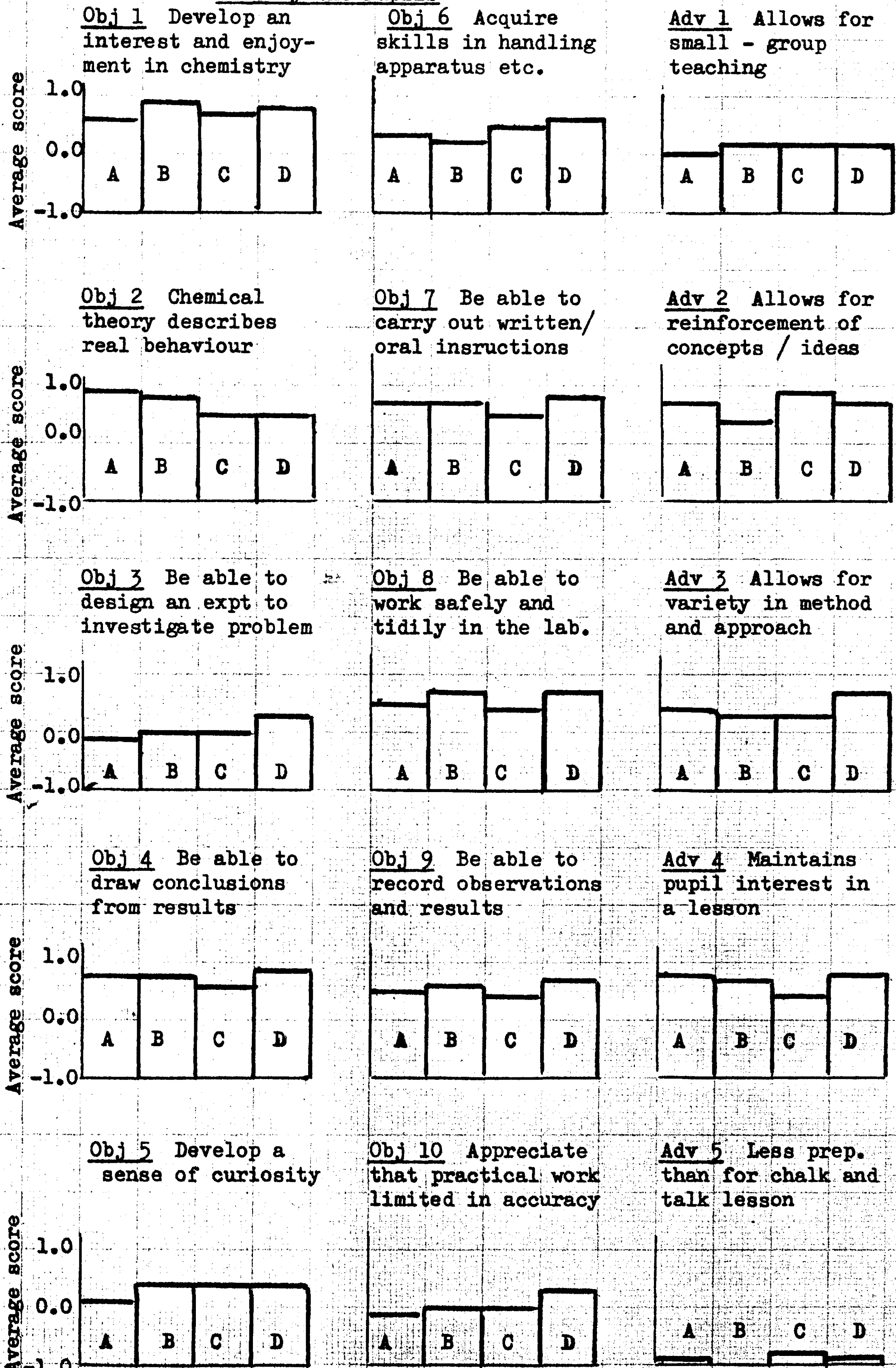
It might be thought surprising that no such trends were found, because it might have been expected that the more importance a teacher placed on practical work, the more experiments he would allow his pupils to do. His judgement of the number of experiments to be done by the pupils might be affected by other factors - but these factors did not include class size or time allocation. (These were shown in chapter 2 to have had no correlation with the number of experiments done by the pupils.)

Figure 3.1 Importance related to Number of Experiments Done



A = schools performing fewer than 70 experiments regularly
B = " " between 70 and 79 " "
C = " " " 80 and 89 " "
D = " " more than 89 " "

Figure 3.2 Importance related to the Number of Experiments done by the Pupils



A = schools where pupils perform fewer than 50 experiments
B = " " " " between 50 and 59 "
C = " " " " between 60 and 69 "
D = " " " " more than 69 "

4. The Objectives for the Four Specific Experiments. The responses to this part of the questionnaire were scored as before and an "order of importance" was drawn up for the objectives for each experiment.

The results are shown in table 3.5.

Some comments might be made on these results.

a) In experiment 6 (Mobility of ions), it was surprising that the objective " pupils should appreciate the need for control of variables " should be rated only as " fairly important " despite the fact that this experiment was normally the first occasion in the O-grade course when such control was essential to obtain usable results.

b) Some confusion was evident in the response to experiment 30 (Heats of neutralisation). The objective which was rated as the most important (knowledge of the fact that the basic neutralisation reaction could be expressed as $H^{+}(aq) + OH^{-}(aq) \rightarrow H_2O(l)$) described something which pupils could not achieve as a result of doing the experiment. This objective might be achieved by consideration and discussion of results after the experiment had been completed. If teachers had judged this objective to be important because they considered the discussion to be a part of the experiment, then it would be expected that the objectives " appreciation of the concept of spectator ions " and " appreciation of the need to use ionic equations " would be considered equally important since the pupils' understanding of these must preclude their attainment of the former objective. The latter two objectives, however, were rated as being only " fairly important ".

c) The objective " ability to handle a hazardous compound " for experiment 47 (Properties of concentrated sulphuric acid) was not rated as highly as might have been expected. However, the low rating might be due to the fact that 53% of schools were demonstrating this experiment.

d) In experiment 89 (Preparation of esters), a similar confusion to that just discussed arose. The objective " knowledge of the structure of esters " was rated as most important - but it could not possibly be achieved by pupils who had prepared some esters in a test-tube. The objective " ability to use smell as a method of detection " could certainly be achieved by doing the experiment and, in the writer's experience, was certainly one of the most memorable parts of this experiment for the pupils. As an objective, however, it was ranked in seventh place and was considered to be less than " fairly important ".

Conclusions and Discussion of Chapter 3.

It is felt by the writer that the response to the section of the questionnaire dealing with the four specific experiments has illustrated a general problem when considering the objectives of practical work. It is suggested that an objective

Table 3.5 Objectives for the Four Specific Experiments

RANK	AVERAGE SCORE	NUMBER IN QUESTIONNAIRE	OBJECTIVE (Pupils should..)
(Experiment 6 - section H4 - Mobility of ions)			
1	0.7	3	Know that ions move at different speeds in a solution
2	0.6	2	Know that conductivity is related to the number of ions in a solution
3½	0.5	1	Know that conductivity in an ionic solution is a result of movement of ions.
3½	0.5	6	Appreciate the need for control of variables
5	0.2	4	Be able to use previous knowledge to solve a problem
6	0.1	5	Appreciate the need to organise practical work in a systematic way.
(Experiment 30 - section J6 - Heats of neutralisation.)			
1	0.9	1	Know that the basic neutralisation reaction can be expressed as $H^{+}(aq)+OH^{-}(aq) \rightarrow H_2O(l)$
2	0.6	2	Know that chemical reactions are accompanied by energy changes
3	0.3	5	Appreciate the need for control of variables
4	0.2	3	Appreciate the advantages of using ionic equations
5	0.1	4	Appreciate the need to organise practical work in a systematic way.
(Experiment 47 - section K6 - Properties of concentrated sulphuric acid)			
1	0.8	2	Know that the concentration of sulphuric acid affects its properties.
2	0.7	1	Know the properties of sulphuric acid
3	0.6	5	Be able to handle a hazardous compound
4½	-0.2	3	Know that pure hydrogen chloride is a gas
4½	-0.2	4	Be able to use chemicals with economy

Table 3.5 (Continued)

RANK	AVERAGE SCORE	NUMBER IN QUESTIONNAIRE	OBJECTIVE (Pupils should....)
(Experiment 89 - section N2 - Preparation of esters)			
1½	0.3	6	Know the social importance of chemical compounds
1½	0.3	1	Know the structure of esters
3	0.2	2	Know the properties and uses of esters
4	0.1	3	Know that oils are esters
5	-0.1	4	Understand the concept of a slow reaction
6	-0.2	7	Be able to use chemicals with economy
7	-0.3	8	Be able to use smell as a method of detection
8	-0.6	5	Be familiar with some sophisticated apparatus.

for practical work must aspire to some knowledge, skill or attitude which the pupil can obtain as a result of his own activity. Many of the objectives discussed in this chapter, and in particular those relevant to experiments 6 (Mobility of ions) and 30 (Heats of neutralisation) could equally well be achieved by the teacher writing a set of results on the blackboard and discussing them with the class.

It may be that teachers, being familiar with the work in the course, can not readily view the practical work through the eyes of a pupil. Because of the teacher's familiarity, and because he is aware of the position of the experiments in the syllabus in relation to the surrounding theory, his expectation of what can be achieved as a result of his pupils' activity may be over-ambitious. If this is the case, then a careful study of each O-grade experiment may be desirable to try to establish -

a) What objectives, if any, does the teacher have in mind before the experiment ?

b) Can these objectives be achieved by the pupil as a result of his practical activity ? If not, then what objectives can the pupil realistically achieve ?

c) Do these realistic objectives justify the time and expense involved in allowing the pupils to do the experiment ?

The general objectives which have been established in this chapter were later used in the construction of an assessment technique for practical work (see chapter 5).

APPENDIX 3.1

Possible Objectives for the Practical Work in the 'O' Grade Chemistry Course

Part A This is a list of possible objectives which should be evident at the end of the course in terms of student behaviour.

As a result of the practical work, pupils should -		very important	fairly important	not important
1. Develop an interest and enjoyment in chemistry	1			
2. Appreciate that chemical theory describes and explains real observable behaviour	2			
3. Be able to design an experiment to investigate a problem	3			
4. Be able to draw conclusions from experimental results	4			
5. Develop a sense of curiosity	5			
6. Acquire skills in the handling of chemicals and apparatus	6			
7. Be able to carry out written and oral instructions	7			
8. Be able to work safely and tidily in the laboratory	8			
9. Be able to record observations and results	9			
10. Appreciate that there are limitations in accuracy involved in practical work.	10			

Please list on the back of this sheet any other objectives which you think are important in terms of student behaviour.

Part B This is a list of advantages of practical work from the teacher's point of view.

1. It allows for small group teaching	1			
2. It allows for reinforcement of ideas and concepts (from a less theoretical angle) in the pupils' minds	2			
3. It allows for variety in teaching method and approach	3			
4. It maintains pupil interest in a lesson	4			
5. It requires less preparation than a "chalk and talk" lesson.	5			

Again please list on the back of this sheet any other advantages, from the teacher's point of view, which practical work has.

NAME OF PRINCIPAL TEACHER . . . .

NAME AND ADDRESS OF SCHOOL . . . .

. . . .

The following list refers to four specific experiments in the 'O' grade course. Again, please tick the appropriate box for each objective.

Experiment 1 Comparison of ion mobilities by measurement of conductivities of equimolar solutions. Section H4

Pupils should, by performing this experiment, acquire -

Objective		very important	fairly important	not important
1. Knowledge that conductivity in ionic solutions is a result of movement of ions	1			
2. Knowledge that conductivity is related to the number of ions in a solution	2			
3. Knowledge that ions move at different speeds in a solution	3			
4. Ability to use previous knowledge to solve a problem	4			
5. Appreciation of the need to organise practical work in a systematic way	5			
6. Appreciation of the need for control of variables.	6			

Experiment 2 Heats of Neutralisation. Section J6

1. Knowledge that the basic neutralisation reaction can be expressed as $H^+ (aq) + OH^- (aq) \rightarrow H_2O (l)$	1			
2. Knowledge that chemical reactions are accompanied by energy changes	2			
3. Appreciation of the concept of spectator ions	3			
4. Appreciation of the advantages of the use of ionic equations	4			
5. Appreciation of the need for control of variables.	5			

Experiment 3 Properties of concentrated sulphuric acid. Section K6

1. Knowledge of the properties of sulphuric acid	1			
2. Knowledge that the concentration of the acid affects its properties	2			
3. Knowledge that pure hydrogen chloride is a gas	3			
4. Ability to use chemicals with economy	4			
5. Ability to handle a hazardous compound.	5			

Experiment 4 Preparation of Esters. Section N2

1. Knowledge of the structure of esters	1			
2. Knowledge of the properties and uses of esters	2			
3. Knowledge that oils are esters	3			
4. Understanding of the concept of a slow reaction	4			
5. Familiarity with some sophisticated apparatus	5			
6. Knowledge of the social importance of chemical compounds	6			
7. Ability to use chemicals with economy	7			
8. Ability to use smell as a method of detection.	8			

Please list here other objectives which should be evident in terms of student behaviour.

Please list here other advantages from the teacher's point of view.

APPENDIX 3.2 Complete List of Objectives from Interviews.

In all cases, the number in brackets which precedes the objective is the number of teachers who suggested each objective during the interviews. (11 teachers were interviewed.)

Experiment 6 - section H4 - Mobility of ions

Pupils should acquire in knowledge and understanding -

(5) Knowledge that conductivity in ionic solutions is a result of the movement of ions.
(4) Knowledge that conductivity is related to the number of ions in solution.
(9) Knowledge that ions move at different speeds through a solution
(1) Knowledge that speed is related to ionic size.
(3) Ability to use previous knowledge to solve a problem.
(7) Knowledge of the importance of the control of variables
(1) Knowledge of chemical symbols and formulae.

Pupils should acquire in attitudes -

(3) Awareness of the need to organise practical work in a systematic way.
(1) Awareness of the need to consider results objectively.

Pupils should acquire in practical skills -

(1) Ability to correctly set up a circuit
(1) Ability to read a meter to the required degree of accuracy.

Appendix 3.2 (continued)

Experiment 30 - section J6 - Heats of neutralisation

Pupils should acquire in knowledge and understanding -

(7) Knowledge that the basic neutralisation reaction is written as

$$H^{+} (aq) + OH^{-} (aq) \longrightarrow H_2O (l)$$

(3) Knowledge that chemical reactions are accompanied by energy changes

(3) Knowledge of the concept of spectator ions.

(6) Knowledge of the use of ionic equations

Pupils should acquire in attitudes -

(5) Appreciation of the need for control of variables

(3) Appreciation of the need to organise practical work in a systematic way.

(4) Appreciation of the advantages in the use of ionic equations.

(1) Awareness of the need to consider results objectively.

(1) Awareness of the need to consider class results as a whole.

Pupils should acquire in practical skills -

(1) Ability to use a thermometer

Experiment 47 - section K6 - Properties of Concentrated sulphuric acid

Pupils should acquire in knowledge and understanding -

(10) Knowledge of the properties of sulphuric acid

(10) Knowledge that the concentration of the acid affects its properties

(3) Knowledge that pure hydrogen chloride is a gas

(1) Knowledge of the properties of elemental sulphur

(1) Understanding of oxidation number

Pupils should acquire in attitudes -

(3) Awareness of the need to handle chemicals with economy

(6) Awareness of the need for safety procedures

(1) Appreciation of the need to organise practical work in a systematic way.

Appendix 3.2 (continued)

Pupils should acquire in practical skills -

(8) Ability to handle a hazardous compound.
(3) Ability to use chemicals with economy.
(1) Ability to deal with spillage of a hazardous compound.

Experiment 89 - section N2 - Preparation of esters

Pupils should acquire in knowledge and understanding -

(7) Knowledge of the social importance of chemical compounds
(8) Knowledge of the structure of esters
(6) Knowledge of the properties and uses of esters
(4) Knowledge that oils are esters
(3) Understanding of the concept of a slow reaction
(2) Knowledge of some sophisticated apparatus
(1) Knowledge of the properties of carbon compounds
(1) Knowledge of methods of structure determination.

Pupils should acquire in attitudes -

(4) Appreciation of the social importance of chemical compounds
(1) Awareness of the need for safety considerations
(1) Awareness of the need to cooperate in a group.

Pupils should acquire in practical skills -

(3) Ability to handle chemicals with economy.
(3) Ability to use smell as a method of detection
(1) Ability to carry out safety procedures
(1) Ability to estimate small quantities of liquid
(1) Ability to keep a test-tube at a fixed temperature.

Appendix 3.2 (contimued)

General Objectives for the Course Practical Work

Pupils should acquire in knowledge and understanding -

(9) Knowlegde of the importance of objective observation
(7) Knowledge of the reasons for carrying out safety procedures
(5) Ability to design an experiment to investigate a problem
(3) Knowledge that practical work is limited in accuracy
(3) Knowledge of the functions and uses of some laboratory apparatus
(1) Understanding of the need for control experiments
(1) Knowledge of chemical symbols and formulae
(1) Understanding of the chemist's ability to produce new compounds

Pupils should acquire in attitudes -

(11) Interest and enjoyment in chemistry
Appreciation of the importance of drawing conclusions from results
(10) and observations
(5) Develop a sense of curiosity
(5) Appreciate that chemical theory is a desription or explanation of real observable behaviour
(2) Appreciate the need for safety procedures
(1) Appreciate the need for cleanliness in the laboratory
(1) Appreciate that accuracy of measurement is important
(1) Appreciate the need for cooperation in a group
(1) Appreciate the need for careful recording of results
(1) Appreciate the need for estimation of experimental errors.
(1) Appreciate the importance of chemistry to everyday life.
(1) Realise that the method of solving problems in chemistry can be applied to other fields.

Pupils should acquire in practical skills -

(10) Ability to work safely and tidily in the laboratory
(10) Ability to record observations and results
(9) Ability to carry out instructions
(6) Ability to handle apparatus and chemicals
(3) Ability to collect and assemble apparatus to investigate a problem
(1) Ability to use measuring devices to the required accuracy
(1) Ability to draw diagrams and graphs
(1) Ability to safely dispose of waste materials
(1) Ability to handle safely a hazardous compound.

CHAPTER 4

THE ACHIEVEMENT OF OBJECTIVES

BY PUPILS

Chapter 4 - The Achievement of Objectives by Pupils

Aim

The aim of this section of the research was to investigate the changes in attitudes, behaviour and knowledge which occur as a result of the pupil having carried out practical work in chemistry. These changes could then be compared to the teachers' expectation of achievement which was discussed in the previous chapter.

Experimental Design

This investigation was carried out on two levels - these being equivalent to those in chapter 3 - i.e.
a) an investigation of achievement by pupils as a result of carrying out the practical work in the O-grade course as a whole.
b) an investigation of achievement by pupils as a result of carrying out each of the four specific experiments - namely
Experiment 6 - section H4 - Mobility of ions
Experiment 30 - section J6 - Heats of neutralisation
Experiment 47 - section K6 - Properties of concentrated sulphuric acid
Experiment 89 - scetion N2 - Preparation of esters

It was thought desirable that the form of investigation should be similar to that described in chapter 3 in order to allow comparison of results. To that end, questionnaires were made up which were based on the second questionnaire sent to teachers. In the following discussion, these questionnaires are referred to as questionnaire P1 (on general practical work) - see Appendix 4.1 - and questionnaire P2 (on the four specific experiments) - see Appendix 4.2. The design differed from that used to investigate teachers' objectives in the following ways -

1. The wording was changed from " As a result of doing practical work, pupils should .... " to " As a result of douing practical work, you........ " . This allowed the pupils to comment on their sense of achievement of the teaching objectives.
2. The column headings " important ", " fairly important " and " not important " were replaced by " true ", " fairly true " and " untrue". For instance, pupils had therefore to respond to the statement - " As a result of doing practical work, you....have become interested in and enjoy chemistry " by ticking one of the above headings.
3. At the time that questionnaires P1 and P2 and the practical test (see chapter 5) were being sent out to schools, the Scottish Certificate of Education examinations were approaching. (It was desirable for the purposes of the research to sample pupils' opinion

at this time because P1 and the practical test were to be filled in by pupils who had completed the O-grade chemistry course.) Because of the impending examinations, it was thought to be an unfair burden to place on schools to ask them to allow pupils to fill in two questionnaires and a practical test. Therefore all schools which had completed the second teachers' questionnaire were divided into three groups. Group A were asked to allow all pupils who were about to sit the O-grade examination to complete questionnaire P1 . Group B were asked to allow pupils who had just done any of the four specific experiments to complete questionnaire P2. Group C were asked to allow pupils to sit the practical test. (See chapter 5).

In practice, this meant that the practical test and questionnaire P1 were completed by pupils in SIV (and by a few pupils in SV) while questionnaire P2 was completed by a mixture of pupils in SIII and SIV (according to which pupils had just completed the specific experiments.)

4. The two most popular objectives which teachers had added in their response to their second questionnaire were included in the list of statements sent to pupils. (See Appendix 4.1.)
5. It was thought that pupils were not in a position to be able to comment on teaching advantages. However, some aspects of the points raised by teachers (see tables 3.2 and 3.3) were included as true/false questions on the back of questionnaire P1.

A letter was sent to schools asking them if they would be willing to take part in this part of the research : on receiving favourable replies, questionnaires P1 and P2 and the practical test were despatched. 30 schools received P1 and 25 schools received P2.

Response to the Questionnaires

Questionnaire P1 was returned by 22 schools (73%) and P2 by 13 schools (59%). No reminder was sent because the S.C.E. examinations had started within a short time of the issue of the questionnaires ; schools which had forgotten to have the questionnaires filled in would not have been able to contact their pupils until the end of the examinations.

It was felt that the response was very praiseworthy, bearing in mind the pressure under which schools and pupils are working at that time during the session.

In total, 1,236 pupils completed P1. The number of pupils completing the sections of P2 devoted to each experiment varied depending on which classes had just done each experiment. The average number of pupils completing each section of P2 was 620.

The views expressed reflected the pupils' opinions in the final term of session 1973 - 74.

Treatment of Results

In order to maintain consistency of treatment, the responses of the pupils to both questionnaires were scored using the system already described in chapter 3. It was felt that the use of the same system would allow some comparison to be made between teachers' and pupils' opinions, Again, small differences would be ignored. The system used was -

+1 point for a tick in the " true " column
0 point for a tick in the " fairly true " column
-1 point for a tick in the " untrue " column.

Results

The results obtained by analysis of the questionnaires will be discussed separately.

Questionnaire P1 (General practical work)

Results can be considered under several headings -

(a) Total Scores The total score for each statement in the questionnaire was calculated, and an order was drawn up. This is shown in table 4.1. Two orders are shown in this table : order 1 is the complete order including all 12 statements and order 2 is the order obtained when statements 11 and 12 are excluded. (These were not contained in the teachers' questionnaire.) A difference 'd' between pupils' score and teachers' score is also shown for statements 1 to 10. This difference indicated the degree of divergence between the teachers' sense of the importance of an objective and the pupils' sense of their achievement of that objective.

When any comparison between pupils and teachers was being made, the scores etc. for the teachers were calculated only from the 22 schools which also returned questionnaire P1.

The Pearson correlation coefficient between the two sets of scores was calculated and found to be $r = 0.28$ (not significant). This lack of correlation and the variability of the value of 'd' from one objective to another would suggest that the pupils' snese of achievement was not a reflection of the teachers' sense of importance of an objective. (If pupils had simply been reticent in commiting themselves but had nevertheless felt most achievement in those areas which teachers felt to be most important, then the value of 'd' would have been fairly constant and large and the value of r would have been positive and

Table 4.1 Results of Analysis of Questionnaire P1

Number in P1	STATEMENT As a result of doing practical work in chemistry, YOU -	PUPILS Average score	 Rank order 1	 Rank order 2	TEACHERS Average score	 Rank order	'd'
1.	Have become interested in and enjoy chemistry	0.2	8½	7½	0.7	3	-0.5
2.	Realise that chemical theory is a desription of real observable behaviour	0.4	5½	4½	0.8	3	-0.4
3.	Are able to design an expt. to investigate a problem	-0.2	11	10	-0.1	9½	-0.1
4.	Are able to draw conclusions from experimental results	0.2	8½	7½	0.9	1	-0.7
5.	Have developed a sense of curiosity	0.1	10	9	0.2	8	-0.1
6.	Are able to handle apparatus and chemicals	0.5	3	2½	0.3	7	0.2
7.	Are able to carry out your teachers instructions	0.4	5½	4½	0.6	5	-0.2
8.	Are able to work safely and tidily in the laboratory	0.3	7	6	0.7	3	-0.4
10.	Realise that practical work is limited in accuracy	0.6	1	1	0.1	9½	0.5
9.	Are able to record results and observations	0.5	3	2½	0.5	6	0.0
11.	Realise the need to cooperate in a group	0.5	3	N/A	N/A	N/A	N/A
12.	Behave better in class	-0.3	12	N/A	N/A	N/A	N/A

'd' = (Pupils' average score) - (Teachers' average score) significant. Neither of these was found.)

Bearing in mind the reservations regarding the scoring system, it was felt that the value of 'd' was especially high in three cases -

Statement 1 (Develop an interest and enjoyment in chemistry)
- d was large and negative.

This indicated that the enjoyment and interest in chemistry which the pupil obtained was less than that which the teacher would like him to obtain. Three suggestions might be made to account for this -

(i) The pupil chooses to study O-grade chemistry at the end of S II and his decision will be based on his experience of chemistry (or science) in SI and II. The courses followed in SI and II are generally shallow in treatment - in that they establish simple skills and basic principles with the minimum of " theory " and the maximum of experimentation by pupils. This approach may lead to practical work which is novel and enjoyable, but which leads to a false impression of what SIII and IV chemistry will be like. The pupil then finds the more serious experimental work in SIII and IV to be less enjoyable than he expected.

(ii) The pupil who chooses to study O-grade chemistry may do so for a variety of reasons. It may be chosen with a career or university in mind, by girls who intend to study domestic science, by pupils who enjoyed SI and II science but do not intend to use chemistry in their later studies or employment, and finally by pupils who have to fill up some spaces in their timetable. These pupils will cover a wide range of ability - it is hoped that questionnaire P1 sampled opinion from all such abilities.

It is clear that a course which involves a terminal examination must include practical work which is vital to the establishment of basic theoretical principles and that such practical work will not be found enjoyable by every group of pupils mentioned above. This will be particularily true of the groups containing pupils of lower ability.

(iii) It is possible that there are two kinds of enjoyment to be got from an experiment - the enjoment of " doing things " and the " intellectual " enjoyment of understanding new ideas or discovering new relationships in chemistry. The number of pupils who are mature enough to obtain the latter enjoyment is small (especially in S III) and therefore the principal source of enjoyment for most pupils will be in " doing things ". It is possible that " doing things " becomes routine and therefore less enjoyable for many pupils before the end of the course (and in some cases may have become routine before the end of S II.)

Statement 4 (Be able to draw conclusions from experimental results).
- d was large and negative.

Teachers considered this to be the most important objective of practical work. Pupils ranked it $8\frac{1}{2}$ out of 12. There are several possible explanations -

(i) The drawing of conclusions - especially those involving abstract concepts - requires the pupil to have reached Piaget's stage of Formal Operations[13]; significant numbers of pupils will not have reached this stage at the beginning of SIII. (Indeed, some pupils may not have reached this stage at the end of SIV.)

(ii) Perhaps the most common method used by teachers to round off an experiment is to discuss the results with the whole class after the completion of the experiment. During this discussion, which may be the time which most pupils associate with " drawing conclusions ", some pupils may not contribute any ideas because most of the discussion may be centred around a few pupils and the teacher.

(iii) It may be that the pupil feels that he is unable to draw conclusions because the conclusions he comes to are not those drawn by the teacher at the end of the experiment. The teacher may use the experimental results / observations to draw conclusions or establish facts which the pupil could not have possibly have gleaned from his practical work. For example, a pupil might, after testing a variety of substances for conduction of electricity, conclude that " gases do not conduct electricity " or " solutions conduct electricity " etc. and the pupil will be able to predict with reasonable accuracy whether a new substance will be a conductor. All this can be done on the basis of his practical activity. However the teacher may use the same results to establish the idea of ions - although this is not a " conclusion " which the pupil could come to on the basis of his activity.

It may often be forgottem by the teacher that the things which the pupil observes, barring accidents, are the " facts " andthat the subsequent " conclusions " may not be facts, but are postulates.

<u>Statement 10</u> - (Realise that practical work is limited in accuracy) - d was large and positive

Judging from the results, pupils seem to feel that they are well acquainted with the idea of limitation in accuracy.

In the writer's experience, this is generally not the case. The above result was treated with scepticism because pupils performed badly on the questions on this topic in the practical test (see chapter 5).

It is suggested that pupils misinterpreted the statement as meaning - " Realise that experiments often do not work properly."

It was noted that in the statements referring to the " mechanical " aspects of practical work such as statement 6 (are able to handle apparatus and chemicals) and 9 (are able to record observations and results) the pupils' sense of achievement was closely similar to the teachers' sense of importance of these abilities.

Of the two extra statements added in P1, pupils felt that they realised the need to cooperate in a group (this statement ranked equal third in the pupils' order) although only four teachers out of 107 added this objective to their questionnaire. The pupils disagreed with the idea that they behave better in class as a result of doing practical work.

(b) The Distribution of Score This was found for each statement 1 to 10 and is shown in figure 4.1. The following points were noted.

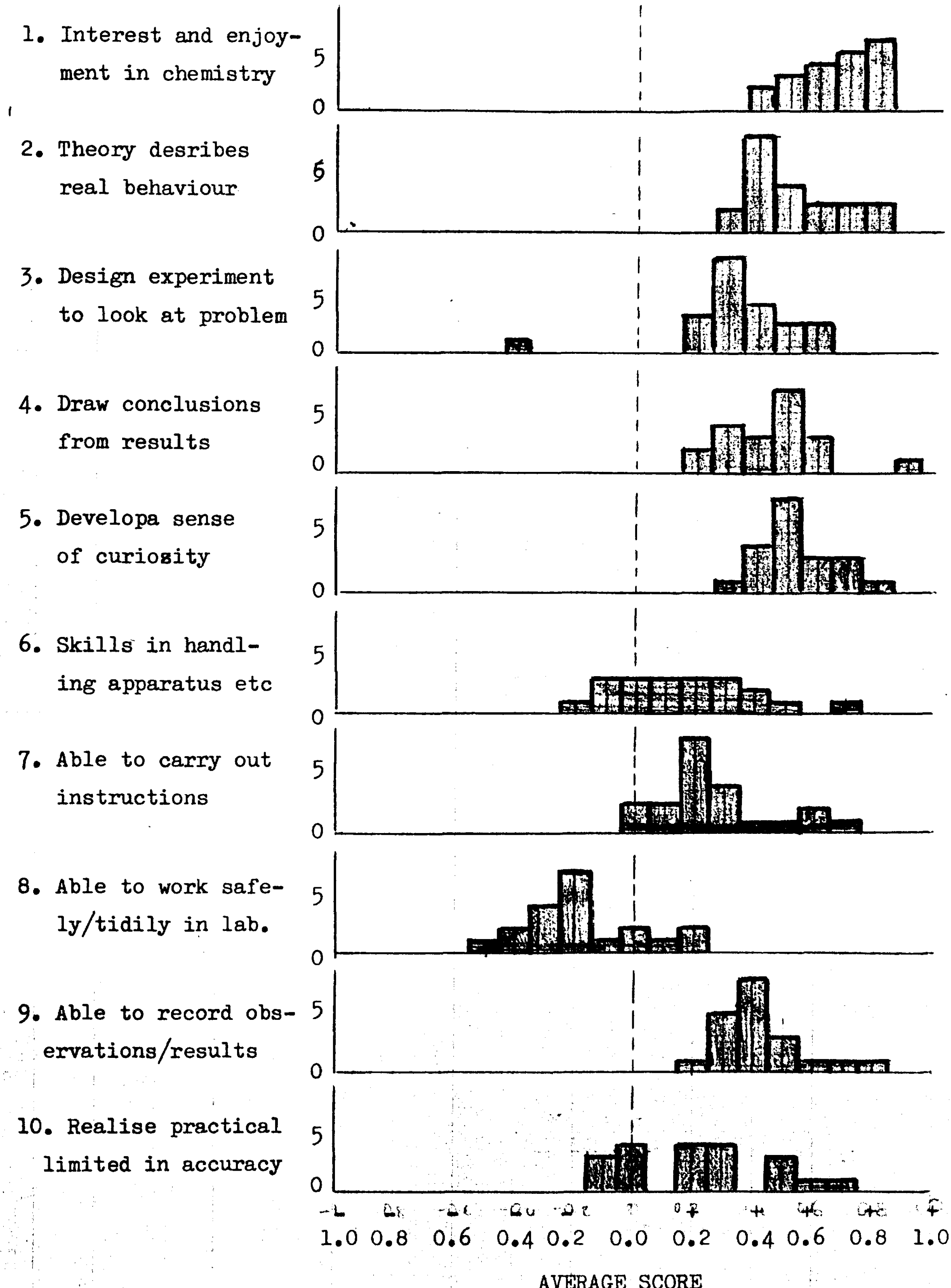
(i) In all cases except three, the mean score was also the most frequent score. The exceptions were statement 10 (limitations in accuracy) where scores were very high and were skewed towards the maximum score) and statements 1 (interest and enjoyment) and 5 (develop a sense of curiosity) where the scores were widely and evenly spread. Both statements 1 and 5 describe the development of attitudes and might be considered to be the two statements which were most subject to influence by the attitude of the teacher to the pupils and to chemistry. It was also noted that when individual schools were examined, the average scores for statements 1 and 5 were within 0.2 points of each other in 17 schools out of 20. This might indicate that these statements were being influenced by a common factor - possibly the teacher's attitude.

(ii) It was thought that the variation in score of the statements concerned with mechanical skills might be influenced by " practice " factors such as the number of experiments done or the time spent in chemistry. Correlation coefficients were calculated using average scores from P1 and information for that school from the teachers' first questionnaire. The correlations are shown in table 4.2 and the significant correlations are discussed below.

Statement 3 (able to design an experiment to investigate a problem)
with Number of experiments done by pupils $r = 0.35$ at 5%
with Number of demonstrations $r = -0.58$ at 1%

This would suggest that pupils' insight into the functions of apparatus and the logic behind methods of investigation was greater when they had much experience in handling the apparatus themselves. Since such insight did not seem to be gained by pupils who watched a large number of demonstrations, it might be inferred that teachers tend not to dwell on the reasons for using a particular experimental set-up. Some confirmation of this inference was later obtained in the analysis

Figure 4.1 The Distribution of Average Pupils' Score



(Results included from 20 schools)

Tble 4.2 Correlation coefficients

The value of Pearson's r is shown and the significance is given in brackets (if 10% or better).

Statement	Time Allocation	Total No. of Expts	Number of Pupil Epts.	Number of Demonstrations
1. Have become interested in and enjoy chemistry	0.22	-0.07	0.07	-0.14
2. Realise that theory is a desription of real behaviour	0.10	-0.12	-0.04	-0.04
3. Are able to design an experiment to look at a problem	0.06	-0.19	0.35 (5%)	-0.58 (1%)
4. Are able to draw conclusions from experimental results	0.03	-0.40 (1%)	0.02	-0.42 (1%)
5. Have developed a sense of curiosity	-0.28	-0.30 (10%)	-0.41 (1%)	0.18
6. Are able to handle apparatus and chemicals	0.13	-0.07	0.42 (1%)	-0.56 (1%)
7. Are able to carry out your teachers written and oral instructions	0.23	-0.36 (5%)	-0.18	-0.08
8. Are able to work safely and tidily in the laboratory	0.39 (1%)	-0.22	-0.07	-0.14
9. Are able to record observations and results	0.31 (10%)	-0.05	0.30 (10%)	-0.42 (1%)
10. Realise that practical work is limited in accuracy	0.00	0.42 (1%)	0.31 (10%)	0.01

of one of the items in the practical test. (See page 54).

Statement 4 (able to draw conclusions from experimental results)

with Total number of experiments r= -0.40 at 1%

with Number of demonstrations r= -0.42 at 1%

Taken together, these results might suggest that pupils' ability to draw conclusions would be developed best by (a) allowing them to carry out the experiments and (b) not doing too many experiments. It might be that the course as it stands concentrates on too many experiments - and that the pupil needs more time during each experiment to develop this ability.

Statement 5 (develop a sense of curiosity)

with Number of experiments done by pupils r= -0.41 at 1%

with Total number of experiments r= -0.30 at 10%

These results suggest that too much experimental work leads to a reduction in the sense of curiosity possibly because (a) the pupils become blasé about apparatus and chemicals (practical work becomes routine) or (b) the carrying out of many experiments means that no time is left for pupils to carry out small investigations of their own which might arise from their activity.

Statement 6 (be able to handle apparatus and chemicals)

with Number of experiments done by pupils r= 0.42 at 1%

with Number of demonstrations r= -0.56 at 1%

It was felt that these correlations showed clearly that if the pupils were to acquire skills in handling apparatus and chemicals then they must carry out the practical work themselves. Such skills were not being fostered by watching the teacher demonstrating experiments. A similar conclusion was reached in a survey of teaching methods in the United States.[14]

Statement 7 (be able to carry out written and oral instructions)

with Total number of experiments r = -0.36 at 5%

This result was perhaps surprising. It might be that teachers who perform large numbers of experiments (by any method) were less precise in their pre-experiment instructions - leading to confusion or misunderstanding among the pupils. Alternatively, pupils who are accustomed to a lot of practical work might possibly pay less attention to instructions than those to whom practical work was less routine.

Statement 8 (be able to work safely and tidily in the laboratory) with Time allocation r = 0.39 at 1%

This correlation might be expected ; it was noted however that there was no correlation with the number of experiments performed.

Statement 9 (beable to record observations and results) with Number of experiments done by pupils r = 0.30 at 10% with Number of demonstrations r = -0.42 at 1%

The former correlation was not unexpected since the more practical work is done by the pupil, the more practice he has in recording his results. The latter correlation is more difficult to account for unless it is suggested that pupils record results only when they themselves have done the experiment, but are not expected to record results if the experiment is demonstrated.

Statement 10 (limitations in accuracy of practical work) with Total number of experiments done r = 0.42 at 1%

This correlation would be expected, whether the pupil was misinterpreting the meaning of the statement or not. (See page 37).

These results taken together indicated the importance of experimental method in the achievement of the objectives of practical work. For many of the objectives examined, the sense of achievement of the pupils who experienced many demonstrations was less than that for pupils who had performed the practical work themselves.

(c) Individual School Results Because of the method of response used in the questionnaires and the fact that a large number of pupils were responding to a statement whereas one teacher was responding to an objective, it was thought that any method of correlating individual teacher / pupil relationships would be unreliable. However it was hoped that some crude comparison could be made to see if the teacher's opinion of the importance of an objective affected his pupils' achievement of that objective. This was done as follows -.

The sample was divided for each objective into three classes depending on which box the teacher ticked in his answer to the second questionnaire. For example, using a sample of 20 schools and considering objective 9 (ability to record observations and results) -

a) 10 teachers ticked " important " - score +1
b) 10 teachers ticked " fairly important " - score 0
c) no teachers ticked " not important ". - score -1

The average score for the pupils of all teachers in each group was then calculated for that objective. Using the same example as above -

a) Average score of pupils of teachers who ticked " important " = +0.54

b) Average score of pupils of teachers who ticked " fairly important " = +0.46

This procedure was repeated for each objective and the scores are listed in table 4.3.

Bearing in mind that small differences in score were being disregarded because of reservations regarding the scoring system, it could be seen from table 4.3 that the pupils' score (sense of achievement) did not seem to be related to the teachers' score (sense of importance).

(d) True-False Statements The response to these statements is shown below. Results are given as a percentage of the total (1210 pupils). The sample is slightly smaller than for the " general objectives " part because some pupils did not notice the true-false statements which were on the back of the rest of the questionnaire.

STATEMENT		
1. The pupil thinks more about chemistry while he is doing practical work.	69%	31%
2. The pupil gets to know the teacher better in a subject involving practical work	68%	32%
3. Doing practical work gives the pupil an idea of what a chemist's job might be like	69%	31%
4. You would be lost in chemistry if there was no practical work - it would then be too difficult	65%	35%

Although the responses to statements 1 and 2 were thought to be encouraging, the opposite might be said of the response to statement 4. This response implied that, although pupils might achieve the objectives of practical work, they found the theory to be difficult. It could therefore be argued that more credit should be given in the O-grade examination for pupils' abilities relating to practical work.

Questionnaire P2 (Four specific experiments)

The total scores and the resultant order for the statements referring to each experiment are shown in table 4.4. The results from the teachers' second questionnaire are also shown for comparison and the difference 'd' between teachers' average score and pupils' average score is again calculated.

The correlation coefficients (Pearson's r) between teachers' scores and pupils' scores for each experiment were calculated. They were found to be -

Experiment 6 (Mobility of ions) .... r=+0.72 at 5%

Experiment 30 (Heats of neutralisation) .... r=+0.91 at 1%

Table 4.3 Score according to teacher response

Statement As a result of doing practical work in chemistry, you -	Average Pupil Score Teacher ticked IMPORTANT	 FAIRLY IMPORTANT	 NOT IMPORTANT
1. Have become interested in and enjoy chemistry	0.24	0.14	-
2. Realise that chemical theory is a description of real behaviour	0.44	0.28	-
3. Are able to design an experiment to investigate a problem	-0.10	-0.15	-0.32
4. Are able to draw conclusions from experimental results/observations	0.32	0.25	-
5. Have developed a sense of curiosity	0.10	0.23	-0.10
6. Are able to handle apparatus and chemicals	0.57	0.50	0.50
7. Are able to carry out your teacher's instructions	0.42	0.50	-
8. Are able to work safely and tidily in the laboratory	0.33	0.30	-
9. Are able to record observations and results	0.54	0.46	-
10. Realise that practical work is limited in its accuracy	0.60	0.70	0.45

Table 4.4 Results of Analysis of Qustionnaire P2

	STATEMENT You have...	PUPILS Average score	 Rank	TEACHERS Average score	 Rank	'd'
EXPERIMENT 6	1. Learned that conductivity in solution is a result of movement of ions	0.7	1	0.8	1	-0.1
	2. Learned that conductivity is related to the number of ions in solution	0.5	2½	0.5	4	0.0
	3. Learned that ions move at different speeds in soln.	0.5	2½	0.7	2	-0.2
	4. Used previous knowledge to solve a problem	-0.3	6	0.3	5½	-0.6
	5. Realise the importance of working systematically	0.3	5	0.3	5½	0.0
	6. Realise the importance of control of variables	0.4	4	0.6	3	-0.2
EXPERIMENT 30	1. Know the expression for the basic neutralisation	0.6	1	0.9	1	-0.3
	2. Know that reactions are accompanied by energy changes	0.5	2	0.6	2	-0.1
	3. Appreciate the idea of spectator ions	0.2	5	0.2	4	0.0
	4. See the advantages in the use of ionic equations	0.3	4	0.0	5	0.3
	5. Realise the importance of control of variables	0.4	3	0.5	3	-0.1
EXPERIMENT 47	1. Know properties of conc. sulphuric acid	0.4	2	0.5	2½	-0.1
	2. Know that its concentration affects properties	0.5	1	0.7	1	-0.2
	3. Know pure HCl is a gas	-0.1	4½	-0.5	5	0.4
	4. Can use chems. economically	-0.1	4½	-0.3	4	0.2
	5. Are able to handle a hazardous compound	0.1	3	0.5	2½	-0.4
EXPERIMENT [illegible]	1. Know structure of esters	0.1	3½	0.6	1	-0.5
	2. Know their properties/uses	0.1	3½	0.0	3½	-0.1
	3. Know that oils are esters	-0.2	6½	-0.4	6½	-0.2
	4. Understand the idea of a slow reaction	-0.1	5	0.0	3½	0.1
	5. See sophisticated apparatus	-0.2	6½	-0.5	8	-0.3
	6. Realise the everyday importance of chemicals	0.5	1	0.5	2	0.0
	7. Can use chems. economically	-0.3	8	-0.2	5	0.1
	8. Can use smell as a method of detection	0.4	2	-0.4	6½	0.8

Experiment 47 (Properties of concentrated sulphuric acid) r= +0.90 at 1%
Experiment 89 (Preparation of esters) .... r= +0.65

The last correlation (Experiment 89) was not significant.

Each experiment will be discussed separately.

<u>Experiment 6</u> (Mobility of ions) As can be seen from the correlation coefficients above, there was fairly good agreement between teachers and pupils. The only major difference was seen in objective 4 (ability to use previous knowledge to solve a problem). The pupils' response here might reflect on the style of teaching of this topic : if the experiment was approached as a problem to be solved by the pupils (i.e. " How can we obtain information about the rate of movement of ions ? Try to devise an experiment....... ") then the pupils would be more aware that they were using previous knowledge to attack a problem. A more common approach in practice might be " Today we will investigate the movement of ions in solution. The method you will use is as follows ..... ".

<u>Experiment 30</u> (Heats of neutralisation) Agreement was good between teachers and pupils on all statements.

<u>Experiment 47</u> (Properties of concentrated sulphuric acid) Agreement was again good, although it was noted that the difference in score was large for objective 5 (ability to handle a hazardous compound). This might be due to the fact that 50% of the schools sampled performed this experiment by demonstration.

<u>Experiment 89</u> (Preparation of esters) Correlation here was not good, although most values of 'd' were small. There were two exceptions to this - these were the objectives already discussed on page 30 and the results here lend support to the comments made on that page. The pupils felt strongly that they had learned that smell could be used as a method of detection - but teachers did not consider this objective to be very important, The opposite was found of the knowledge of the structure of esters - teachers felt that this was the most important objective of this experiment but pupils rated it less strongly.

It must be said that the pupils' opinion of what could be achieved as a result of doing this experiment seemed to be more realistic than the teachers' opinion with respect to objectives 1 and 8. As has already been stated on page 30, it did not seem likely that pupils could discover the structure of an ester by preparing it in a test-tube.

<u>Individual School Results</u> These results were obtained in the same way as those discussed on page 40. Results are shown in table 4.5.

As was found for the general objectives, the pupils' sense of

Table 4.5 Score according to teacher response

	STATEMENT	AVERAGE PUPIL SCORE		
		Teacher Ticked		
		Important	Fairly important	Not important
EXPERIMENT 6	1. Learned that conductivity in solution is a result of ion movement	0.7	-	0.6
	2. Learned that conductivity is related to the number of ions in soln.	0.4	0.4	-
	3. Learned that ions move at different speeds through a solution	0.4	0.6	-
	4. Used previous knowledge to solve a problem	-0.2	-0.3	-0.4
	5. Realise the importance of working systematically	0.3	0.4	0.4
	6. Realise the importance of control of variables	0.3	0.4	-
EXPERIMENT 30	1. Know the expression for the basic neutralisation reaction	0.6	0.5	-
	2. Know that reactions are accompanied by energy changes	0.5	0.5	-
	3. Appreciate the idea of spectator ions	0.1	0.2	0.2
	4. See the advantages in the use of ionic equations	-0.1	0.3	0.4
	5. Realise the importance of control of variables	0.3	0.3	0.5
EXPERIMENT 47	1. Know the properties of concentrated sulphuric acid	0.4	0.5	-
	2. Know that its concentration affects its properties	0.6	0.5	-
	3. Know that pure HCl is a gas	0.0	-0.1	0.0
	4. Can use chemicals economically	0.3	0.0	0.0
	5. Can handle a hazardous compound	0.2	0.2	-
EXPERIMENT 89	1. Know the structure of esters	0.1	0.0	-
	2. Know the properties/uses of esters	0.0	0.2	-
	3. Know that oils are esters	-0.2	-0.3	-0.3
	4. Understand the idea of a slow reactn	-0.1	-0.1	0.1
	5. See some sophisticated apparatus	-	-0.4	-0.1
	6. Realise the everyday importance of chemical compounds	0.4	0.3	-
	7. Can use chemicals economically	-	-0.1	0.1
	8. Are able to use smell as a method of detection	-	0.4	0.4

Note ' - ' indicates that no teacher ticked that box for that objective.

achievement did not seem to be dependent on the teachers' sense of importance of that objective.

Conclusions and Discussion of Chapter 4

The following general points may be made from the results shown in this chapter.

1. The pupils seemed to have a greater sense of achievement of practical skills than of intellectual attitudes.
2. The attitude of the pupil to practical work seemed to depend most on the attitude of his teacher to practical work.
3. The development of practical skills depended strongly on the methods which the teacher used to carry out the practical work. Mechanical skills were best developed by having the pupils carry out the experiments.
4. The response to the " interest and enjoyment " objective indicated a general problem with an examinable course - i.e. that not all pupils will be stimulated by the course. It should be remembered that the syllabus was presumably designed in such a way that the objective " develop an interest and enjoyment in chemistry " could be achieved. However it is possible that the conditions under which the people who designed the course evaluated topics (which were likely to promote interest and enjoyment) was different from those experienced by pupils because -

   a) pupils, especially those in SIV, are subject to the pressure of having to sit O-grade examinations. Such pressure may diminish the enjoyment of the course - particularily that part of the course covered late in SIV (sections N and O).

   b) the syllabus designers' judgement of enjoyment may have been atypical of the views of the pupils - because the intellectual ability and maturity of the designers would be greater than that of most of the O-grade pupils.

QUESTIONNAIRE TO PUPILS

This questionnaire is designed to try to discover what benefits you have gained as a result of the experiments which you do in chemistry.

This is NOT a test of any kind, and you should NOT put your name on the sheet. Please answer honestly - do not be afraid to tick box C - it will not be held against you.

Before answering, please remember that the statements, and your answer, should refer ONLY TO THE EXPERIMENTAL WORK IN CHEMISTRY - and not to the theory which your teacher does with the class.

Please think carefully about your answers.

Tick Box A if you think the statement is TRUE (i.e. the statement refers to something which you now definitely KNOW or APPRECIATE as a result of doing experimental work)

Tick Box B if you think the statement is FAIRLY TRUE.

Tick Box C if you think the statement is UNTRUE (i.e. the statement refers to something which you have not learned or realised as a result of doing experimental work)

As a result of doing experiments in chemistry, YOU -	TRUE A	FAIRLY TRUE B	UNTRUE C
1. Have become interested in, and enjoy, chemistry			
2. Realise that chemical theory is a description and explanation of the behaviour which you observe			
3. Are able to design an experiment to investigate a problem			
4. Are able to draw conclusions from your experimental results			
5. Have developed a sense of curiosity			
6. Are able to handle chemicals and apparatus			
7. Are able to carry out instructions - both written and spoken by your teacher			
8. Are able to work safely and tidily in the laboratory			
9. Are able to record observations and results			
10. Appreciate that practical work is limited in its accuracy			
11. Realise the need to co-operate in a group			
12. Behave better in class.			

Please also answer the following questions - either true or false.

	TRUE	FALSE
1. The pupil thinks more about chemistry while he is doing practical work.		
2. The pupil gets to know the teacher better in a subject involving practical work.		
3. Doing practical work gives the pupil an idea of what a chemist's job may be like.		
4. You would be lost in chemistry if there was no practical work - because chemistry would then be too difficult.		

QUESTIONNAIRE TO PUPILS

This questionnaire is designed to try to discover what benefits you have gained as a result of doing the four experiments listed below.

This is NOT a test of any kind, and you should NOT put your name on the sheet. Please answer honestly; do not be afraid to tick box C if you think that the statement is untrue - it will not be held against you.

Before answering, please remember that the statements, and your answer, should refer ONLY TO THE EXPERIMENTAL WORK IN CHEMISTRY - and not to the theory which your teacher does with the class.

In each case - Tick Box A if you think the statement is TRUE
Tick Box B if you think the statement is FAIRLY TRUE
Tick Box C if you think the statement is UNTRUE.

Experiment 1 Mobility of Ions (You measured the conductivity of solutions in order to compare the mobilities of different ions in water.)

As a result of doing this experiment, YOU	TRUE A	FAIRLY TRUE B	UNTRUE C
1. Learned that conductivity in ionic solutions is a result of the movement of ions			
2. Learned that conductivity is related to the number of ions in a solution			
3. Learned that ions move at different speeds in a solution			
4. Used previous knowledge to solve a problem			
5. Realise that it is important to organise your practical work in a systematic way			
6. Realise that the variables in an experiment must be controlled.			

Experiment 2 Heats of Neutralisation (You added equal quantities of different acids and alkalis together and measured the rise in temperature on mixing.)

As a result of doing this experiment, YOU	TRUE A	FAIRLY TRUE B	UNTRUE C
1. Know that the basic reaction in all neutralisations can be expressed as $H^+(aq) + OH^-(aq) \quad H_2O(l)$			
2. Know that chemical reactions are accompanied by energy changes			
3. Appreciate the idea of spectator ions			
4. See that there are advantages in the use of ionic equations			
5. Realise that the variables in an experiment must be controlled.			

Experiment 3 Properties of concentrated sulphuric acid. (You added the concentrated acid to substances such as sugar, copper sulphate, a chloride, a nitrate, metals such as copper and zinc.)

As a result of doing this experiment, YOU

	TRUE A	FAIRLY TRUE B	UNTRUE C
1. Know the properties of concentrated sulphuric acid			
2. Know that the concentration of sulphuric acid affects its properties			
3. Know that pure hydrogen chloride HCl is a gas			
4. Are able to use chemicals economically			
5. Are able to handle a dangerous compound.			

Experiment 4 Preparation of esters (You reacted together some alcohols and organic [carboxylic] acids to produce esters.)

As a result of doing this experiment, YOU

	TRUE A	FAIRLY TRUE B	UNTRUE C
1. Know the structure of esters			
2. Know the properties and uses of esters			
3. Know that oils are esters			
4. Understand the idea of a slow reaction			
5. Are familiar with some complicated apparatus			
6. Realise the everyday importance of chemical compounds			
7. Are able to use chemicals economically			
8. Are able to use your sense of smell as a method of detection.			

CHAPTER 5

A METHOD OF ASSESSMENT

OF

PRACTICAL WORK

Chapter 5 A Method of Assessment of Practical Work

Introduction

The assessment of practical work was traditionally done by setting a " practical examination ". This involved the pupil in carrying out a specified experiment or investigation and completing some form of written report. This type of assessment had several serious drawbacks.

a) The carrying out of only one experiment was unlikely to measure the achievement of all of the course objectives.

b) Teachers were encouraged to train their pupils in certain activities of the type needed in the examination - such as manipulative skills and measurement.

c) The organisation of such examinations on a national scale, and their administration in a school, was difficult if large numbers of pupils per class were involved. Problems of security also arose in those circumstances.

To overcome these drawbacks, assessment of practical work in which the class teacher measures his pupils' abilities was proposed and tried.[15] It was shown in England that teachers preferred this method to the use of a terminal examination[16]. In various trial studies in England and Wales[17,18], the teacher, on the basis of his observation of the work of his pupils throughout the course, drew up an order of merit for the class (or completed a form giving details of pupils' abilities in specific skills, this form then being used to draw up an order of merit). For such an assessment procedure to be used in a number of schools, some method of relating the standard of practical ability in one school to that in another was needed. This comparison ("moderation") could be done in a variety of ways. For example -

a) By marking experimental reports written by the pupils

b) By using the marks in part or all of the terminal written or objective examination

c) By using a specially constructed test.

Whichever system of moderation was chosen, it would have to show significant positive correlation with the teachers' assessed order of merit and must assess the same objectives as those on which the teachers' rank order was produced.

Aim

The aim of this section of the research was to investigate the assessment of practical work by teachers and to relate it to the pupils' performance on a specially designed " paper and pencil " test.

Experimental Design

The design of the experiment can be considered in two parts.

a) The Method of Assessment by the Teacher. Two methods were used for this assessment -

1. In a preliminary study carried out before the results of the teachers' questionnaire on objectives were known, the class teacher was asked, on the basis of his knowledge of his pupils' practical ability, to construct an order of merit for the class.

2. When the results of the teachers' questionnaire on objectives were known, these were used to draw up a grid of skills and abilities which the class teacher would fill up for each pupil. The grid contained six categories of ability which were related to the objectives suggested by teachers, but some, as can be seen from the list below, were composites of several of these objectives. It was felt that a balance had to be struck between reliability (using many categories of clearly defined objectives) and practicability (since each category had to be completed for every pupil). The six categories were -

(1) Ability to draw conclusions from experimental results and to relate experiments to the theoretical work.

(2) Ability to work safely and tidily in the laboratory.

(3) Showing an interest and enjoyment in chemistry.

(4) Ability to carry out written / oral instructions.

(5) Ability to report / record observations and results.

(6) Ability in the handling of apparatus and chemicals.

The categories are shown in their order of importance according to teachers. Teachers were asked to grade each pupil on a five-point scale for each category. The scale to be used was -

A - very good
B - good
C - average
D - poor
E - very poor

It should be pointed out that the use of a grid containing six categories involved the teacher, in his non-teaching time, in allocating 120 individual grades for an average-sized class.

The grid which teachers were asked to complete is shown in Appendix 5.1.

b) The Test of Practical Work. It was decided that the paper and pencil test would be an objective test - i.e. one in which the pupil selected one appropriate answer from a list of four given responses. Such a test was not subject to value judgments in marking since there was only one correct answer (the key).

Two tests were constructed -

1. A preliminary test was made up ; as stated previously, this was done before the teachers' objectives had been established.

2. A second test was made up which was based on the teaching objectives drawn from the teachers' second questionnaire. This test also incorporated some modifications which were thought to be necessary as a result of experience gained from the preliminary test. These will be discussed later.

The Preliminary " Paper and Pencil " Test

This test was tried out in one school in June 1973. 120 pupils in six classes took part and three teachers were involved.

Each teacher was asked to construct an order of merit for each class on the basis of the pupils' abilities in practical work. No guidance was given as to the criteria to be considered in the construction of the order of merit. The pupils then sat the objective test (see Appendix 5.2) which consisted of 20 items. All items had four responses of which only one was correct. The pupil recieved one mark for choosing the correct response and no mark if he chose an incorrect response.

The marks obtained by the pupils in the test were then used to construct a second order of merit. The Spearman rank order correlation coefficient 'R' was then calculated for each class in order to establish whether any relationship existed between the teachers' estimate rank order and the pupils' test rank order. Results are shown in table 5.1.

The results suggested that either the method of assessment by the teacher or the objective test (or both) needed to be modified. The following points were considered.

a) The method of assessment by the teacher was too subjective in that it might be influenced by external factors such as ability in written examinations, class behaviour, the pupils' role in group work, etc.. It was thought that the use of a grid of skills and attitudes would improve objectivity. Also the use of a grid meant that the teacher was not actually involved in the construction of the order of merit (- this was done externally -) . Rather he was making comparisons of pupils' abilities against an impersonal scale and was not comparing one pupil to another.

b) The preliminary test did not assess the achievement of all of the objectives considered by teachers in their questionnaire. Too much emphasis had been placed on the knowledge and selection of apparatus

Table 5.1 Results of Preliminary Test

Spearman rank order correlation coefficient shown for teachers' estimate rank order against pupils' test rank order.

Teacher	Class Name	Number of Pupils	Spearman's R	Significance
Mr.A	IV (1)	22	-0.01	no
Mr.A	IV (5)	20	0.06	no
Mr.A	V (2)	22	0.08	no
Mr.B	IV (2)	21	0.22	no
Mr.B	V (3)	17	0.43	no
Mr.C	IV (4)	19	0.53	5%

Table 5.2 Revised Test - Teachers' Assessment - Second Scoring Method

Category/Objective	Teachers' Order of Importance	Assessment Grades - Points Awarded				
		A	B	C	D	E
1	1	+12	+6	0	-6	-12
2	2	+10	+5	0	-5	-10
3	3	+ 8	+4	0	-4	- 8
4	4	+6	+3	0	-3	- 6
5	5	+ 4	+2	0	-2	- 4
6	6	+ 2	+1	0	-1	- 2

Category 1 - Ability to draw conclusions from results and to relate experiments to the theoretical work

Category 2 - Ability to work safely and tidily in the laboratory

Category 3 - Showing an interest/enjoyment/cuiosity in chemistry

Category 4 - Ability to carry out written/oral instructions

Category 5 - Ability to record/report observations and results

Category 6 - Ability in the handling of apparatus and chemicals and not enough on the drawing of conclusions from experimental observations and results.

c) It was thought that in some cases, and especially where judgement is involved, credit should perhaps be given to pupils for a second-best answer. This would mean that the strictly objective format would be upset.

The Revised " Paper and Pencil " Test

This test was given to 576 pupils in 36 classes and involved 10 schools. It was set in April 1974. Each school recieved a " Teacher's Assessment Sheet " (Appendix 5.1) copies of the revised test (Appendix 5.3) and an answer sheet for each pupil (Appendix 5.4).

1. The Teacher's Assessment The teacher was asked to complete the grid of skills and attitudes for each pupil. The set of grades was transformed into an order of merit by two methods -

a) Each category in the grid was treated alike and the A to E grades were transformed into a 5 to 1 point scale. Total points for each pupil were calculated and an order of merit constructed for each class.

b) Each category in the grid was scored differently according to the teachers' view of the importance of the objectives in that category. The system used for transforming grades into points is shown in the table 5.2. Again total points were calculated for each pupil and an order of merit constructed for each class.

In practice, the orders of merit produced by systems a) and b) were closely similar. In only 24 cases out of 576 (4%), the pupil's position in the two rank orders differed by 2 places or more. The system b) produced fewer cases of equal score (and hence equal rank) than system a).

2. The Objective Test Format. After the teacher had assessed his pupils, they were set the practical test. In the light of experience gained from the preliminary test, the items used were of three types -

a) Standard objective items were used. These had four responses, of which only one was correct. These items made up Part 1 of the test. (Items numbered 1 to 10).

b) Modified objective items were used. These had four responses of which one or several might be correct. These items made up Part 2 of the test. (Items numbered 11 to 23).

c) A second type of modified objective item was used. These contained four responses which described courses of action open to a pupil in a given situation. Pupils were instructed to choose one resonse, but marks were awarded for more than one response and half-marks were given for second-best answers. These items, which were mainly concerned with attitudes, made up Part 3 of the test. (Items numbered 24 to 28).

All items were designed with the teachers' objectives in mind. It was hoped that the number of items testing each objective would be related to the importance of that objective. In practice, this was found to be difficult to arrange because of the problems associated with assessing certain skills by objective items.

The objective or objectives being tested by each item are shown in table 5.3. As can be seen from this table, certain objectives were thought to be most conveniently assessed by using one of the three types of item. For example, the " drawing of conclusions " was tested using type b) items. This was thought to be reasonable since a pupil would normally be expected to consider a variety of possibilities and to select as many conclusions as were appropriate and valid. Similarily, the attitudes " interest, enjoyment and curiosity " were assessed using type c) items, since these could incorporate possible " desirable behaviour " by a pupil in an imaginary situation rather than involving a single correct answer.

The pupil was allowed 40 minutes to complete the test.

<u>Marking of the Test</u> It was decided that the modified test would be marked using three systems. These were -

<u>System 1</u> - All correct responses in parts 1 and 2 recieved one mark. Answers in part 3 recieved one mark or one-half mark. This was the simplest system and allowed for rapid marking. The maximum possible score was 37 marks.

<u>System 2</u> - In this, the number of marks allocated to items was weighted in such a way that the objectives considered by teachers to be most important recieved the most marks. The distribution of marks among the objectives is shown in table 5.4. The maximum possible score was 46 marks.

<u>System 3</u> - Again marks were weighted to reflect importance. Also, credit was given for boxes which the pupil had <u>not</u> ticked (and which corresponded to an incorrect response) in part 2 of the test. This system was tried because it was thought possible that some pupils might tick all four responses in part 2 whether they thought them to be correct or not. System 3 would penalise such pupils, but systems 1 and 2 would not. The distribution of marks among the objectives is also shown in table 5.4. The maximum possible score was 52 marks.

A summary of the number of marks obtained for each pupil's tick for any item is shown in table 5.5.

In each case, marks were transormed into an order of merit for

Table 5.3 Objectives Tested by Each Item

Objectives The pupil should (as a result of practical work)....

1. Show an interest and enjoyment in chemistry
2. Appreciate that the theory is a desription of real observable behaviour
3. Be able to design an experiment to investigate a problem
4. Be able to draw conclusions from experimental results
5. Develop a sense of curiosity
6. Acquire skills in the handling of apparatus and chemicals
7. Be able to carry out written/oral instructions
8. Be able to wotk safely and tidily in the laboratory
9. Be able to record observations and results
10. Appreciate that practical work is limited in its accuracy

Item Number		1	2	3	4	5	6	7	8
Primary Objective		6	7	8	10	8	6	8	6
Secondary Objective		-	-	-	5,4	-	-	6	8
Item no.	9	10	11	12	13	14	15	16	17
Primary Ob.	3	9	2	4	2	4	2	4	7
Second. Ob.	-	-	4	-	4	-	4	-	-
Item n0	18	19	20	21	22	23	24	25	26
Primary Ob.	2	3	8	7	4	4	1	5	1
Second Ob.	3,6	2	-	-	10	-	5	1	-
Item no.	27	28							
Primary Ob.	5	10							
Second. Ob.	-	-							

Objective		1	2	3	4	5	6	7	8	9	10
Rank in Importance		3	3	9½	1	8	7	5	3	6	9½
Number of Items	Primary	2	4	2	5	2	3	3	4	1	2
	Secondary	1	2	1	4	2	1	0	1	0	1

Table 5.4 Number of Marks Allocated to Each Objective

Objective	Rank Order of Importance	Percentage of Total Number of Marks		
		System 1	System 2	System 3
1. Interest and enjoyment in chemistry	3	5	15	14
2. Theory is a desription of real behaviour	3	22	15	14
3. Design an experiment to investigate a problem	9½	8	7	5
4. Draw conclusions from experimental results	1	22	20	17
5. Develop a sense of curiosity	8	5	9	7
6. Skills in the handling of apparatus and chemicals	7	8	9	7
7. Carry out written and oral instructions	5	8	9	12
8. Work safely and tidily in the laboratory	3	14	17	15
9. Record observations and results	6	3	7	5
10. Practical work is limited in its accuracy	9½	5	7	3

Table 5.5 Marks Scored for Each Response

ITEM	SYSTEM 1				SYSTEM 2				SYSTEM 3			
	A	B	C	D	A	B	C	D	A	B	C	D
1.	-	-	1	-	-	-	$\frac{1}{2}$	-	-	-	$\frac{1}{2}$	-
2.	1	-	-	-	2	-	-	-	1	-	-	-
3.	-	-	1	-	-	-	2	-	-	-	3	-
4.	-	-	-	1	-	-	-	1	-	-	-	1
5.	-	1	-	-	-	-	1	-	-	-	1	-
6.	-	1	-	-	-	$\frac{1}{2}$	-	-	-	$\frac{1}{2}$	-	-
7.	-	-	-	1	-	-	-	1	-	-	-	1
8.	-	-	-	1	-	-	-	1	-	-	-	1
9.	-	1	-	-	-	1	-	-	-	1	-	-
10.	-	-	1	-	-	-	3	-	-	-	3	-
11.	1	1	-	1	1	1	-	1	$\frac{1}{2}$	$\frac{1}{2}$	E$\frac{1}{2}$	$\frac{1}{2}$
12.	-	-	1	1	-	-	1	1	E$\frac{1}{2}$	E$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
13.	1	1	-	-	1	1	-	-	$\frac{1}{2}$	$\frac{1}{2}$	E$\frac{1}{2}$	E$\frac{1}{2}$
14.	1	-	-	-	1	-	-	-	$\frac{1}{2}$	E$\frac{1}{2}$	E$\frac{1}{2}$	E$\frac{1}{2}$
15.	-	-	1	-	-	1	-	-	E$\frac{1}{2}$	E$\frac{1}{2}$	$\frac{1}{2}$	E$\frac{1}{2}$
16.	1	-	-	1	1	-	-	1	$\frac{1}{2}$	E$\frac{1}{2}$	E$\frac{1}{2}$	$\frac{1}{2}$
17.	-	-	1	-	-	-	1	-	E$\frac{1}{2}$	E$\frac{1}{2}$	$\frac{1}{2}$	E$\frac{1}{2}$
18.	-	-	1	1	-	-	$\frac{1}{2}$	$\frac{1}{2}$	E$\frac{1}{2}$	E$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
19.	1	-	-	1	1	-	-	1	$\frac{1}{2}$	E$\frac{1}{2}$	E$\frac{1}{2}$	$\frac{1}{2}$
20.	-	-	1	1	-	-	2	2	E1	E1	1	1
21.	-	-	-	1	-	-	-	2	E1	E1	E1	1
22.	-	-	1	1	-	-	1	1	E$\frac{1}{2}$	E$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
23.	-	-	1	-	-	-	1	-	E$\frac{1}{2}$	E$\frac{1}{2}$	$\frac{1}{2}$	E$\frac{1}{2}$
24.	1	-	-	1	1	-	-	1	2	-	-	2
25.	$\frac{1}{2}$	1	$\frac{1}{2}$	-	1	2	1	-	1	2	1	-
26.	1	-	-	$\frac{1}{2}$	2	-	-	1	2	-	-	1
27.	-	$\frac{1}{2}$	1	-	-	1	2	-	-	1	2	-
28.	1	$\frac{1}{2}$	-	-	1	$\frac{1}{2}$	-	-	1	$\frac{1}{2}$	-	-

Note '-' means ' no marks for that response '.

E$\frac{1}{2}$ means 'one-half mark if that response has not been ticked'.

each class.

Overall Results from the Revised Test As already discussed, the two teachers' assessment grades and the three pupils' test scores were transformed into orders of merit for each class. Spearman rank order correlation coefficients were then calculated for each combination of assessment method and marking system.

The complete set of correlation coefficients for all classes and their significance is shown in table 5.6.

The number of correlation coefficients of each particular significance is summarised below.

ASSESSMENT METHOD	MARKING SYSTEM	SIGNIFICANT AT 1%	5%	10%	NOT SIGNIFICANT
1	1	2	3	7	24
1	2	2	4	7	23
1	3	1	6	6	23
2	1	2	4	7	23
2	2	2	3	10	21
2	3	1	7	5	23

It was seen that Marking System 3 gave poorer correlations than the others but that Marking Systems 1 and 2 and Assessment Methods 1 and 2 were very similar in their degree of correlation. It was also noted that only 9 of the total of 216 correlation coefficients were negative in sign. Therefore it was decided that a chi-squared test should be carried out. The assessment marks (using Metod 2) and the test marks (using System 1) were transformed into a set of grades A to E where the percentage of pupils in each grade was kept constant for all classes. The grades corresponded approximately to the areas under a normal distribution curve within one and two standard deviations from the mean - i.e.

Grade	A	B	C	D	E
% of Pupils in that Grade	10%	20%	40%	20%	10%

The grades were then used to construct table 5.7. The " observed frequency " in each box shows the number of pupils who obtained that assessment grade and that test grade. (e.g. 8 pupils who recieved assessment grade A also obtained test grade A). The " expected frequency " is calculated on the assumption that the number of pupils in each box is random (i.e. that there is no relationship between a pupil's assessment grade and his test grade). χ^2 was calculated using the formula shown in table 5.7.[19]

Table 5.6 Corrèlations for the Revised Test

Notes on the table ;

E1 and E2 are the two methods of scoring the teachers' assessed (or estimate) rank order.

T1, T2 and T3 are the three scoring systems for the marking of the pupils' answers to the revised "paper and pencil" test.

The class code - 03/3 means - school number 03, class number 3.

Figures shown are Spearman rank order correlation coefficients.

Figures in brackets are the significances of the values of Spearman's R.

CLASS CODE	SIZE OF CLASS	Correlation of					
		E1-T1	E1-T2	E1-T3	E2-T1	E2-T2	E2-T3
01/1	19	0.39 (10%)	0.40 (10%)	0.33	0.37 (10%)	0.40 (10%)	0.32
01/2	20	0.14	0.11	0.11	0.16	0.12	0.08
02/1	18	0.32	0.33 (10%)	0.42 (10%)	0.33	0.38 (10%)	0.45 (10%)
02/2	9	0.18	0.24	0.29	0.47	0.45	0.56
03/1	23	0.18	0.23	0.15	0.16	0.23	0.14
03/2	19	0.08	0.08	0.06	-0.12	-0.10	0.05
03/3	19	0.13	0.31	0.27	0.18	0.27	0.31
04/1	14	0.66 (5%)	0.80 (1%)	0.75 (1%)	0.77 (1%)	0.85 (1%)	0.81 (1%)
04/2	22	0.58 (1%)	0.50 (5%)	0.53 (5%)	0.55 (5%)	0.50 (10%)	0.52 (5%)
04/3	14	0.39	0.31	0.25	0.40	0.33	0.25
05/1	20	0.23	0.14	0.25	0.25	0.14	0.26
05/2	9	0.57 (10%)	0.36	0.31	0.52	0.32	0.34
06/1	14	0.22	0.53 (10%)	0.22	0.54 (5%)	0.51 (10%)	0.21
06/2	11	0.50 (10%)	0.57 (10%)	0.46	0.44	0.55 (10%)	0.44
06/3	19	0.07	0.13	-0.03	0.06	0.14	-0.02
06/4	23	0.32 (10%)	0.35 (10%)	0.36 (10%)	0.37 (10%)	0.40 (10%)	0.45 (5%)
06/5	15	-0.13	0.04	-0.25	-0.19	0.06	-0.23
07/1	7	0.64	0.55	0.58	0.64	0.55	0.58
07/2	23	0.13	0.04	0.14	0.21	0.17	0.27
08/1	10	0.51	0.58 (10%)	0.61 (10%)	0.57 (10%)	0.67 (5%)	0.61 (10%)
08/2	11	0.20	0.28	0.35	0.20	0.27	0.25

(contimued)

Table 5.6 (Continued)

CLASS CODE	SIZE OF CLASS	Correlation of					
		E1-T1	E1-T2	E1-T3	E2-T1	E2-T2	E2-T3
09/1	14	0.50 (10%)	0.36	0.49 (10%)	0.43	0.23	0.54 (10%)
09/2	22	0.48 (5%)	0.44 (5%)	0.43 (5%)	0.42 (10%)	0.38 (10%)	0.38 (10%)
09/3	14	0.11	0.18	0.45 (10%)	0.32	0.33	0.60 (5%)
09/4	8	0.35	0.32	0.42	0.38	0.33	0.41
10/1	17	0.27	0.00	0.41 (10%)	0.26	-0.06	0.28
10/2	17	0.22	0.19	0.19	0.30	0.25	0.23
10/3	17	0.42 (10%)	0.48 (10%)	0.33	0.41 (10%)	0.47 (10%)	0.34
10/4	15	0.41	0.40	0.53 (5%)	0.46 (10%)	0.45 (10%)	0.55 (5%)
10/5	16	0.16	0.12	0.01	0.16	0.12	0.01
10/6	16	0.16	0.28	0.25	0.16	0.28	0.26
10/7	15	0.49 (10%)	0.54 (5%)	0.05	0.55 (5%)	0.61 (5%)	0.11
10/8	14	0.64 (5%)	0.58 (5%)	0.60 (5%)	0.62 (5%)	0.56 (5%)	0.58 (5%)
10/9	15	0.49 (10%)	0.50 (10%)	0.53 (5%)	0.48 (10%)	0.47 (10%)	0.54 (5%)
10/10	18	0.65 (1%)	0.65 (1%)	0.56 (5%)	0.64 (1%)	0.64 (1%)	0.55 (5%)
10/11	19	0.16	0.07	0.26	0.17	0.08	0.27

Table 5.7 Table of Observed and Expectaed Frequencies

Key

f_o f_e d

f_o = observed frequency

f_e = expected frequency

$$d = \frac{(f_o - f_e)^2}{f_e}$$

The expected frequency is calculated by the expression -

$$f_e = \frac{(\text{ row total }) \times (\text{ column total })}{(\text{ grand total })}$$

Hence for the box A - A ; f_e is given by $\frac{54 \times 49}{549}$ = 4.82.

		TEACHERS' ASSESSMENT GRADE					
		A	B	C	D	E	f_o totals
TEST SCORE GRADE	A	8 4.82 2.10	22 11.61 9.30	15 22.03 2.24	5 9.93 2.45	4 5.61 0.46	54
	B	12 9.10 0.92	29 21.92 2.29	46 41.62 0.46	11 18.76 3.21	4 10.59 4.10	102
	C	19 21.51 0.29	53 51.80 0.03	105 98.33 0.45	39 44.34 0.64	25 25.02 0.00	241
	D	7 8.66 0.32	11 20.85 4.65	38 39.58 0.06	26 17.85 3.72	15 10.07 2.41	97
	E	3 4.91 0.74	3 11.82 6.58	20 22.44 0.27	20 10.12 9.65	9 5.71 1.90	55
	f_o total	49	118	224	101	57	549

$\sum d = \chi^2 = 59.24$; Degrees of freedom = (no. of rows - 1) x (no. of columns - 1) = 16.

Figure 5.1 Ditribution of Estimate Scores (Method 2)

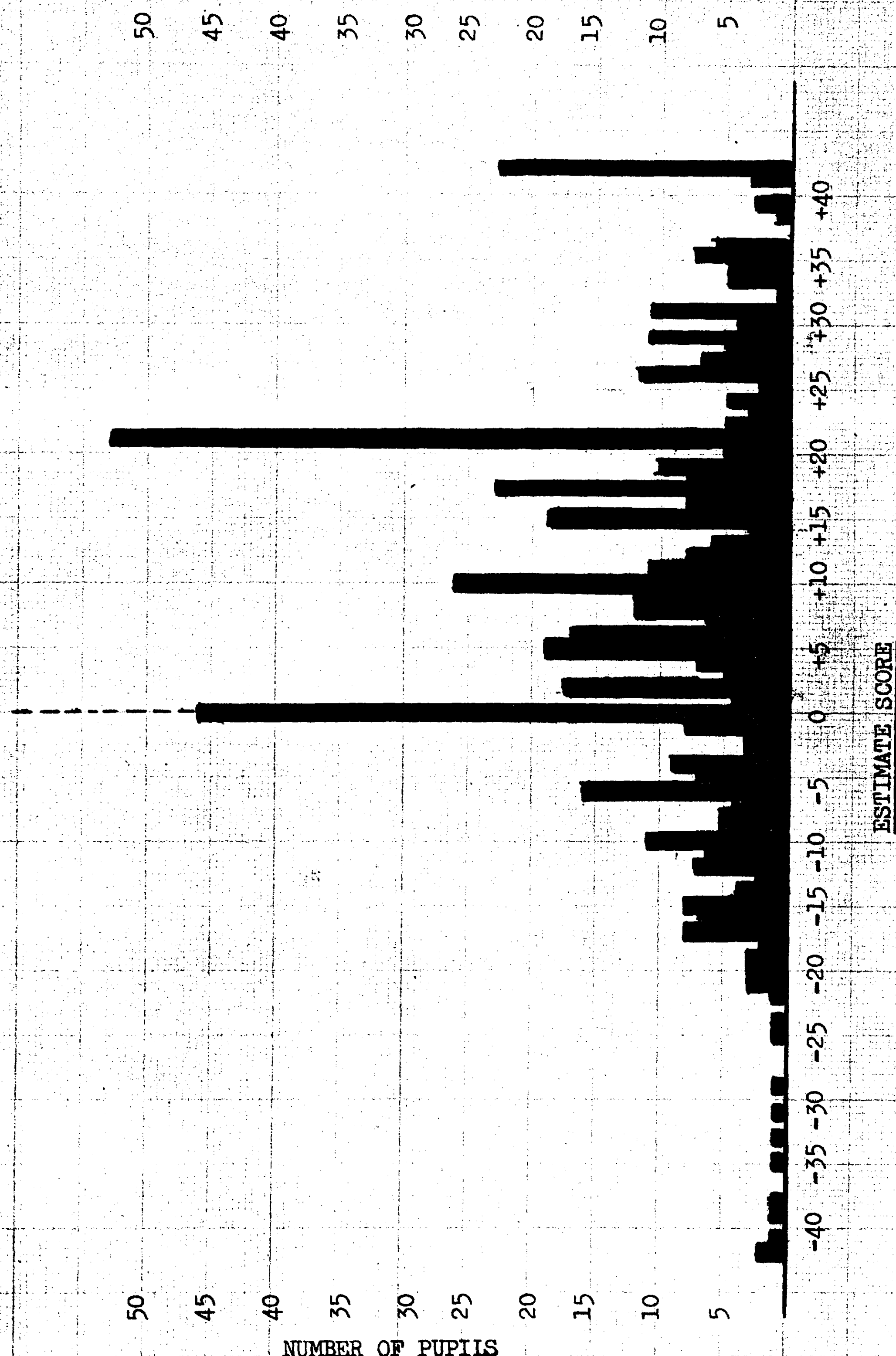
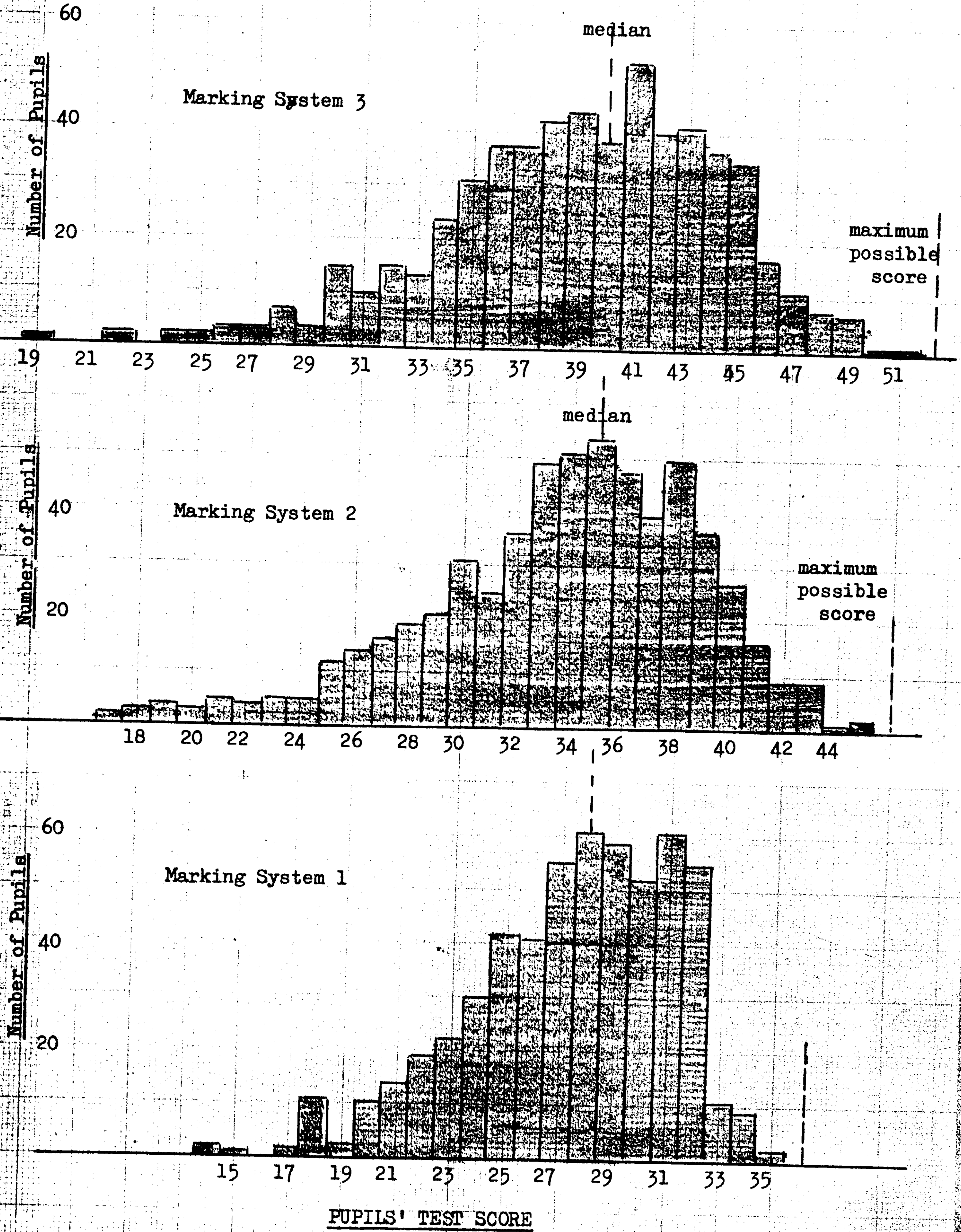


Figure 5.2 Distribution of pupils' test scores



It was found that $\chi^2 = 59.24$ for 16 degrees of freedom. This value indicated that the null hypothesis (that thereis no relationship between test grades and assessment grades) could be rejected at better than 1% significance. Hence there was a better than 99% probability that the relationship between test grades and assessment grades was not due to chance.

It was thought that this result was encouraging in that it suggested that the " paper and pencil " test was measuring the same abilities as the teachers when they assessed their pupils. Had time permitted, the following improvements would have been made -

a) All test items would have been pre-tested to measure their discrimination and facility values. (See page 52)

b) Meetings between teachers from different schools would have been helpful so that more general criteia could have been established for the allocation of estimate grades to pupils.

c) Ideally, all pupils in a school should have been set the test simultaneously to ensure that no class had fore-knowledge of the items. In practice, this would have led to disruption of classes in the trial schools, and therefore no such stipulation was made.

A more detailed analysis was carried out into the test scores and the pupils' answers to individual items.

Test Analysis

a) The Distribution of Teachers' Assessment Scores This distribution is shown in figure 5.1. Bearing in mind that in this assessment a pupil who was average in all categories should have scored 0 points, the histogram clearly showed that teachers tended to give more high grades than low grades. The peak score at 21 points corresponds to a pupil with a B grade in all categories.

b) The Distribution of Pupils' Test Scores This distribution is shown for each marking system in figure 5.2. For convenience of presentation, half-marks have been rounded up to the nearest whole number. In all marking systems, the distribution was skewed towards the high marks. The overall similarity in distribution and the similarity in the orders of merit produced by the marking systems suggested that few pupils had taken advantage of items in Part 2 by ticking more boxes than they honestly believed to be correct.

The distributions indicated that the " paper and pencil " test had been relatively " easy " and that it did not discriminate efficiently between pupils with high ability in practical work.

c) <u>Item Analysis</u> Analysis of all pupils' answers was carried out in order to compute three parameters for each item.

(i) Facility Value - this is the fraction of the sample which chooses the correct response. Facility values can range from 0.00 (all pupils selected an incorrect response) to 1.00 (all pupils selected the correct response).

(ii) Discriminatory Factor - this is the difference for each item between the facility value for the pupils with the highest scores and the facility value for the pupils with the lowest scores. In this analysis, the highest 144 and lowest 144 scores were used. (This corresponded to the top and bottom 25% of all scores.) Values of the discriminatory factor 'D' range from 0.00 (best and worst pupils answered the item equally well and the item does not therefore discriminate between these groups of pupils) to 1.00 (all "best" pupils answered correctly and all "worst" pupils answered wrongly).

(iii) The percentage of pupils choosing each response was calculated for each item.

An item may be said to be "good" at assessing a particular objective if the following criteria are satisfied -

1. Some pupils should have chosen each of the responses. A response which is incorrect and is chosen by no pupils is not functioning as a distractor. The effective number of responses is thus reduced and the chance of guessing correctly increases.
2. The item should neither be too easy nor too difficult ; it should have a facility value of between 0.30 and 0.75[20].
3. The item must discriminate between able and less able pupils since this is the function of the test as a whole. A reasonable discriminatory factor would be greater than 0.30[20].

The results of the item analysis are shown in tables 5.8 and 5.9. It should be noted that where more than one correct response was present in an item, the facility value F and discriminatory factor D were calculated for each correct answer and for combinations of correct answers. Also in items 11 to 23, the percentage of pupils choosing each response is shown for that response alone and for that response in combination with any others.

<u>Notes on the Results of the Item Analysis</u> In these notes, the phrases "top pupils" and "bottom pupils" refer to the 144 pupils (25% of the sample) who scored highest and lowest marks in the test as a whole.

Table 5.8 Item Analysis

a) Complete analysis of items 1 to 10 and 24 to 28.

b) Facility values and discriminatory factors for items 11 to 23.

a) Notes

The correct answer (the key) or those for which marks were awarded are shown by *.

'Q_1' shows the percentage of the bottom pupils who ticked each response.

'Q_3' shows the percentage of the top pupils who ticked each response

'All' shows the percentage of all pupils who ticked each response.

'F' is the facility value for the item.

'D' is the discriminatory factor for the item.

Item and Response	Q_1	Q_3	ALL	F	D	Item and Response	Q_1	Q_3	ALL	F	D
1. A	18.5	1.3	8.8			9. A	17.8	2.6	9.3		
B	1.3	0.0	0.3			* B	49.7	94.7	76.4	0.76	0.45
* C	79.0	98.7	90.2	0.90	0.20	C	8.9	2.0	4.8		
D	0.0	0.0	0.0			D	21.7	0.7	9.0		
2. * A	39.5	68.0	56.7	0.57	0.29	10. A	5.7	0.7	2.6		
B	14.6	5.2	7.9			B	6.4	0.7	2.6		
C	24.8	26.1	24.7			* C	81.5	98.0	93.1	0.93	0.18
D	17.8	0.7	8.6			D	7.6	0.7	2.9		
3. A	38.2	13.1	26.6								
B	14.0	6.5	9.7								
* C	35.0	78.4	58.3	0.58	0.43						
D	10.8	1.3	4.8								
4. A	27.4	8.5	17.2			24. * A	26.1	22.9	26.0		
B	4.5	0.0	1.9			B	10.2	0.7	5.0		
C	3.8	0.0	1.7			C	8.3	2.0	2.4		
* D	63.1	91.5	79.3	0.79	0.28	* D	51.0	73.2	63.3		
5. A	3.2	0.0	1.0			25. * A	58.0	66.7	62.1		
* B	77.7	98.0	89.3	0.89	0.20	* B	20.4	25.5	22.9		
C	8.3	1.3	3.3			* C	8.9	1.3	4.1		
D	10.2	0.7	6.4			D	8.3	5.2	8.6		
6. A	31.8	22.2	28.6			26. * A	53.5	79.1	65.9		
* B	60.5	77.1	63.8			B	3.8	0.0	2.9		
C	3.8	0.0	1.6			C	11.5	5.2	7.2		
D	2.5	0.7	1.9			* D	25.5	13.7	21.0		
7. A	5.7	1.3	2.4			27. A	14.6	5.9	10.7		
B	1.9	0.0	0.7			* B	3.2	0.7	1.4		
C	15.9	3.9	12.2			* C	65.0	90.8	78.3		
* D	77.7	93.5	85.0	0.85	0.16	D	11.5	1.3	6.7		
8. A	1.3	0.0	0.7			28. * A	15.3	37.9	29.3		
B	0.6	0.0	0.7			* B	6.3	13.7	10.9		
C	26.8	4.6	15.0			C	59.6	43.8	51.0		
* D	70.7	95.4	83.4	0.83	0.25	D	11.8	3.3	5.7		

Table 5.8 (Continued)

b) Notes -

Items 11 to 23 - the values of F and D are shown for the correct answer (i.e. only those boxes which correspond to correct responses have been ticked.)

Also shown are values of F and D for each combination containing a correct response (e.g. in item 11, F_A = fraction of pupils who ticked box A alone or in combination with any other box or boxes - it therefore includes pupils who ticked boxes A, AB, AC, AD, ABC, ABD, ACD, and ABCD. It gives an indication of how easy pupils found that response (A) alone to be.)

ITEM	KEY	F_{key}	D_{key}	F and D for combinations			
11.	ABD	0.12	0.20	F_A 0.60 D_A 0.24	F_B 0.84 D_B 0.24	F_D 0.36 D_D 0.20	F_{AB} 0.49 D_{AB} 0.27
				F_{AD} 0.17 D_{AD} 0.14	F_{BD} 0.29 D_{BD} 0.29	F_{ABD} 0.12 D_{ABD} 0.20	
12.	CD	0.27	0.36	F_C 0.88 D_C 0.18	F_D 0.43 D_D 0.41	F_{CD} 0.38 D_{CD} 0.42	
13.	AB	0.82	0.32	F_A 0.95 D_A 0.14	F_B 0.94 D_B 0.13	F_{AB} 0.90 D_{AB} 0.24	
14.	A	0.78	0.25	F_A 0.93	D_A 0.19		
15.	C	0.34	0.33	F_C 0.65	D_C 0.44		
16.	AD	0.26	0.01	F_A 0.94 D_A 0.20	F_D 0.80 D_D 0.25	F_{AD} 0.73 D_{AD} 0.36	
17.	C	0.45	0.16	F_C 0.85	D_C 0.21		
18.	CD	0.57	0.59	F_C 0.69 D_C 0.40	F_D 0.82 D_D 0.37	F_{CD} 0.58 D_{CD} 0.58	
19.	AD	0.40	0.49	F_A 0.79 D_A 0.36	F_D 0.55 D_D 0.28	F_{AD} 0.43 D_{AD} 0.49	
20.	CD	0.10	0.14	F_C 0.31 D_C 0.27	F_D 0.68 D_D 0.38	F_{CD} 0.21 D_{CD} 0.33	
21.	D	0.91	0.15	F_D 0.95	D_D 0.11		
22.	CD	0.21	0.32	F_C 0.87 D_C 0.29	F_D 0.56 D_D 0.47	F_{CD} 0.50 D_{CD} 0.59	
23.	C	0.35	0.27	F_C 0.75	D_C 0.32		

Table 5.9 Analysis of Items 11 to 23

Note The percentage of pupils choosing each response is shown ; the upper figure gives the percentage choosing only the given response , and the lower figure gives the percentage choosing that response in combination with any others.

e.g. Item 11 ; pupils who ticked boxes A and B -

33.6% chose only boxes A and B

49.1% chose A and B alone or in combination (i.e. AB, ABC, ABD, ABCD.)

	Item Number and Key												
	11 ABD	12 CD	13 AB	14 A	15 C	16 AD	17 C	18 CD	19 AD	20 CD	21 D	22 CD	23 C
NONE	0.7	0.2	0.2	0.3	3.3	0.2	0.9	0.0	0.3	0.5	0.0	0.7	1.2
A	3.1 60.3	1.4 24.0	1.6 94.7	77.6 93.2	1.0 46.4	5.0 93.6	2.8 5.3	2.4 14.5	24.0 78.6	1.4 14.5	4.7 8.7	2.1 59.5	7.6 41.4
B	14.5 84.3	3.1 32.0	2.8 94.2	2.2 7.5	1.0 33.4	0.9 31.8	2.9 7.9	3.1 12.1	4.3 13.6	13.6 74.1	0.0 0.7	1.7 11.8	3.3 24.8
C	0.9 15.3	24.0 87.8	0.3 9.0	0.2 10.8	34.3 69.2	0.9 53.1	45.3 85.1	5.3 69.0	2.8 17.5	1.9 31.2	0.5 0.9	8.4 87.3	34.5 75.1
D.	0.9 36.3	0.7 43.2	0.0 7.0	0.3 6.2	0.7 40.7	1.6 80.0	6.7 45.6	13.6 81.6	7.1 54.6	3.8 67.5	90.9 94.8	2.1 55.7	1.6 22.8
AB	33.6 49.1	2.1 7.9	82.2 90.1	2.8 3.0	5.3 23.3	3.6 26.4	0.6 0.4	0.2 2.4	2.4 4.0	4.5 8.8	0.2 0.2	1.4 3.7	4.3 12.1
AC	3.1 8.1	10.3 17.6	1.6 7.8	8.8 9.2	7.4 24.5	8.4 48.7	0.7 1.1	1.6 2.8	8.3 11.8	3.1 6.0	0.2 0.2	24.1 53.6	16.0 25.5
AD	3.6 17.4	1.6 6.8	0.7 6.2	3.6 3.8	6.6 30.3	26.0 73.2	1.2 1.4	7.6 9.0	39.5 43.2	1.2 4.8	3.6 3.6	1.7 31.0	2.6 8.7
BC	4.3 8.6	12.2 23.6	0.5 6.1	0.7 1.1	4.8 14.7	0.7 15.4	2.4 3.6	4.1 5.1	1.7 2.9	4.7 14.3	0.2 0.2	4.3 6.4	5.5 12.9
BD	15.7 28.8	1.9 11.0	0.5 5.6	1.4 1.6	3.4 19.9	3.4 23.2	1.2 2.2	2.2 3.4	3.1 4.5	40.3 50.6	0.3 0.3	1.6 3.5	2.9 6.9
CD	1.6 4.2	27.1 37.7	0.3 8.5	0.5 0.9	4.7 20.3	1.4 39.7	35.3 36.5	56.7 57.7	0.7 4.0	10.2 20.8	0.0 0.0	20.5 49.6	8.6 14.3
ABC	3.1 3.6	3.3 4.5	3.1 5.3	0.2 0.2	2.4 9.0	3.4 12.5	0.2 0.2	0.5 0.7	0.7 0.7	0.7 1.2	0.0 0.0	0.9 1.6	4.8 6.4
ABD	11.9 12.4	1.0 2.2	2.6 4.8	0.0 0.0	9.0 15.6	10.3 20.2	0.0 0.0	0.7 0.9	0.9 0.9	1.4 1.9	0.0 0.0	0.7 1.4	1.4 3.0
ACD	1.4 1.9	2.8 4.0	0.7 2.9	0.2 0.2	8.1 14.7	27.8 36.9	0.2 0.2	0.5 0.7	2.8 2.8	1.7 2.2	0.0 0.0	27.9 28.6	3.1 4.7
BCD	0.7 1.2	6.9 8.1	0.3 2.5	0.3 0.3	0.9 7.5	1.4 10.5	1.0 1.0	0.3 0.5	0.5 0.5	8.4 8.9	0.0 0.0	0.5 1.2	1.0 2.6
ABCD	0.5	1.2	2.2	0.0	6.6	9.1	0.0	0.2	0.0	0.5	0.0	0.7	1.6

(1) On the criteria mentioned on page 52, the items which could be considered as being "good" were -

Items 3 , 9 , 15 , 18 , 19 .

Items which were "almost good" were -

Items 2 , 4 , 12 , 13 , 14 , 23 .

Of the items which were not "good", -

2 items had reasonable F values but low D values

3 items had low F values and low D values

1 item had low F value and reasonable D value

6 items had too-high F values.

(2) In the items which tested the objective " realise that practical work is limited in accuracy ", the facility values were -

Item 4 - F = 0.79

Item 22 F = 0.21 (Response A especially tested this objective ; 60% answered it wrongly.)

Item 28 F = 0.29 (57% of the pupils were prepared to accept that a burette or dropping pipette could be read to an accuracy of three decimal places.)

The lack of success of pupils on these items might lend support to the suspicion (see page 37) that pupils misinterpreted the meaning of this objective.

(3) Many teachers express misgivings about their pupils' ability to draw graphs. Although this test did not ask for the drawing of a graph, 93% of the pupils recognised a correctly drawn graph given four possible graphs and the data from which they were supposed to have been drawn. (Item 10)

(4) Pupils seemed to be confused about the difference between conclusions (from experimental results) and inferences. For example, in item 12, 32% chose response B despite the lack of evidence in the stem. Similarily in item 16, 32% chose response B and 53% response C, again with insufficient evidence to justify their choice.

(5) Pupils did not seem to be aware of the relevance of information with regard to the drawing of conclusions. In item 15, responses A, B and D were facts of which the pupil would be aware (- the taste of and tests for sugars) but 46%, 33% and 41% respectively considered that these responses supported a theory on carbohydrate chain-lengths.

(6) It was seen that 26% of pupils in item 24 stated that they preferred to " keep a note of observations and results " during practical work - in preference to doing the experimental part of the work. This figure did not seem to arise from laziness or lack of interest since it did not vary much with ability - 23% of the "top pupils" and 26% of the

"bottom pupils" chose this resonse.

(7) In item 26, 21% of the pupils answered that " they would not have chosen chemistry if it had contained no practical work ". As already discussed on page 36, the pupils' decision to study O-grade chemistry would have been taken on the basis of their experience of SI and II science. This science contained a different style of practical work.

It was also noted that the response " I find the experimental work less interesting than the theory " drew a greater response from the "bottom pupils" (12%) than from the "top pupils" (5%).

(8) In item 27, pupils were faced with the situation of an experiment which was not giving the results expected by the teacher. It was seen that 79% of the pupils would have " consulted other groups to compare results " while 11% (15% of the "bottom pupils" and 6% of the "top pupils") would have scrapped the experiment and started again. This suggests that the "bottom pupils" tended to be more ready to accept the teacher's expected results as being the only correct outcome of the experiment. Any observation which these pupils made which was contrary to the teacher's expectation must have been " wrong " on this basis.

(9) In item 17, most pupils seemed to be able to follow instructions correctly (only 5% and 8% chose responses A and B respectively - where a detail in the apparatus was wrong) but 46%, irrespective of their ability, chose response D, which showed a condenser fitted to a flask with the condenser sloping "uphill". Furthermore 85% chose the correct response C and 37% chose both C and D together. Presumably then, at least this 37% considered that the apparatus would function whether the condenser sloped upwards or downwards. This would suggest that these pupils did not understand the use of a condenser. (It is likely that all pupils will have seen this apparatus during the science taught up to O-grade. In particular, it is likely to have been used in the experiments - Distillation of water (Integrated Science Course, section 5)
Distillation of Crude Oil (Experiment 57, section L4)
Fermentation of yeast (and separation of the ethanol)
(Experiment 86, section N2))

(10) In item 11, pupils were given the theory that " the depth of colour of a solution of copper (II) sulphate depends on both the copper (II) ion and sulphate ion concentrations ". They were then asked to choose responses which supported this theory.

84% correctly chose response B (adding copper (II) sulphate crystals to a copper (II) sulphate solution turns the solution a deeper blue) and 85% correctly did <u>not</u> choose response C (adding sodium sulphate crystals to a copper (II) sulphate solution does not change the blue colour). These two responses and their popularity suggested that many pupils had grasped the flaw in the stated theory and had realised that the colour was due only to the copper "part" of the copper (II) sulphate.

However, only 36% chose response D (adding copper (II) nitrate crystals to copper (II) sulphate solution turned the solution a deeper blue) suggesting that many pupils (possibly as many as 48% of them) were not aware that copper (II) ions from copper (II) nitrate could be considered to be identical in solutiön to copper (II) ions from copper (II) sulphate. These pupils must have been rather suspect in their understanding of one of the most basis concepts in the O-grade course - that of free ions in aqueous solution.

Conclusions on Chapter 5

Although the individual class correlation coefficients were rather inconsistent in value, the chi-squared test for the overall results suggested that, with modifications, such a "paper and pencil" test could possibly be used as a reliable method of assessing the achievement of the stated objectives of practical work, or of moderating the teachers' assessment of pupils' practical ability. Perhaps the major drawbacks of such a "paper and pencil" test are -

A) It was found to be difficult to make up items which tested such objectives as " ability to record observations and results ". One possible method might be found by the use of a specially prepared film and associated questions [21].

B) It was difficult to assess attitudes such as enjoyment using a standard objective item.

The analysis of responses to specific items indicated that the pupils' response to their questionnaire P1 was probably a fair reflection of their true abilities and attitudes (as measured by the "paper and pencil" test.)

APPENDIX 5.1

The Preliminary Test

READ THE FOLLOWING INSTRUCTIONS CAREFULLY, THEN ANSWER THE QUESTIONS

Each question has one correct answer ; choose the answer you think is correct and put a tick in that box in the answer sheet.
You have 30 minutes to complete the paper.

The following refers to items 1 to 5.

Preparation of the Ester Ethyl Ethanoate

Measure out $5cm^3$ ethanol and place in a clean, dry test-tube. Add $5cm^3$ ethanoic acid. Now add 5 drops of concentrated sulphuric acid and shake gently. Heat the test-tube to 75^oC and maintain at this temperature for 5 minutes. Now pour this mixture into a beaker containing $20cm^3$ dilute sodium hydroxide solution. The ester, which floats to the surface of the alkali, can be recognised by smell.

1. Which apparatus would you use to measure the $5cm^3$ portions ?
   A. Burette B. Pipette C. Measuring cylinder D. Balance

2. How would you add the drops of concentrated sulphuric acid ?
   A. Pour from bottle into beaker then pour into test-tube from beaker
   B. Pour straight from bottle into test-tube
   C. Pour from bottle into burette then drop into test-tube from burette
   D. Draw from bottle into dropping pipette then drop into test-tube

3. Which size of beaker would you use to hold the sodium hydroxide ?
   A. $10cm^3$ B. $25cm^3$ C. $50cm^3$ D. $100cm^3$

4. Why must the test-tube be dry before the start of the experiment ?
   A. Heating a wet test-tube might cause it to crack
   B. Adding sulphuric acid to water might cause spurting of the acid
   C. Water would dilute the ethanoic acid
   D. Water would react with ethanol and prevent the ester forming

5. Which method would you use to heat the test-tube ?
   A. Water-bath B. Bunsen burner C. Electric oven D. Red-hot wire

The following refers to items 6 to 9

Four common methods of heating are -

A. Bunsen burner B. Water bath C. Electric hot-plate D. Electric oven

Which method would you use for the following experiments ?

6. Dissolve some glucose in water in a test-tube; add drops of Fehling's solution and heat the mixture to 80^oC for 5 minutes.

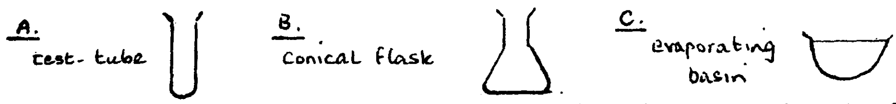
7. Heat crude oil in a distillation flask to 120^oC and collect the first fraction ; contimue heating and collection until the oil reaches 350^oC

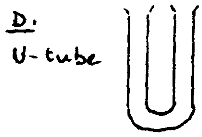
8. Heat a $100cm^3$ beaker containing $50cm^3$ ethanol to $60^\circ C$, then add 10g potassium hydroxide pellets and stir until dissolved.

9. Place $20cm^3$ toluene (formula C_7H_8 boiling-point $111^\circ C$) in an evaporating basin and heat until the toluene boils.

The following refers to items 10 to 12.

Shown below are four common containers used in the laboratory.





Which one would you choose for the following experiments ?

10. Heat the solution in the container ; boil off the water to get crystals.

11. Pour $25cm^3$ acid into the container and add indicator; now add alkali from a burette until the indicator changes colour.

12. Some copper (II) carbonate can be made by adding $2cm^3$ sodium carbonate to $2cm^3$ copper (II) sulphate in a container.

---

13 A pupil calculated the percentage by weight of copper in a sample of copper (II) oxide by reducing the oxide with hydrogen. Results -

Weight of apparatus = 5.22g Wt. of apparatus + copper oxide = 8.42g

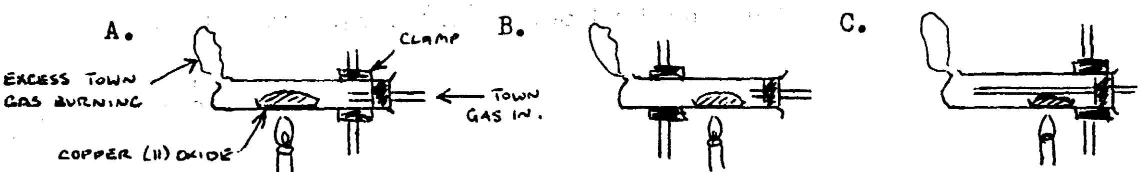
Wt. of apparatus + copper = 7.85g

He then calculated his answer. Which of these should he enter in his lab. book ?

A. 82.188% B. 82.19% C. 82.2% D. 82%

---

14. Which of the following apparatus would be most suitable for the reduction of copper (II) oxide by town gas ?



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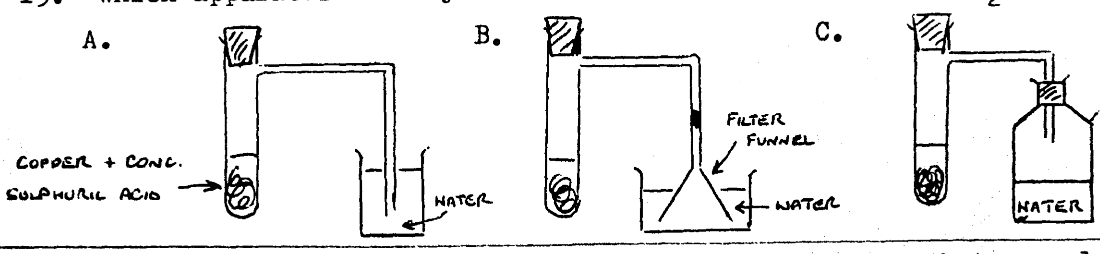
15. Which apparatus would you choose to make a solution of SO_2 in water ?



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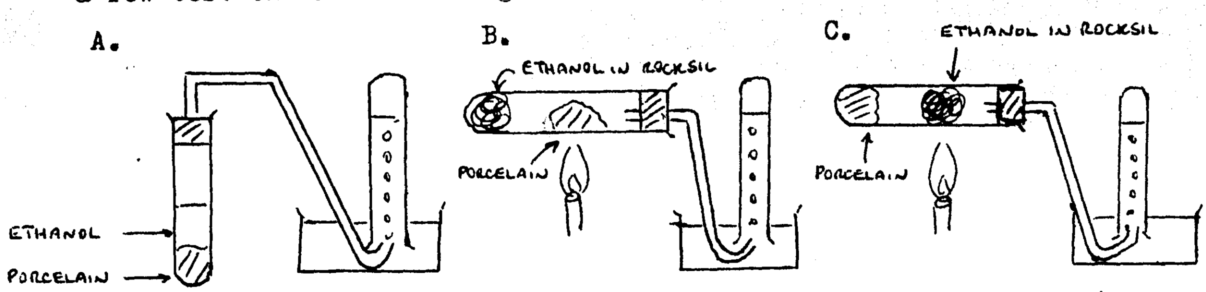
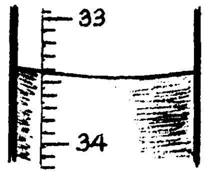
16. Ethene gas can be made by passing ethanol vapour over hot porcelain chips. Which of the following apparatus would enable you to collect a few test-tubes of ethene gas ?

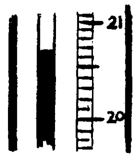


17. Which reding would you take from the burette shown below ?



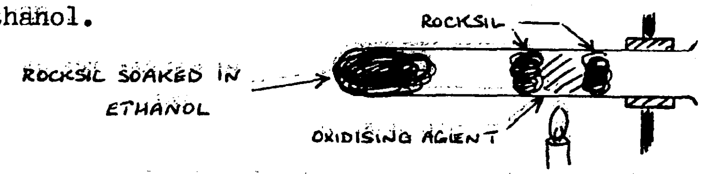
A. $33.40cm^3$ C. $34.60cm^3$
B. $33.45\ cm^3$ D. $34.45cm^3$

18. Which reading would you take from the thermometer shown below ?



A. 21.35°C C. 21.65°C
B. 20.65°C D. 20.35°C

19. The apparatus shown has been set up to investigate the oxidation of ethanol.

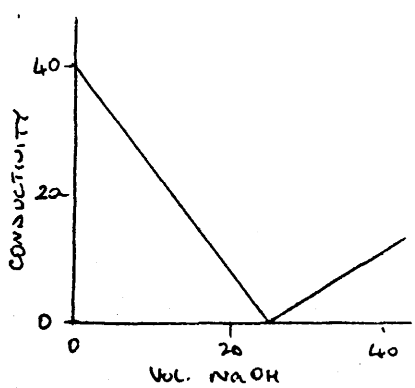


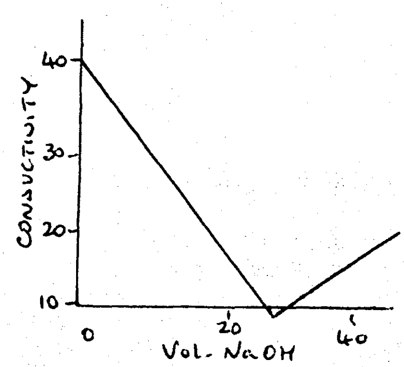
The heat is applied <u>only</u> to the oxidising agent as shown because -

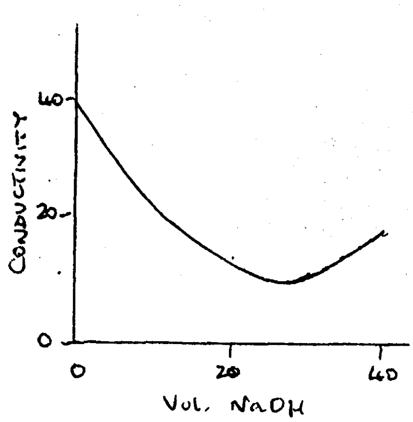
A. heating the end of the tube would cause it to crack
B. enough heat is carried down the tube to vapourise the ethanol
C. heating the ethanol would cause it to catch fire
D. heating the ethanol would cause it to react with the rocksil

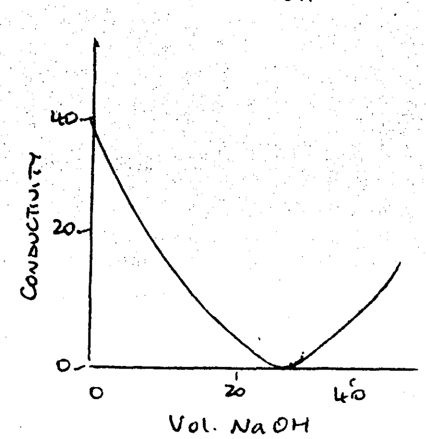
20. Shown below are values of conductivity measured as sodium hydroxide is added to dilute hydrochloric acid. Which of the graphs shown is a true representation of the experimental results ?

Volume of NaOH (aq)	0	5	10	20	22	23	24	25	26	30	40
Conductivity	38.0	32.0	23.0	12.5	11.0	10.0	9.5	9.0	9.0	11.0	17.5









TEACHERS' ASSESSMENT SHEET

APPENDIX 5.2

Please fill in the table for each pupil who attempts the "Practical Test". It would be helpful if you could fill in this sheet BEFORE your pupils sit the test. Your pupils have forty minutes to complete the test. When they have finished, please thank them for their help in this project.

For each pupil - please grade them in each of the categories in the table.

GRADES A - very good B - good C - average D - poor E - very poor

CATEGORIES

1. Ability to draw conclusions from experiments and to relate experiments to the theoretical work
2. Ability to work safely and tidily in the laboratory
3. The showing of interest / enjoyment / curiosity in chemistry
4. Ability to carry out written or oral instructions
5. Ability to report or record the experimental results / observations
6. Ability in the handling of apparatus and chemicals

(Please leave the last column blank)

																								NAME
Draw conclusions																								1
Work safely and tidily																								2
Interest Enjoyment Curiosity																								3
Carry out instructions																								4
Report / record results																								5
Handling apparatus/ chemicals																								6

APPENDIX 5.3

The Revised "Paper and Pencil" Test

This test is designed to try to find out what you have learned as a result of doing experiments in chemistry.

It is NOT a part of your 'O' grade examination, and the result will have nothing to do with the mark you get in that examination.

The test is in three sections ; in the first section, the questions - which are all of the objective type (multiple choice) - have ONLY ONE correct answer, and you should, therefore, tick only one box in the answer sheet for part 1.

In part 2, the questions may have more than one correct answer - and you can, therefore, tick as many boxes as you think correct.

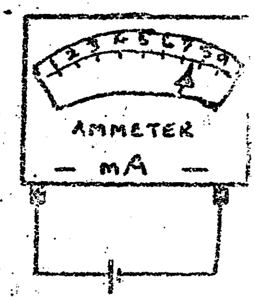
In part 3, you will have to imagine yourself to be in the situations described. In these questions, please do not look for the correct answer - because there is NO correct answer. Just think about the situation, and choose the answer which describes most closely what you think you would do.

You have 40 minutes to try this test

PLEASE THINK CAREFULLY ABOUT YOUR ANSWERS

Part 1 These questions have only ONE correct answer.

1. The drawing shows an ammeter connected in a circuit.
The reading on the ammeter is -

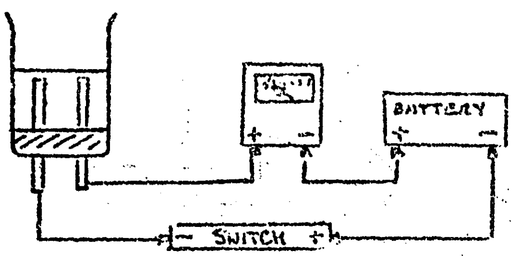


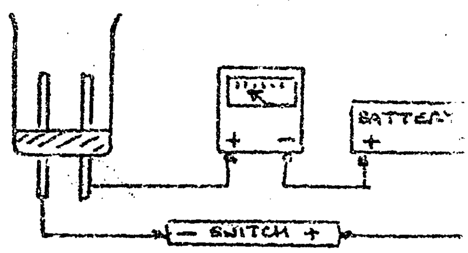
A. 7·5 amps
B. 8·5 amps
C. 7·5 milliamps
D. 8·5 milliamps

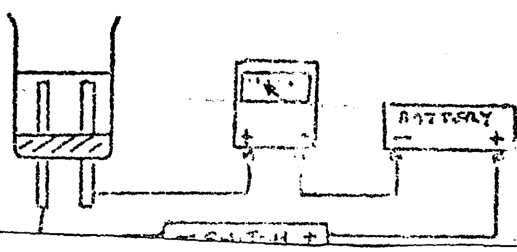
---

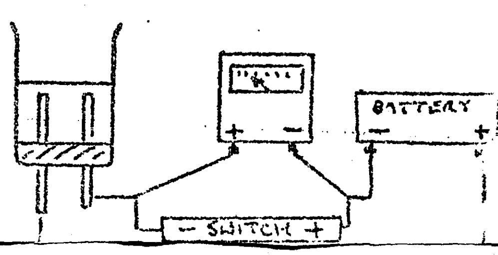
2. The following instructions were given to pupils by the teacher.
"Connect the battery to an ammeter, a switch and an electrolysis cell (all in series). Pour enough hydrochloric acid into the cell to just cover the electrodes. Now switch on."

The diagrams below show how four groups connected their circuits. Which group followed the instructions correctly ?

A.


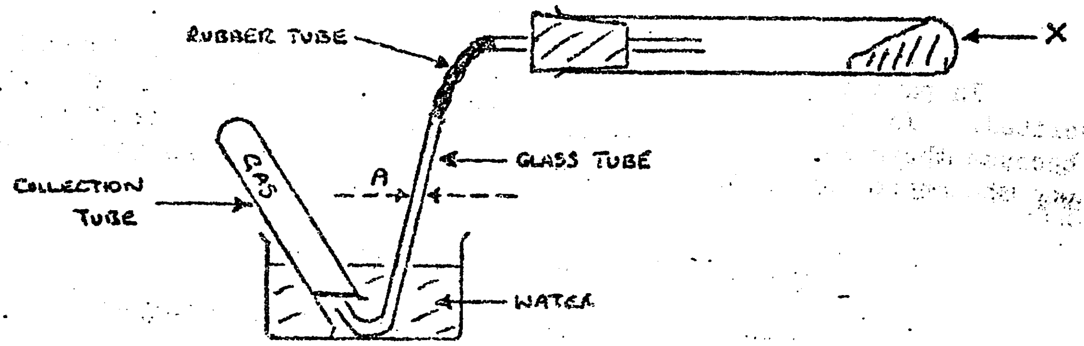
B.


C.


D.


3. A gas is being prepared using the apparatus shown in the sketch. Substance X has been strongly heated for 15 minutes; all of the gas needed has been collected. The heating is stopped, and water starts to suck back up the glass delivery tube as the gas in the apparatus contracts. It has reached point A and is rising quickly.

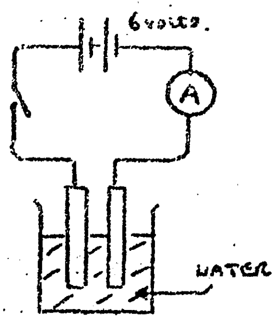
If the cold water reaches the hot test-tube, the test-tube may shatter. To prevent an accident, which <u>one</u> of the following courses of action would you take?



A. Lift the delivery tube out of the water
B. Heat the delivery tube at A
C. Pinch the rubber tube hard, then loosen the stopper
D. Let the gas escape from the collection tube.

---

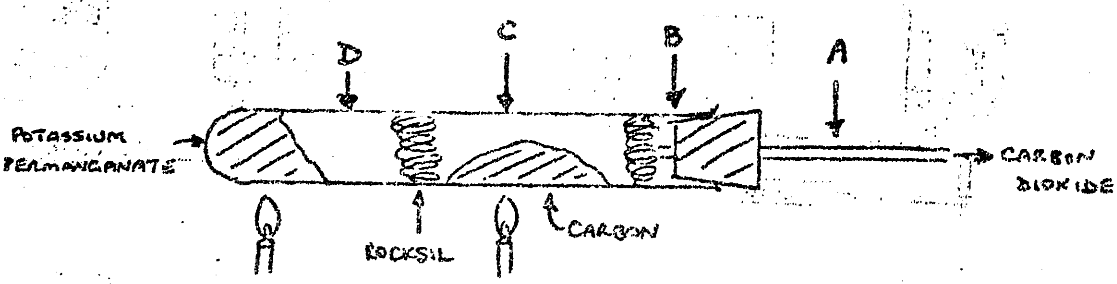
4. An experiment is set up to measure the conductivity, if any, of pure water. The apparatus is shown. The battery gives 6 volts; the ammeter reads 0 to 1 amp in 0·1 amp divisions. The conductivity cell contains 50 cm^3 of water.
No reading is obtained when the apparatus is switched on. What do you do next –



A. Conclude that pure water is a non-conductor
B. Put more water in the conductivity cell
C. Use a battery which gives a lower voltage
D. Use a more sensitive ammeter.

---

5. The diagram shows apparatus used to prepare some carbon dioxide – it is made by passing oxygen (prepared by heating potassium permanganate crystals) over hot carbon.
In which of the positions marked (A, B, C or D) should the apparatus be held by a clamp?



The following refers to items 6, 7 and 8.

The following instructions were found on a worksheet:-

"Preparation of the Ester ETHYL ETHANOATE"

Measure out 5 cm^3 of ethanol and place in a clean dry test-tube. Add 5 cm^3 of ethanoic acid. Now add 5 drops of concentrated sulphuric acid and shake the tube gently. Heat the tube gently to 75°C and keep it at this temperature for five minutes. Now pour the mixture into a beaker containing 20 cm^3 dilute sodium hydroxide. The ester floats to the surface and can be smelled.

6. Which apparatus would you use to measure out the 5 cm^3 portions?

A. burette
B. measuring cylinder
C. balance
D. beaker

7. How would you add the drops of concentrated acid?

A. Pour from the bottle into a beaker, then pour into the test-tube from the beaker
B. Pour straight from the bottle into the test-tube
C. Pour from the bottle into a burette, then drop into the test-tube from the burette
D. Draw from the bottle into a dropping pipette, then drop into the test-tube from the dropping pipette.

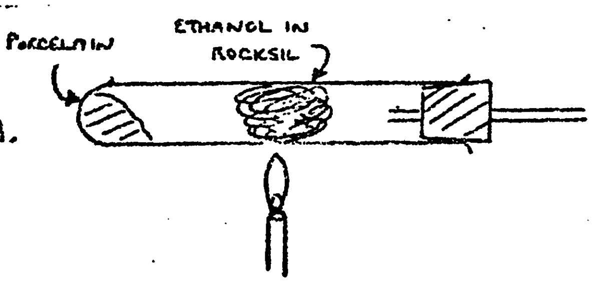
8. What size of beaker would you use to hold the sodium hydroxide solution?

A. 5 cm^3
B. 10 cm^3
C. 25 cm^3
D. 50 cm^3

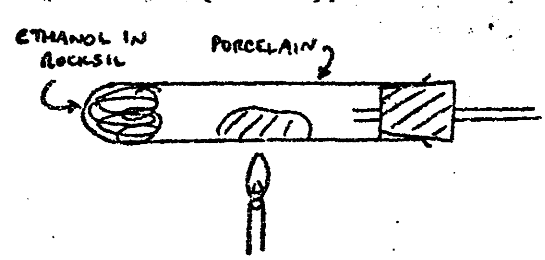
---

9. Ethene gas can be made by allowing ethanol vapour to come in contact with hot porcelain chips. Which of the following apparatus could be used to carry out this reaction?

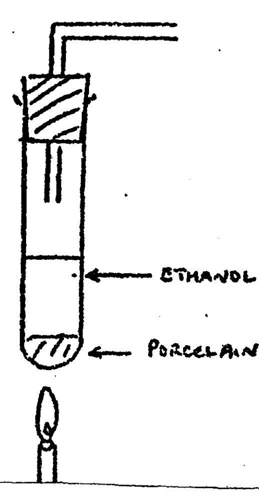
A.



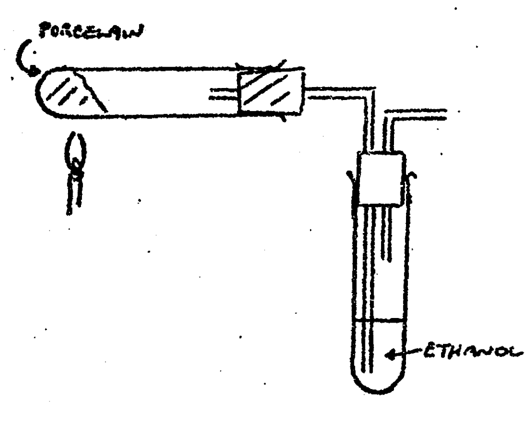
B.



C.



D.

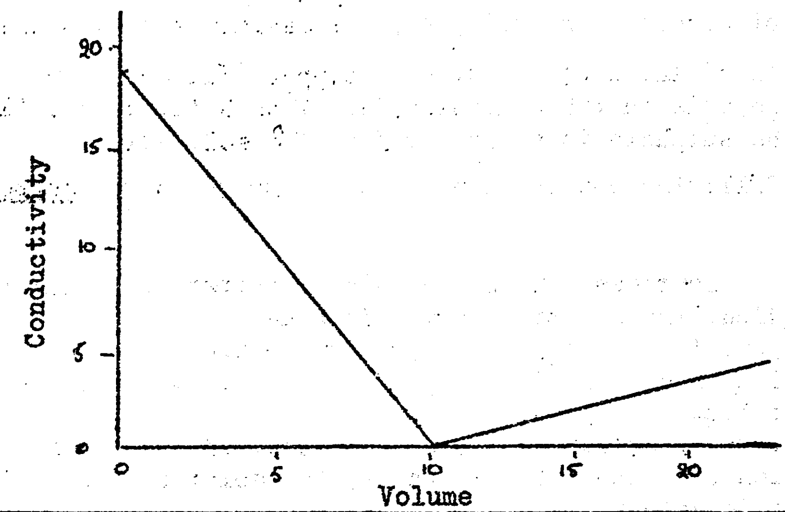


10. A pupil obtained the following results during an experiment to measure the conductivity during the addition of sodium hydroxide to a sample of hydrochloric acid. The results are -

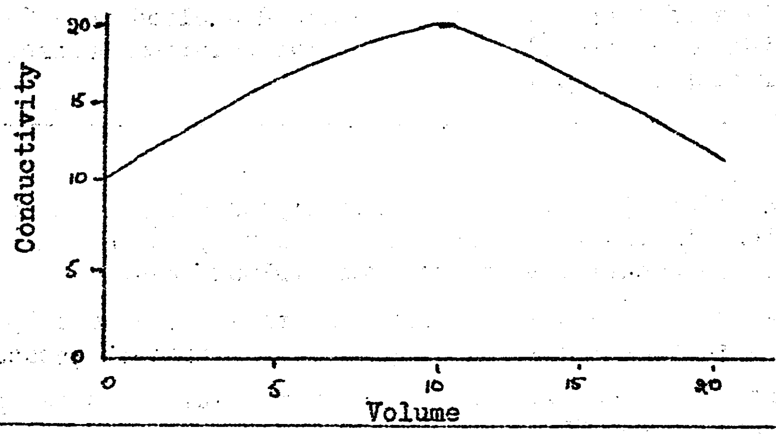
Volume of Sodium Hydroxide (cm^3)	Conductivity
0	18
2	16
4	14
6	12
8	11
10	10
12	11
14	12
16	13

Which of the graphs on the next sheet correctly show the relationship between the conductivity and the volume of sodium hydroxide added?

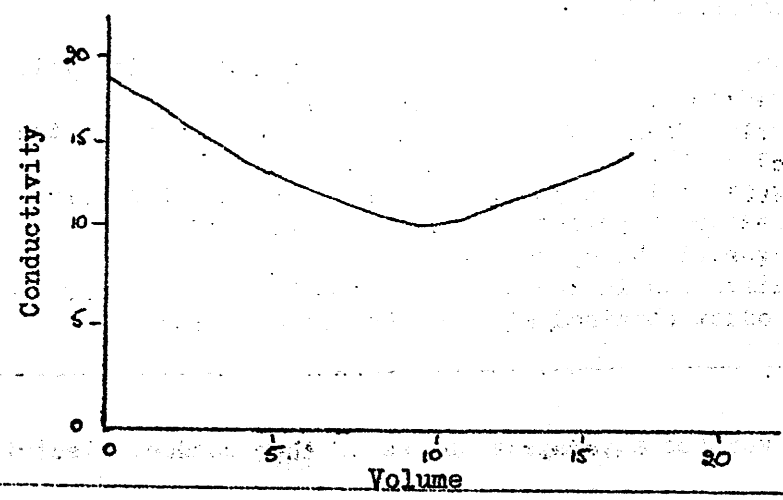
A.


20
15
10
5
0
Conductivity
0
5
10
15
20
Volume

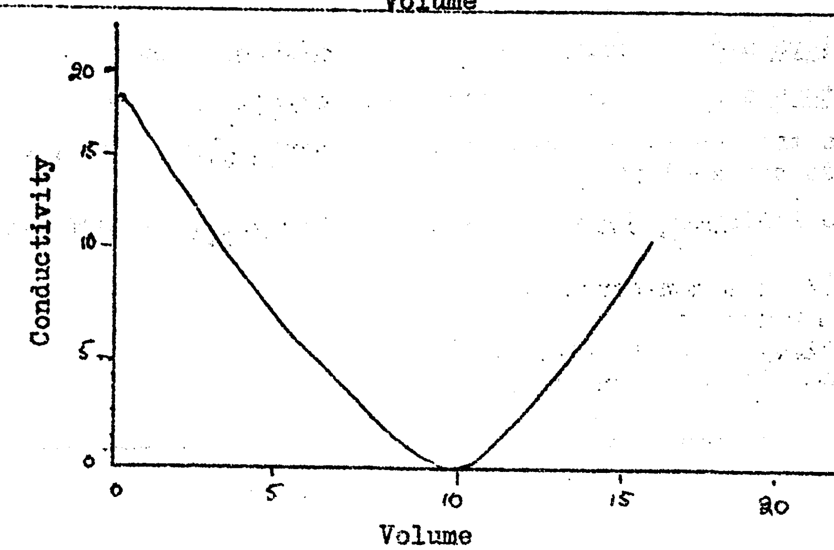
B.


20
15
10
5
0
Conductivity
0
5
10
15
20
Volume

C.


20
15
10
5
0
Conductivity
0
5
10
15
20
Volume

D.


20
15
10
5
0
Conductivity
0
5
10
15
20
Volume

Part 2 These questions may have MORE THAN ONE correct answer.

11. On the basis of observations made, a pupil devises a theory which states:-

"The strength of the blue colour of a copper (II) sulphate solution depends on the concentration of both the copper (II) ions and the sulphate ions dissolved in the solution."

Which of the following observations made by another pupil support his theory?

A. Water is colourless; when crystals of copper (II) sulphate are added, the solution formed is blue.
B. If more crystals of copper (II) sulphate are added to a 0·1M solution of copper (II) sulphate, the solution becomes deeper blue in colour.
C. If crystals of sodium sulphate are dissolved in a 0·1M solution of copper (II) sulphate, the solution does not change in colour.
D. If crystals of copper (II) nitrate are dissolved in a 0·1M solution of copper (II) sulphate, the solution becomes deeper blue in colour.

---

12. A number of solutions in water were electrolysed using platinum electrodes. All the solutions in the list below were electrolysed, and in EVERY case, the product at the negative electrode was HYDROGEN gas.

Solutions - sodium chloride; sodium nitrate; sodium sulphate; potassium chloride; potassium nitrate; potassium sulphate

Which of the following conclusions could justifiably be made from these experimental results only?

A. The product at the negative terminal during electrolysis of any solution is always hydrogen.
B. The material used for the electrode has no effect on the product at the negative electrode.
C. The product at the negative electrode during electrolysis of a sodium or potassium salt using platinum electrodes will probably be hydrogen.
D. The negative ion in the solution probably has no effect on the product obtained at the negative electrode.

---

13. A pupil tests various substances to see if they conduct electricity. He finds -

Conductors are - iron; copper; magnesium; zinc

Non-conductors are - air; water; salt crystals; wood

He now draws the conclusion that "metals conduct electricity; other substances do not conduct".

Which of the following observations by another pupil SUPPORT his conclusion?

A. plastic is a non-conductor
B. tin is a conductor
C. salt solution is a conductor
D. molten salt is a conductor

14./

14. A pupil measures the conductivity of various solutions of sodium chloride. His results are :-

Concentration of solution	0·0001 M	0·001 M	0·01 M	0·1 M
Conductivity (mA)	14	26	54	88

On the basis of these results, which of these conclusions can he justifiably make?

A. From 0·0001 M to 0·1 M solutions, the conductivity increases as the concentration increases.
B. From 0·0001 M to 0·1 M solutions, the conductivity increases as the concentration decreases.
C. Sodium chloride crystals do not conduct electricity.
D. A 5 M solution would have a lower conductivity than a 1 M solution.

---

15. Read the following piece of theory, then choose statements (these are experimental observations) which support the theory.

"Carbohydrates can be molecules made up of chains of atoms. Starch has a long-chain molecule; sucrose has a shorter-chain molecule; glucose has an even shorter-chain molecule."

A. Starch turns iodine solution blue-black; sucrose and glucose do not.
B. Glucose and sucrose both have a sweet taste.
C. When acid is added to sucrose, the sucrose yields two sugars - one which is glucose.
D. Glucose reacts with Fehling's (or Benedict's) solution; sucrose and starch do not.

---

16. Consider the following report which describes an experiment done by a student.

"A sample of mercury oxide was heated by a bunsen burner; after a short time, beads of mercury could be seen. When iron oxide was heated in the same way, no iron metal appeared, even after ten minutes heating."

<u>On the basis of his report only</u>, which of the following conclusions could be made?

A. It is easier to break up mercury oxide than iron oxide.
B. Iron oxide does not break up when heated.
C. Oxygen could be prepared by heating mercury oxide.
D. Iron oxide is stable up to the temperature provided by the bunsen burner.

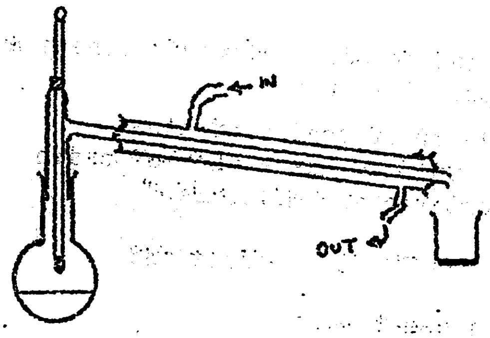
---

17. /

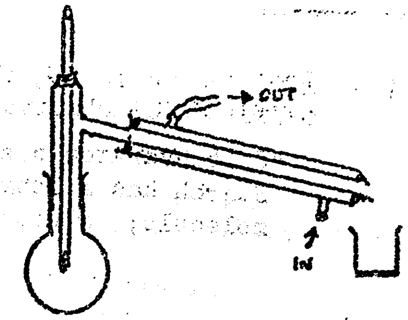
17. Read the instructions below for the setting up of a distillation apparatus - then decide which of the diagrams below shows the apparatus correctly set up.

"The liquid to be distilled is poured into a round-bottomed flask. The T-piece is placed in the neck of the flask, and the condenser fitted to it. A thermometer is placed in the top of the T-piece with its bulb level with the opening to the condenser. The water supply is connected to the lower side-arm of the condenser; the upper side-arm is connected to the waste-pipe. A beaker is placed under the lip of the condenser."

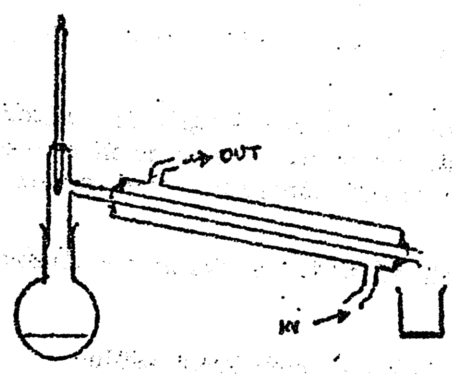
A.



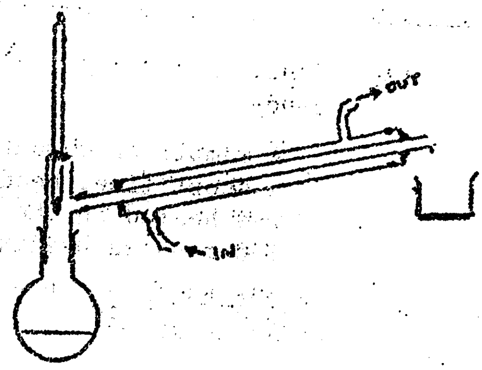
B.



C.



D.

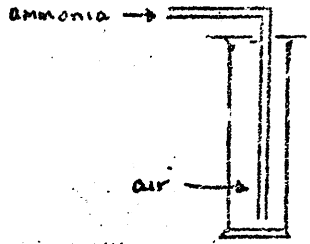


Items 18 and 19 concern the gas AMMONIA.

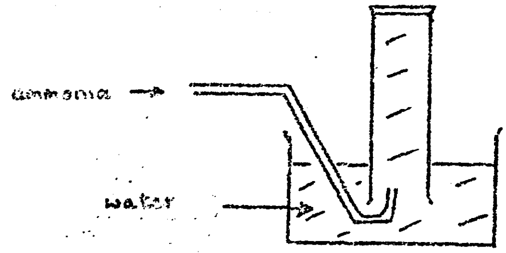
This gas is - colourless; less dense than air; very soluble in water (forming an alkaline solution); insoluble in paraffin.

18. Which of the following could be used as a method of collecting a fairly full jar of ammonia?

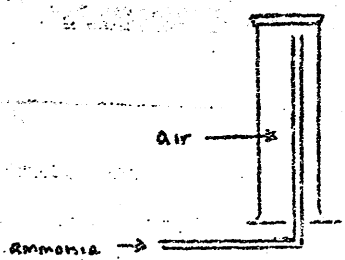
A.



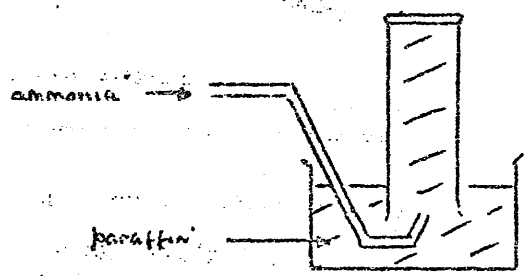
B.



C.

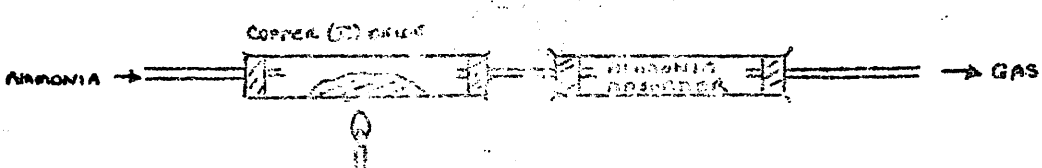


D.

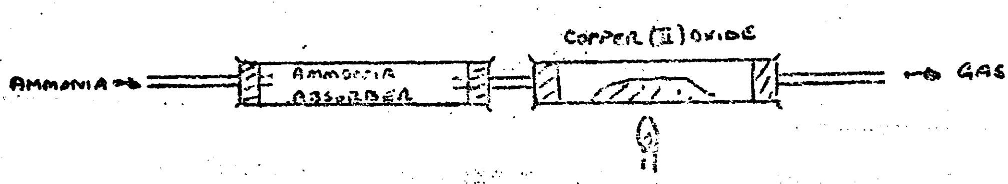


19. You are asked to investigate what happens when ammonia reacts with heated copper (II) oxide. You are told that the product of the reaction is a gas. Which of the following pieces of apparatus would enable you to collect a fairly pure sample of the gas formed in this reaction?

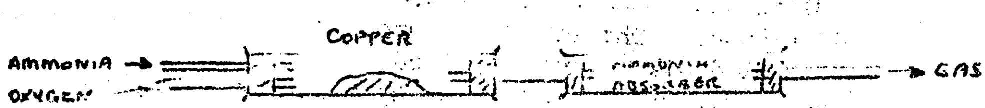
A.



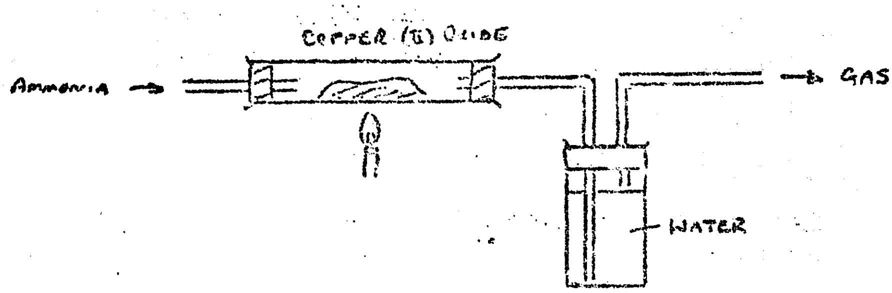
B.



C.

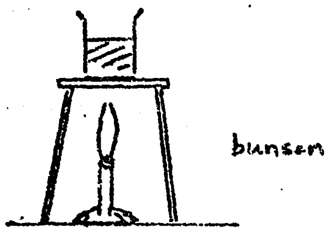


D.

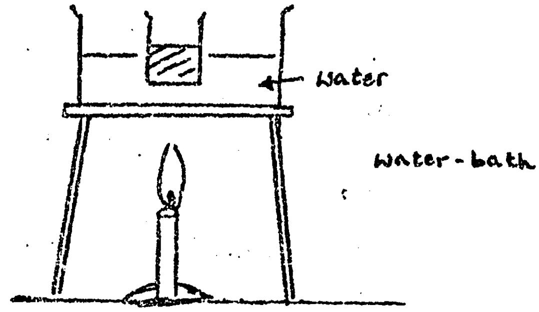


20. Which of the following methods could safely be used to heat a beaker of ethanol? (x)

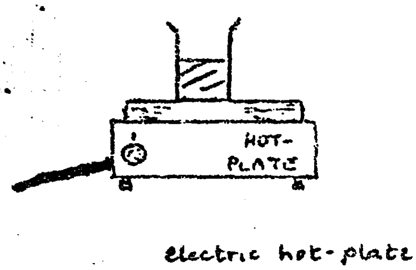
A.



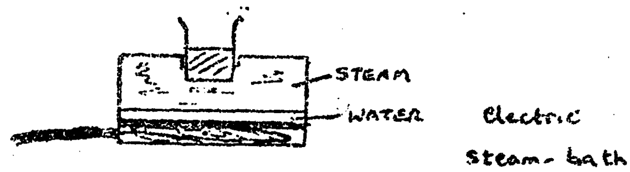
B.



C.



D.

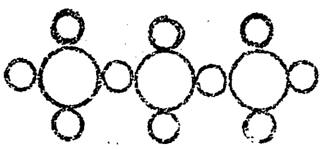


21. A teacher gives the following instructions for the building of a model -

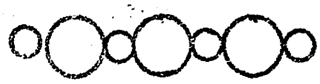
"The three large spheres are joined in a line; the eight small spheres are then attached - three to the outside large spheres, and two to the central large sphere. You now have a model of a propane molecule. Draw a sketch of your model."

From the sketches done by several groups - which built the model correctly?

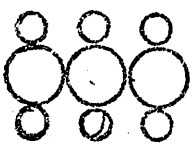
A.



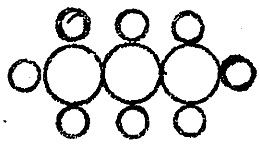
B.



C.



D.



22. Consider the following experiment and results.

20 cm^3 portions of acid were added to the same volume of sodium hydroxide solution. The rise in temperature caused by the reaction between the acid and alkali was measured.
(All volumes were measured by measuring cylinder.)
Results :-

Acid	Temp. rise (class results)					Average (°C)
1 M nitric acid	5·1	4·9	4·8	5·5	7·0	5·5
1 M hydrochloric acid	5·3	4·9	5·6	4·9	5·6	5·3
1 M ethanoic acid	4·4	4·2	3·8	3·9	4·0	3·9

Which of the following conclusions could you come to on the basis of this evidence only?

A. /

A. Neutralisation involving hydrochloric acid releases less energy than that involving nitric acid.
B. Sulphuric acid will release more energy during neutralisation than nitric acid.
C. Neutralisation involving ethanoic acid releases less energy than that involving hydrochloric or nitric acids.
D. The difference between the results for hydrochloric and nitric acids may be due to experimental error.

---

23. Two pieces of metal were connected through a voltmeter and were dipped into a beaker of dilute acid. Using different metals, the reading on the voltmeter was noted. The results were :-

Metals	copper and zinc	sodium and copper	copper and silver	zinc and magnesium	sodium and magnesium
Reading	0·15	0·35	0·05	0·05	0·15

Which of the following conclusions could you come to on the basis of this evidence only?

A. A high voltage is obtained if sodium is used.
B. Low voltages are obtained when any unreactive metal is used.
C. Using two metals close together in the reactivity series causes a low reading.
D. Zinc must be above hydrogen in the reactivity series.

Part 3 Think about the following questions. In each case, choose the ONE answer which you honestly feel would be your response to the situation.

24. Imagine that you are to be a member of a group of four pupils who have to do an experiment? Which of the following roles would you rather have?

A. Keep a note of the results and observations.
B. Watch the others in case they make a mistake.
C. Help with the tidying up at the end of the experiment.
D. Carry out the experimental part.

---

25. A complicated piece of apparatus has been set up in a corner of your chemistry laboratory. It has a master switch, and a notice reading, "Sixth year project - DO NOT TOUCH ! "

Do you -

A. Go and have a look, but leave it alone.
B. Ask your teacher to explain what it is for.
C. Switch it on and see what happens.
C. You never bother with other people's experiments.

---

26. Choose one of the following phrases which describes your feelings towards experimental work.

A. I find it enjoyable to handle apparatus and chemicals.
B. I find experimental work boring.
C. I find experimental work less interesting than the theory.
D. I would not have chosen chemistry if it had contained no practical work.

---

27. /

27. You are doing an experiment in which, according to your teacher, you -

"Heat a blue solid, and a colourless gas will be given off."

When you do the experiment, no gas is given off, and the solid changes to a white colour when heated.

Do you -

A. Scrap the experiment, since something must have gone wrong, and start again.
B. Get another bunsen burner, and heat the substance more strongly.
C. Consult the other groups in the lab. to see if any other groups are finding the same thing happening.
D. Blame your partner for setting the experiment up wrongly.

---

28. Your group is doing an experiment involving measurement from a burette (or dropping pipette). Your partner carries out the experiment, and says

"the volume needed was 20·021 cm^3 "

Do you -

A. Assume that he really means "20 cm^3".
B. Wash out the apparatus and repeat the experiment yourself.
C. Write down "volume needed = 20·021 cm^3" in your notebook.
D. Think that you are lucky to be working with someone who gets good results.

PUPIL ANSWER SHEET

Please put a tick in the box or boxes which you think are correct.

NAME . . . .

CLASS . . . . **SCHOOL** . . . .

Part 1

ONE correct answer for questions 1 → 10

Q.	A	B	C	D
1				
2				
3				
4				
5				

Q.	A	B	C	D
6				
7				
8				
9				
10				

Part 2

Tick as many boxes as you think are correct

Questions 11 → 23

Q.	A	B	C	D
11				
12				
13				
14				
15				
16				
17				

Q.	A	B	C	D
18				
19				
20				
21				
22				
23				
/	/	/	/	/

Part 3

Please tick ONE box only.

Questions 24 → 28

Q.	A	B	C	D
24				
25				
26				

Q.	A	B	C	D
27				
28				

CHAPTER 6

CONCLUSIONS , DISCUSSION

and

RECOMMENDATIONS

Chapter 6 Conclusions, Discussion and Recommendations

CONCLUSIONS

The results of the first questionnaire to teachers (see chapter 2) showed that a lot of practical work was being done in Scottish schools, and that teachers thought that most of it was useful. It was noted that more experiments were being demonstrated than was recommended in the syllabus.

The results of the second questionnaire - on objectives - (see chapter 3) indicated that -

a) Teachers considered objectives of practical work in the affective domain to be more important than those in the psychomotor domain.
b) There was some doubt about the practicability of teachers' choice of objectives for specific experiments. It was felt that some of these objectives could not be achieved as a result of doing the experiment.

When the opinion of pupils of their achievement as a result of having done practical work was obtained (see chapter 4) it was noted that -

a) Pupils felt a greater sense of achievement in the psychomotor domain than in the affective domain.
b) The pupils' sense of achievement of attitudes such as interest, enjoyment and curiosity depended on the attitude of their teacher.
c) The development of psychomotor skills was best achieved by allowing the pupils to carry out experiments themselves. Such skills were not developed as effectively by demonstration of experiments.

Finally, assessment by a "paper and pencil" test was shown in chapter 5 to be one possible way of measuring pupils' ability in some of the objectives of practical work. The test also indicated the validity of the pupils' response to their questionnaires.

DISCUSSION

(1) Some comments might be made on teaching methods. The syllabus states[4] that chemistry should be taught in " an exploratory manner, where a pupil is not told all the facts, but as far as possible discovers them for himself ". The syllabus is arranged so that such teaching methods can be used. This method might be described as " controlled discovery " in that the teacher defines the general area of work and the pupils' practical work and its results lead to the establishment of the theory. This will be called " discovery method " in the subsequent discussion.

It has been shown[22] that discovery methods develop a better understanding of the logic behind practical work than "cook-book" methods. Although both methods developed laboratory skills equally well, the former method led to less of a negative feeling for chemistry at the end of the course than the latter method. Thus studies have indicated[22,23] that discovery methods are efficient at helping pupils achieve those affective objectives which Scottish teachers considered to be important.

However, the results of this research suggested that discovery methods were not often being used in practice. This might be because -

(a) Not all experiments in the syllabus lend themselves to discovery methods ; some are more suited to " confirmatory " or " cook-book " methods.

(b) The open-ended nature of discovery methods leads to difficulty because -

  (1) more time is needed to conduct practical work by this method and it is more difficult to plan time requirements for such work.

  (2) more control of working groups is needed since they are not working to a strict pre-set pattern.

  (3) extra investigations or exercises have to be devised to keep rapidly-working groups occupied while other groups finish their experiments.

  (4) Storage and security of apparatus might create problems, both in terms of space and equipment being tied up, possibly over several days.

It is therefore suggested that if the desirability of using discovery methods is accepted, then the work-load involved in the teaching of the syllabus must be reduced to allow the teacher more time to develop such teaching methods.

It should be noted that a similar state of affairs seems to occur in England, where it has been reported[24] that there is a marked difference between stated course aims and methods of teaching of practical work.

(2) It was shown in this research that the objectives which a teacher had in mind when setting practical work were not necessarily those which were achieved by the pupils. Despite this, teachers thought that 79% of the experiments were 'useful'. One possible conclusion to be drawn from these results is that teachers were not sufficiently aware of what the pupils were achieving as a result of their activity - it is possible that teachers considered that the experiment is

useful if it keeps the pupils active - and the 'usefulness' can therefore be judged by simply looking at the class as they conduct their experiments. (It may be that " keeping pupils busy at a manipulative task (as opposed to a mental task)" is a perfectly valid objective of practical work - although it was not offerred as such by any of the teachers in the sample.)

It is reasonable to assume that most teachers are not aware that the pupils' achievement as a result of having done practical work is different from their (the teachers) expectations. For this reason, it is suggested that there is a need for more assessment of practical work at O-grade. Such assessment would not only give credit to pupils for the development of certain skills but would also provide teachers with valuable feedback which would enable them to judge whether their teaching methods (for practical work) are achieving the stated objectives or whether (as this research has indicated) some changes are required. Such assessment would have been particularly desirable soon after the introduction of the present "new" syllabus to ensure that teachers would be aware of the dangers of using "old-syllabus methods" to carry out the experiments in the "new" syllabus. Indications in this research are that "old-syllabus methods" are still in evidence some 12 years after the appearance of the "new" syllabus. Of course it should be remembered that the great majority of teachers (and more especially Pricipal teachers) of chemistry were themselves taught " old syllabus " chemistry at school.

(3) The difficulty which pupils encountered in one item of the "paper and pencil" test (see discussion of item 11 on page 54) seemed to be as much due to lack of understanding of the concept of ionic solutions as to problems of a practical nature. Such lack of understanding might be partly due to the need to translate the facts which a pupil observes (e.g. the beaker contains a blue solution) into a mental picture of an abstract nature (the beaker contains charged ions moving among water molecules) or into a chemical formula <u>before</u> any meaningful conclusions can be drawn from the given experiment (e.g. on conductivity or even on a "simple" reaction like that between copper (II) sulphate solution and sodium carbonate solution.) It is possible that teachers take such mental steps for granted. But it should be remembered that at the time that experiments on ionic theory are being done (early in SIII), few pupils will have reached the stage of Formal Operations in their mental development.

RECOMMENDATIONS

(1) The points raised in discussion (1) on page 57 would suggest that a detailed inspection of all O-grade chemistry practical work is needed. This inspection should establish whether the skills and attitudes which a pupil can achieve (as a result of doing each single experiment) can justify the cost of carrying out that experiment. On completion of this survey, a list of realistic objectives and teaching methods could be drawn up for all experiments and must then be made available to teachers.

(2) It has already been suggested that more credit should be given for practical skills at O-grade. This could be done by modifying the present examination to include more questions based on the course practical work, or by introducing some form of separate assessment of practical work.

(3) The comments made on page 59 concerning the methods being used to teach the new syllabus would indicate that not enough has been done in the past to ensure that changes in the syllabus were accompanied by the required changes in method. The most practical way to rectify this would be to re-examine the provisions which are made for in-service training. The present arrangements may be failing because they offer blanket courses for all (chemistry) teachers. Perhaps there is a need to offer a series of different courses ; that which an individual teacher attends being determined by (say) his length of service.

(4) It has already been mentioned that research in England showed a difference between aims and methods used, despite the fact that most teachers in the survey had undergone in-service training. It was suggested[24] that teaching methods were not changing because of conditions existing within schools ; this was being investigated.

A similar investigation should be set up in Scotland to establish how school conditions dictate the teaching methods which a teacher can use.

(5) Some research into the particular difficulties associated with chemical " thinking " might be useful. Chemistry seems to differ from the other school sciences in that its conclusions drawn from practical work are one step removed from the actual practical observation or measurement. The extra mental step is required to convert the visual image (e.g. a blue solution) into a mental picture (i.e ions) before any conclusions can be reached. Such research might

also be able to suggest whether the present arrangement of the syllabus (especially with regard to the introduction of abstract concepts) fits in with the mental development of the average O-grade pupil.

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