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A STUDY OF INTERACTIVE PROJECTED DEMONSTRATION TECHNIQUES FOR SCHOOL SCIENCE IN OMAN

BY

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TO MY PARENTS

"MY LORD! BESTOW ON THEM THY MERCY EVEN AS THEY CHERISHED ME IN CHILDHOOD"

and

TO MY BELOVED WIFE AND CHILDREN

IN THE NAME OF ***ALLAH***, THE MOST

MERCIFUL, THE MOST PASSIONATE

Abstract

Laboratory based practical work has been considered as one of the "Sacred Cows" of chemistry teaching for many years. However, attempts to measure the benefits of the laboratory experience to which learners are subjected, with regard to how much learning actually occurs, revealed what can be described as a "pessimistic picture". Whilst practical work is generally popular with learners and can, to varying degrees of proficiency, engage hand-skills, its ability to generate much active thought or teach theory appears at best questionable.

It is my contention (and that of many others) that, for many experiments, the learner's Working Space is bombarded with information from a variety of different sources which swamps it, leading to an unstable overload state which precludes systematic, intelligent working and causes the learner to seek some more stable (and comfortable) state by a number of devices leading to poor learning. Consequently, it is common to find observers of laboratory classes, who have their own anecdotes of learners whose behaviour suggests a lack of appreciation or understanding of what is happening.

What may be clearly organised and understood by the teacher (expert) may not be so for the learner (novice), in that information received by the latter may have no apparent structure since adequate previous knowledge is required to make sense of the incoming information. As the important can not be distinguished from the irrelevant, the point of the lesson is lost to the learner.

The very common response to this is that the learner follows instructions line by line (blind recipe following) or gives one section of the experiment an inordinate amount of time and attention, whether it warrants it or not and so never finishes the experiment. He may copy nearby learners' actions or even volunteer to act as the recorder of information for group experiments.

All the above actions are attempts by the student to lessen the load and their facts. Also the strain on school resources by the increased number entering schools, could increase the reluctance to change to demonstration. However, the weak points of demonstration are the issues of visibility and the fact that the learners are not engaged in such an activity. A new technique which considers these points, is required and demanded. Therefore, Tested Overhead Projections (**TOPs**) might be the remedy for the problems mentioned above. In addition to that, in TOPs the teacher has the control to reduce the "noise", enhance the "signal", and engage learners both in hands and minds and, as a

bonus, brings benefits of safety, cost, speed, durability, visibility, student-friendliness and easy disposal of smaller quantities of chemicals.

It is the researcher's hope to convince the reader (and people in-charge of Education in Oman) that the benefits of this new technique far outweigh the effort which would be required in adopting this new system.

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CHAPTER ONE

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1.1. Introduction

Practical work has gained world-wide acceptance as one of the most important and essential element in the teaching of school science, which is now firmly embedded in the laboratory. Evidence of faith and conviction in this mode of instruction is obvious from the enthusiasm with which laboratories have been built, old ones refurbished, and new ones still being built specifically for science instruction. The developing countries are contending with each other to provide necessary facilities and utilise their existing resources to fulfil this major element in science teaching.

Thus, in order to educate each new generation in science, there is a widespread belief that students should learn science by first-hand experience of practical experiment; doing as scientists do. This active form of learning in science is seen by many science educators as likely to be more effective than are other instructional methods because the learner is involved in practical activities and takes an active part in the learning procedure.

However, there is a degree of confusion and a degree of naivety in the assumption that such significantly different kinds of goals for practical work (chapter 2, section 2) can all be well served by a single type of learning experience. There is also a degree of confusion and naivety in the assumption that 'practical work' necessarily means individual laboratory bench work. Any learning method that requires the learner to be active, rather than passive, accords with the belief that students learn best by direct experience and so could be described as 'practical work'. In that sense, practical work need not always comprise activities at the laboratory bench.

What is more, mainly due to the many different factors which affect the learner in the practical working situation, the learning process in the practical sessions may not achieve what is intended.

In the laboratory and in front of the bench, the learner has to cope with many types of learning stimuli that may lead to a state of overload. So it is not surprising that many of the attempts made to measure the learning outcomes from practical work have produced disappointing results.(Letton, 1987 and Johnstone, 1997b)

Many researchers (Johnstone and letton, 1989a+b, 1991, Hodson, 1993 and Johnstone, 1997b) have recorded that students perceive practical work as boring and a waste of time with students following experimental procedures like a recipe without thinking about what they are doing and why they are doing it.

1.2. Limitation of practical work in school science.

The effectiveness of practical work must depend, to a large extent, on many factors. Some of these are related to laboratory facilities, time available, class size, and staffing.

In developing countries, where curricula prescribe the use of practical activities, a number of constraints may prevent the implementation of these in classrooms. Commonly reported constraints include lack of equipment, large classes, overcrowded syllabi, and an examination system focused on factual recall while ignoring formal assessment of practical outcomes and the application of scientific reasoning to solve problems.

Another factor is the role of practical activities as perceived by teachers in developing countries. In many cases, these activities are seen as having the role of confirming scientific knowledge as opposed to being exploratory in nature. (Thair *et al.,* 1999)

While it is helpful to know that a particular experiment consumed a certain sum in chemicals, that figure is often insignificant compared with the costs of the capital equipment, staff time and laboratory accommodation. It might be helpful to examine these more closely in three main categories.

1- Factors related to staff:

Lab staff includes both science teachers and technicians. Factors appearing here are as follows:

- poor quality teacher preparation:

Due to the lack, in teacher training institutions, of well-equipped labs, teachers may lack training in using labs effectively. The overload of syllabi and time restraints also operate in these institutions. In some developing countries there is a lack of local teachers, so they rely on expatriate teachers to do this job. These teachers are, however, unwilling to teach science practically for the reason above or for the reason stated by Allsop (1991) that "local teachers were more likely to have positive attitudes to investigational approach than expatriate teachers, many at that time coming from industrialised countries".

- ❖ Some teachers hold the thought that pupils in school science will not behave like 'real scientists', so there is no point in carrying out senseless work like experimenting.
- ❖ Technicians are not well trained to deal with school labs and lack in-service training to update their scientific skills and knowledge.
- ❖ Often as a consequence of pupil misbehaviour in a lab session, either the teacher or the technicians would deprive pupils of any sort of practical activities.
- ❖ The claim from some teachers to do practical work as an essential feature of school science can restrict the science curriculum. Some teachers will say that we won't teach this topic because we cannot do practical work in it; therefore, some topics are neglected from science such as earth science, astronomy and even some topics in chemistry.
- ❖ Even although the equipment or chemicals required by some experiments are available, teachers will not attempt these activities, getting away from any responsibilities.

2- Factors related to the nature of practical work.

These factors affect the kind of activities to be undertaken.

- ❖ Some experiments are dangerous when carried out by pupils individually such as those activities using concentrated acids or bases or volatile solvents.
- ❖ Some experiments take a long time to complete. A pupil following a recipe line by line and word by word, will run out of time in the middle of the procedure or at best they may complete it but at the expense of notes or writing about the observation and its explanation.
- ❖ Occasionally, individual or even group lab work may result in confusion rather than illumination of laws and verification of theories. This is mainly happening if pupils go wrong whilst experimenting.

3- Factors related to resources available, time and size of the class:

These are serious constraints facing and confronting developing countries and the third world. There are many limitations. A few can be mentioned as follows:

- ❖ Lack of facilities, equipment, materials and chemicals in most schools, since they are too expensive. Johnstone, (1992) stated that the accountant could see that labs are 10 times more expensive to run than other forms of teaching. They need special accommodation, are often underused, they consume chemicals and apparatus and are heavily staffed in terms of teachers and technicians.

The cost of consumable materials can be a significant burden depending on how these are provided and how much practical activity is undertaken. Costs tend to be higher for chemistry if analytical quality reagents are used for classroom practicals. Biological materials are more likely to be available in the local environment at low cost. Much physics teaching does not consume material, since many things can be re-used such as wires, lenses, thermometers, etc.

- Class size is, in many cases, considered as a major stumbling block to the practicing of regular practical work. The number of pupils per class actually varies a great deal from country to country. It is very high in most African countries, such as 60-64 pupils per class in Burkina Faso. Table 1.1 shows class size and class allocation of teachers in Oman over the period 1994/95 to 1998/99. What we should bear in mind is that these figures are the average. Omani schools are scattered as in rural schools, where the average class is just 12 pupils / class such as in secondary schools in Al Wusta Region (*chapter 4*) whereas in urban schools (*which represent more than 80% of the total schools*) the average is more than 35 like in Muscat and Batinah Regions. These figures give some idea of the difficulty in providing practical work to each pupil.
- Time allocated for science teachers to cover syllabi and do paper work is too short to carry out practical work. A survey (*Daily Mail* newspaper Feb 19th, 2000) commissioned by Scotland's largest teaching union (the Educational Institute of Scotland) revealed that the average teacher worked 42 hours a week and that one in seven worked more than 50 a week. (*The European limit is 48 hours*). Only three hours each day were actually spent teaching with the rest taken up with paperwork and management tasks.

Level of Education	**Statistical Indicator**	**94/95**	**95/96**	**96/97**	**97/98**	**98/99**
Elementary	Average class size	34	34	34	34	34
(Years 1-6)	Teacher / Class	1.3	1.3	1.3	1.3	1.3
ages (6-12)	Pupils / Teacher	27	26	27	27	26
Preparatory	Average class size	32	31	31	32	32
(Years 7-9)	Teacher / Class	1.7	1.7	1.7	1.7	1.7
ages (13-15)	Pupils / Teacher	19	19	19	19	19

Secondary	Average class size	29	29	30	30	31
(Years 10-12)	Teacher / Class	1.8	1.9	1.9	1.9	1.9
ages (16-18)	Pupils / Teacher	16	16	16	16	16

(Source, Ministry of Education, Oman, 1999b)

Table 1.1: Class Size and Class Allocation of Teachers in Omani Public Schools in Past Five Years (94/95-98/99).

Overall, Lab work in chemistry is an expensive activity. Labs are costly to build and fit out and academic and technical staffing, instruments and consumables are a drain on resources.

It is probable that restrictions imposed by safety legislation on the use and disposal of chemicals have a major effect on practical work, particularly in the less well endowed institutions.

The perception is that it is becoming increasingly difficult to provide students with a high quality conventional practical experience. The 1994 the Royal Society of Chemistry report on '*The design and delivery of degree courses in Chemistry*' states that the restrictions on resources and the time allocated to practical work are causing a decline in the extent of practical work and the standards achieved (Bennett, 1997).

To generalise, the requirements of individual practical work compared with courses for lectures have always been higher. For example, the space occupied per pupil, the ratio of staff / pupil, need for technician back up, chemicals used and use of specialist rooms, and equipment are higher for lab than lectures. And so departmental (school administration) decisions on finance will obviously have a major effect on any revision of laboratory courses.

Hence, for those who design laboratories, service them, demonstrate in them or learn in them there are clear messages from the previous few paragraphs.

As scientists we have a touching faith in what labs can achieve, but such faith has got to be supported by evidence. At present, for many labs, the evidence for learning is thin, but could be considerably and uniquely enhanced by the help of the kind we will outline in the next chapter.

CHAPTER TWO

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2.1.The history of practical work:

Practical work in school science has a very long history. In early eighteenth century chemistry was taught only by lecturing. Later on in the same century, it was felt that some practical work should be introduced in the form of demonstration in lectures. Until the middle of the 18^{th} century, chemistry existed mainly as an adjunct to medicine, but in 1748 and at the University of Glasgow, Scotland, William Cullen was appointed to the first ever lectureship in chemistry. He and his successor Joseph Black (1728-1799), included some chemical demonstration in their lectures to undergraduates; otherwise only assistants or demonstrators in the laboratories did practical work. (Johnstone, 1993)

At the end of the 18^{th} century individual practical work was accepted as an essential part of a chemistry course. In 1795, the Ecole Polytechnique of Paris (France) introduced laboratory work.

By the beginning of the 19^{th} century, and specifically in 1806 practical work had been adopted in Germany, at the University of Gottingen, a practical course was introduced by Friedrich Stromeyer who believed that chemistry could only really be learnt through laboratory practice and that the students must be given an opportunity to carry out analyses on their own.

In 1808 in Stockholm (Sweden) at the Collegium Medium, Berzelius had opened his own private teaching laboratory for a few students, first situated in Hisinger's house and then in the Swedish Academy of Sciences, attended by his more famous pupils.

In addition, the first teaching laboratory in a British university was established by Thomas Thomson in the University of Edinburgh in 1807 and then he introduced it to the university of Glasgow in 1819 where he tried to establish a research school based on his teaching laboratory as he took up a teaching post in this university. Other universities followed suit.

The most crucial event in the history of 19^{th} century science was in 1824 when Liebig's chemistry laboratory was opened at the University of Giessen. It was the first institutional laboratory in which students were deliberately trained for membership of a highly effective research school by systematic research.

Liebig's laboratory was so successful that 11 out of 30 of Liebig's pupils occupied most of the important posts in chemistry laboratories of British universities.

Aberdeen was holding practical classes in 1829 under Dr. French and Dr. Perceval in Dublin was running a teaching laboratory around the beginning of the 19th century. London, Cambridge and Oxford followed until there were several chemistry teaching laboratories in the UK.

In England, much of what constituted a lecture-demonstration course depended upon availability of apparatus and necessary items. Until the 1830s, there were no formal courses of lab instruction despite the fact that occasional texts presented practical work, which could be performed in a home kitchen laboratory.

Later in 1835, David Boswell Reid and John Joseph Griffin initiated a purpose-built teaching laboratory to cater for individual practical experience. In spite of having an interest in bringing practical work into English schools, without laboratories suited to the purpose, there was little likelihood of launching laboratory-based instruction in science. In 1851 and just after the Great Exhibition of this year, a two-thirds support grant for scientific apparatus was allowed for training and elementary schools. Three years later, there was a good display of ideas for classroom science (including apparatus for chemistry, meteorology, microscopy and astronomy) at the Educational Exhibition.

School science apparatus continued to be exhibited in South Kensington, London, and there had been success in introducing science into elementary schools, if only by demonstration. A recommendation was then made about the need for secondary school science and this led to the grant fund for science being diverted away from the elementary schools.

These all led to the general need for school laboratories particularly in chemistry.

Laboratory classes then gradually developed, over the next fifty years until eventually, in 1899, it came to be considered necessary that pupils be allowed to carry out experiments for themselves. By this time, however, most schools had already adopted this way and regarded practical work as an essential requirement for science teaching. (Gee and Clackson, 1992)

During the period of 1810 until 1826 the first laboratory course in chemistry was offered in the USA by William James MacNeven, professor of chemistry in the College of Physicians and Surgeons of New York, where the students had an opportunity to practise the techniques, processes and procedures of chemistry.

However, credit for the growth of practical work is accorded to Edward Frankland, a graduate of Liebig's laboratory, who, throughout his life did much to encourage the introduction of laboratory instruction. Largely, due to his efforts, by 1876 there were one hundred and fifteen (115) laboratories in operation in Britain, most giving very elementary instruction.

Thus, practical training in chemistry sprang up in universities all over Europe and North America devoted to the teaching of skills directly usable in industry and research. ((Letton, 1987), (Johnstone and Letton, 1989b), (Vianna, 1991), (Khan,1996)).

It was at the turn of the nineteenth-century that laboratory-based methods of teaching achieved their most rapid growth associated with the growth of research schools in chemistry. So it was that individual practical work was accepted as an essential part of university chemistry course. Until then, laboratory instruction had been an isolated activity with little support: some of it private instead of institutional and outwith the curriculum, i.e. it was not compulsory.

Practical work at this time filled a largely supportive role, that of confirming the theory, which had already been taught in lectures. There was still little evidence of detailed instructions for students and fully trained staff gave any help required during this period. It was during this period too, however, that doubts started to arise about the efficacy of teaching through individual practical work in chemistry – doubts, which grew from then until the Second World War.

In the years following 1910, the progressive education movement had a major impact on the nature of science teaching in general, and on the role of lab work in particular. John Dewey, leader of the progressive education movement, advocated an investigative approach and "learning by doing".

Following World War I, lab activities came to be used largely for confirming and illustrating information learned from the teacher or the textbook. (Hofstein and Lunetta, 1982)

In 1882 the Education Department declared that " the instruction of scholars in science subjects shall be given mainly by experiments". Obviously, they had in mind demonstration experiments performed by teachers, rather than the direct experimentation by pupils advocated by pioneers such as Armstrong whose heurism fell into disrepute and, with the impetus provided by the Thomson Report's declaration that too much time was wasted on repetitive individual practical work, attention switched back to teacher demonstration. The same idea was supported the Board of Education in its pamphlet No.89 in 1932 which declared that there was "too much practical work of the wrong kind… too much remote from the natural interests and everyday experience of the children". (Hodson, 1990 and 1993).

Siebring and Schaff (1977) noted from a study of the manuals from the 1930s and 40s that the chemistry did not appear to have to be 'sold' to the students.

"In 1935 Schlensenger studied the contribution of laboratory work to general education and was concerned to notice that students who had previously exhibited ' real interest in chemistry' developed the habit of doing their experiments mechanically to get the result expected rather than to observe what is actually going on in their test tubes". (Quoted from Letton, 1987).

Hodson, (1993) mentioned that practical work in the mid-nineteenth century "filled a largely supportive role, that of confirming the theory that had already been taught and that teacher demonstrations were much more widespread than individual experimentation by students". *Moreira*, as Donnely (1998) stated, that "In England and Wales there have been two major government- sponsored initiatives in the last decade which are seen as having increased the emphasis on the lab in secondary schools, though both had complex and in some cases problematic results".

Nevertheless, in the first three decades of the 20th century, there were several investigations comparing the individual practical instruction with the demonstration method (*See chapter 3, Section 1 for details*). Demonstration experiments were seen as a feasible and efficient alternative. Later more sophisticated alternatives to individual lab work were also considered. Film and video experiments were compared, and also computer simulations were tried.

After the Second World War the discussion moved from two forms of practical work to a greater concern for the objectives of laboratory instructions (*See the next section*).

The advent of curricular changes in chemistry was seen in many countries of the English speaking world during the 1960s. CHEM Study and CBA (Chemical Bond Approach) appeared in the USA, the Scottish Alternative Syllabus and the Nuffield and School Council in the UK, as well as the ASEP (Australian Science Education Project) in Australia, signalled the end of a long period of stability in the school chemistry curriculum.

Things had remained relatively unchanged until the new science curricula of the 1960s which resulted in several changes in the role of traditional laboratory work. This new curriculum stressed the processes of science and placed emphasis upon the

developments of higher cognitive skills. Laboratory work required a central role as the core of the science learning process, not just a place for demonstration or confirmation. It was thought that the laboratory ought to provide students with opportunities to engage in the process of investigation and inquiry. (Hofstein and Lunetta (1982))
According to Ausubel (1968) the laboratory "gives the students an appreciation of the spirit and method of science, …promotes problem-solving, analytic and generalisation ability, …provides students with some understanding of the nature of science". (Cited in Hofstein and Lunetta, (1982))

In the 1970s, laboratory teaching was beset by 'inquiry-discovery' methods and 'problem-solving' approaches, with the aim that students should discover for themselves much of what used to be taught to them in lectures. Therefore, laboratory courses during this period stressed that students should learn how to deal with systems as they actually behave in the real world, in contrast to the 'ideal' behaviour normally portrayed in lectures.
Over the years many researchers, who recognised the existence of problems in laboratory teaching, had attempted to redesign their courses; putting forward hybrid schemes involving various degrees of student participation and concentrating on one particular aspect of it. For example, 'Chemical measurement' was used by Atkinson (1972), 'art of observation' was emphasised by Swinehart (1979); methods of class participation where the students were more actively involved by being asked to do things for themselves. From then on students should be encouraged to acquire specific skills in order to answer questions, which they posed in the laboratory.
The literature reported a number of courses, where the students were given greater freedom after initial instruction in basic techniques. These courses ran with fairly low student numbers and involved standard experiments and experimental procedures.
A unified laboratory program was suggested by Aikens *et al.* (1975) in which the learners received instructions about experimental techniques, experimental procedures, evaluation of results, planning design and executing laboratory projects that required a significant degree of judgement.
Wade (1979) argued that for students, the purpose of practical work with detailed experimental procedures was to follow the prescribed procedure as carefully and closely as possible to obtain the optimum result. Johnstone and Wham in 1980 affirmed the importance of doing lab work in a systematic manner. They suggested

mini projects with minimum instructions and more freedom within the student's knowledge.

This was the view, nevertheless, that was not to remain unchallenged for long.

Are goals of lab teaching and learning achieved in practice? To answer such a question sufficient data must be available from appropriate research.

2.2. Aims and objectives of practical work

In order to justify the importance of practical work, it is essential to examine its objectives.

If we accept that practical work can be a valid and effective teaching strategy, it follows that aims and objectives should be defined.
The question now is, which aims and objectives could and should be pursued through practical activities?
Such a question has been under investigation for decades, especially in places like Britain where a great deal of time and money has been spent on doing practical activities in school science. (Woolnough, 1983).
After the Second World War a movement to re-examine laboratory work objectives was started. Before the war, chemistry had been taught with primary emphasis on knowledge objectives, which gradually shifted to a greater concern for process, attitude and interest, and cultural awareness objectives. The important aims and objectives of practical work had been stressed from as far back as the early nineteenth century and special attention to this has been given in the post World War period by teachers and researchers. The need was recognised for a list of practical objectives to help laboratory teachers to think clearly about their intentions and to ensure that all important goals of the course have been pursued. Also there is a consensus about the need for a list of aims or objectives in order to be able to assess practical work. (Vianna, 1991)

Before going through lists of aims and objectives, which have been produced by researchers, it should be clarified what the terms 'aims' and 'objectives' mean. In the literature on practical work the two terms are often used fairly synonymously to give a general description of performance of the practical work. Sutton in1985 defined aims as *General statements of what the teacher intends to do, while objectives are specific* *statements of what the students should be able to accomplish as a result of being taught*. Cited in (Refaa, 1991)

Kerr carried an important study of practical work out some forty years ago in 1961. Over a two-year period he conducted a survey of practical work in England and Wales asking teachers to give information about the nature, purposes, assessment, and views about practical work they had encountered at schools.

Kerr compiled a list of ten aims for practical work, which the teachers were asked to rank in order of importance. These were:

1- To encourage accurate observations and careful recording.
2- To promote simple, common sense scientific methods of thought.
3- To develop manipulative skills.
4- To give training in problem solving.
5- To fit the requirements of practical examinations regulations.
6- To elucidate the theoretical work so as to aid comprehension.
7- To verify facts and principles already taught.
8- To be an integral part of the process of finding facts by investigating and arriving at principles.
9- To arouse and maintain interests in the subject.
10- To make phenomena more real through actual experience.

Later Buckley and Kempa (1971) constructed a list of principal objectives, which covered four main areas 'manipulative skills, observational power, ability to interpret experimental data, and the ability to plan experiments'. Table 2.1:

Main and sub-objectives

The development of manipulative skills

Students should be able to:

A1. Manipulate, erect and maintain the standard apparatus required carrying out simple experiments.

A2. Handle chemical substances in such a way that their awareness of the inherent dangers and necessary safety measures are apparent

A3. Work Accurately with reasonable speed.

The development of observational powers

Students should be able to:

B1: *Observe accurately.*

B2: *Record observations correctly.*

B3: *Read instruments correctly.*

The ability to interpret experimental data

Students should be able to:

C1: *Interpret observations and experimental data.*

C2: *Assess and judge the validity and reliability of experimental procedure.*

The ability to plan experiments

Students should be able to:

D1: *Solve practical problems using standard experimental techniques.*

D2: *Device simple experimental procedures for the investigation of chemical problems.*

(Source: Buckley and Kempa (1971)).

Table 2.1: Suggested main and sub-objectives of practical work in Chemistry.

These aims and objectives have been voiced from the early nineteenth century and remain almost the same to-day. Numerous attempts have been made to articulate the objectives and aims of practical work such as; Shulman and Tamir (1973), Swain (1974), Thompson (1975), Kempa and Ward (1975), Johnstone and Wood (1977), Gould (1978), Boud *et al.* (1980), TAPS project (Techniques for Assessment of Practical Skills in Foundation Science, Glasgow, 1981), Simpson and Anderson (1981), Lunetta *et al.* (1981), Lynch and Ndyetabura (1983), Romiszowski (1984), Denny (1986), Lynch (1987), Kirschner and Meester (1988), Bentley *et al.* (1989), Boyer and Tiberghien (1989), Garnett and O'Loughlin (1989), Qualter *et al.* (1990), Gunston (1991), Woolnough (1991), Edwards *et al.* (1993) and Wellington (1994).

There are several ways of categorising and grouping these objectives. One of the most convenient ways of grouping these objectives is in terms of their relationship with the experimental process. Objectives can be grouped, for examples, according to whether they relate to the planning, experimenting, analysing or concluding phases of the experimental process. Table 2.2 below contains an extensive list of lab objectives organised in this way.

A: Planning:

1- Identify a problem for investigation, select relevant variables and describe possible relationships between them.

2- Express the problem in the form of research questions and/or hypotheses.

3- Identify variables as manipulated, responding or controlled.

4- Operationally define the variables in terms of how they are observed or measured.

5- Describe and select appropriate experimental procedures and techniques and explain the theoretical principles underlying them.

6- Identify potentially dangerous apparatus, materials or procedures and describe relevant safety procedures.

B: Experimenting

1- Follow experimental procedures and instructions accurately.

2- Assemble units of equipment into appropriate configurations for an experimental procedure.

3- Efficiently and safely operate experimental apparatus.

4- Carry out a range of common experimental procedures effectively and safely, e.g. filtering, distilling, pipetting, titrating and weighing.

5- Use lab instruments to make accurate measurements of physical quantities, e.g. volume (measuring cylinder, pipette, burette), time (stop clock), temperature (thermometer), current (ammeter), and voltage (voltmeter).

6- Accurately observe and record quantitative and qualitative chemical phenomena.

7- Use appropriate tables, sketches, charts or written notes to record observations and data.

8- Use appropriate safety procedures in making observations and measurements, e.g. wafting odors.

C: Analysing and interpreting observations and data

1- Draw inferences from observations.

2- Propose explanations of observations and data based on theoretical principles.

3- Use appropriate mathematical techniques to analyse data.

4- Use conventional notations, symbols and units for recording data.

5- Construct graphs to show relationships between variables and display trends.

6- Use techniques such as forming a line of best fit, interpolation and extrapolation to analyse graphical information.

D: Drawing conclusions

1- Determine the appropriateness of experimental procedures in addressing specific research questions.

2- Describe relationships between variables quantitatively and qualitatively on the basis of experimental results.

3- Propose appropriate generalisations and conclusions based on experimental results and theoretical principles.

4- Correctly accept or reject hypotheses on the basis of experimental results.

5- Recognise limitations inherent in experimental results and conclusions.

Table 2.2: Objectives of laboratory work. **(Source: Garnett and O'Loughlin (1989))**

The planning phase includes objectives such as identifying variables and describing experimental procedures. Experimenting includes following instructions, carrying out common experimental procedures, using lab instruments and making accurate observations. The analysing and interpreting phase incorporates a range of process objectives such as interpreting data, making inferences, determining mathematical relationships and constructing graphs. Drawing conclusions includes objectives such as describing relationships between variables, proposing generalisations and recognising experimental limitations.

Another way of grouping objectives is classifying them into three Domains derived from Bloom's Taxonomy as the following example illustrates:

1- Cognitive Domain

- To make the learning more effective.
- To give training in problem solving and using scientific methods.

2- Manipulative (psychomotor) Domain

- To develop manipulative and measurement skills; observation.

3- Affective Domain

- To stimulate curiosity and motivate pupils.

Each of these will be considered separately:

(1) Cognitive Domain:

- *To make the learning more effective.*

A number of writers and researchers have supported the phrase "we learn by doing". For example Head (1982) emphasised the importance of working in the laboratory so that through 'smelling' the gas, 'feeling' the temperature and 'watching' the changing in colours, the learning will be more effective than from a set of verbal or written instructions.

Experiments help consolidate the subject matter already taught in class and help in the acquisition of knowledge, which leads to understanding of the principles involved. Several authors pointed out that practical work illustrates theory that has already been taught. Other writers, however, question the value of using practical work as a teaching strategy.

- *Give Training in problem solving and using scientific method.*

One of the most important aims of science education is to give the learners a chance to develop their basic skills in problem solving. These skills enable students to generate reasonably accurate data as well as analyse and interpret it.

The term 'problem solving' may refer to a variety of activities, in theoretical as well as in practical situations. However, to solve a problem is not an end in itself, the important thing is the approach to tackling the problem. By solving the problem through scientific methodology, the learner would find the answer to most problems he may face later in his/her life which results in getting an answer for the question "What does a scientist do?". Skills that the learner may acquire through problem solving include identifying the problem, formulating hypotheses, controlling variables and interpreting data, in addition to the basic processes of measuring, communicating, classifying, predicting and observing.

(2) Psychomotor Domain:

- *Developing manipulative skills.*

There is a range of practical skills, which are fundamental in scientific education. Woolnough and Allsop (1985) have summarised the skills which have to be acquired as observation, measurement, estimation and manipulation.

Apart from observation, which will be discussed later, these three skills are more likely to be 'bench' skills which are needing 'hands on' experience to be acquired.

Observation:

Observation is a cognitive process and it becomes scientific when it has purpose and theoretical perspective.

What then is scientific observation?

Young (1979) made it clear that there is a difference between "seeing" and "observation" when he stated that children "see" many things, but they do not always "observe" them.

Observation (Hodson, 1986) would appear to be more than merely seeing and seeing would appear to be more than simply receiving sense data. Something is added at each state.

It is important to distinguish clearly between these two kinds of interpretation.

It is necessary to establish quite early in a child's science education that it is not possible to make observations without theoretical interpretation of some kind. Because the collection of observational data can only take place within a theoretical framework, what is valuable in science is the ideas one has about the data, rather than the data itself.

In a similar way scientists have to test their observations for acceptability by using theory. This is the reverse of what science teachers usually tell children. The usual message is that we have to test our theories for acceptability against reliable observations. In reality, however, scientists often have to reject sense data on theoretical grounds: the Earth is not flat, a stick is partially immersed in water is not bent, distant stars are not red. When theory and observation conflict, nothing in the logic of the situation necessarily demands that the theory should be rejected. Rejection of observational evidence is a crucial part of scientific research.

Students who lack the requisite theoretical framework will not know where to look, or how to look, in order to make observations appropriate to the task in hand, or how to interpret what they see. Consequently, much of the activity will be unproductive. In practice, Hodson (1996) stated:

> "*...the situation can be much more complex and considerably more prejudicial to learning. When learners have a different theoretical framework from that assumed by the teacher, they may look in a different (wrong?) place, in a different / wrong way, and make different / wrong interpretations, sometimes vehemently denying observational evidence that conflicts with their existing views*".

Hodson (1986) remarks, "Knowing what to observe, knowing how to observe it, observing it and describing the observations are all theory-dependent and therefore fallible and biased. Observation statements do not provide the objective certainty for making generalisation and building laws, which the inductivists claim; they are only as reliable as the theories they presuppose. The validity of theoretical statements cannot be guaranteed by observational evidence. First, because of the unreliability of observations. Second, because of the theory-dependence of all concepts involved in observations. Third, because the experimental procedures that produce observational evidence are all theory-dependent and often involve elaborate instrumentation, each with its own theoretical underpinnings. For example, designing apparatus to detect sub-atomic particles requires us to make assumptions about their properties and behaviour. We must speculate in advance of observation about the nature and properties of that which we wish to observe. What is described and explained in science is never 'pure phenomena', but phenomena seen through particular 'theoretical eyes'. Theoretical knowledge opens up possibilities of interpretation that would otherwise not exist. As a science develops and acquires new theoretical knowledge, it acquires new abilities to generate knowledge by making 'better' and different observations. Thus, we learn about nature and we also learn how to learn about it, by learning (i) what constitutes information, (ii) how to collect it, and (iii) how to interpret it."

Observation is carried out to check on theories, not only to collect 'facts'. However, as indicated earlier, again Hodson (1986) asserted that "We may reject observations, just as we may reject theories. Thus we have an interesting paradox: our theoretical knowledge can show us that certain observations are unreliable and in need of revision, and our observations can tell us that our theories are inadequate and in need of revision. When theory and observation conflict, how do we know which is to be rejected? We may reject a theory in the light of falsifying observations or we may modify those observations in order to retain a well-loved and otherwise useful theory. The view promoted in school science courses, that a change in observational evidence always brings about a change in theory, implies a simple direct relationship between observation and theory which seriously underestimates its true complexity".
A further complication is the danger that our acceptance of a particular theory prevents us from making the observations that might refute it. Scientists who accept a particular theoretical structure may find it difficult to recognise deficiencies in that structure because their theoretical biases blind them to the theory's shortcomings and prevent them obtaining or even seeking appropriate counter evidence. (Hodson, 1986)

Overall, it would be a mistake not to consider the link between observation and understanding, because what is observed depends as much on what is in the mind of the observer as on what is there to be seen. In practical work a further complication to observation is that apparatus often masks a phenomenon. An example given by Frost *et al.* (1995) is that "The size and the noise of the Van der Graaf generator often masks the significance of the spark being generated. The noise from the vacuum cleaner in a linear air track can distract from the significance of the movements of the air-borne pucks". People's memories of their school science often relate more to the dramatic equipment than to its significance for scientific ideas. Because of this a teacher may often be heard taking some time to explain a piece of apparatus, with the purpose of making it sufficiently familiar that the class can forget it and focus attention on the phenomenon. (Frost *et al.*, 1995)

Conclusion:

Besides carrying out manipulative experimental tasks, lab work requires pupils to observe closely the phenomena arising from the manipulative work.

But do learners notice every observation that could be made? Kempa and Ward (1975) stated that pupils failed to notice or record one of every three observations since they found that the highest observational attainment was about 65%.

They reported (1988) that observability is a function of both the nature and intensity of a stimulus and the observer's perceptual characteristics. This observational stimulus should reach a certain level below which, observation will not be made (observation threshold).

Kempa and Ward (1988) pointed out that, as the intensity or magnitude of an observational stimulus is reduced, it becomes more difficult to detect. Moreover, and in case of multi-stimuli, the detectability of one stimulus can be seriously affected by the presence of another stimulus; the dominant stimulus will affect the non-dominant one.

In practice, using projected experiments *(later to be called Tested Overhead Projections or **TOPs**)*, visual observational changes are well above detection threshold and then easily observable such as gas evolving, precipitation, change in colour or layer reactions. Haptic (things related to the sense of hearing) changes, however, can be "observed" to some extent in certain experiments. On the other hand, olfactory (things related to smelling sense) changes, in TOPs, have a lower magnitude than the threshold and therefore are undetectable because of distance and the small-scale of the reactants.

Thus, whilst projecting a particular task, the instructor should highlight what learners should see in order to fulfil the task's aim, i.e. focusing in 'signals' and ignoring 'noise' as manifested by Johnstone *et al.* (1982). Teachers also have to ensure that signals offered to pupils should be with enough observational magnitude and intensity as to be above the threshold. They should also be aware of the dominant observation in situations of multi-stimuli.

This way of asking learners to pay attention is absent in the case of individual/group practical work where at any one time not all pupils were actively engaged in the same practical work. Some learners are writing up experiments, some are carrying out investigations, some are setting up apparatus, some are reading procedures.

(3) Affective Domain:

The most important term which comes to mind when the affective domain is mentioned is attitudes. This word 'attitudes' is reserved solely for the affective dimension, indicating evaluative judgement or favourability towards an object. Other terms are closely related to attitudes such as "interest" and "opinion".

The former term "interest" refers to selection of stimuli or attending to something and is often used as an alternative for the word "attitudes" whereas "opinion" deals with matters which can be factually verified.(Refaa, 1991)

As Tamir and Shulman stated in 1973 "…we are entering an era when we will be asked to acknowledge the importance of affect, imagination, intuition and attitude as outcomes of science instruction at least as important as their cognitive counterparts", so affective outcomes of laboratory instruction should certainly be given more emphasis in research studies. Cited in Hofstein and Lunetta (1982)

Generally, laboratory work is used extensively to develop learners' conceptual learning and understanding of science. Most often these activities are used to introduce, illustrate or verify information dealt with in course work and to provide concrete experiences of chemical phenomena. In the curriculum reforms of the 1960s and 1970s emphasis was placed on learners 'discovering' knowledge and concepts from contrived laboratory experiences which guided them towards the acquisition of this knowledge. More recently, within the context of constructivist theory, some emphasis has been placed on using laboratory work to enable learners to reconstruct 'personal theory' (Gunstone, 1991) and encourage a higher level of metacognition.

Most chemistry courses at senior secondary and tertiary levels include objectives, which recognise the importance of practical skills and techniques. However, as Hegarty-Hazel (1990) points out, given their vocational relevance the development of these skills often receives less emphasis than might be appropriate. This lack of emphasis possibly results from difficulties associated with assessing these skills, although examples of the successful implementation of skill assessment have been described (Bryce &Robetson, 1985 and Garnett & O'Loughlin, 1989).

In the context of laboratory work, investigation skills include planning an investigation, the ability to conduct the investigation, processing and interpreting data, and evaluating findings. Investigation skills include cognitive and affective components as well as the techniques and manipulative skills needed to conduct the investigation. Investigations encompass both the ways in which understanding is generated within the natural sciences and an approach to solving problems. An investigation can be construed as problem solving in a laboratory context, and is similar to what Klopfer (1990) calls 'scientific inquiry'. An investigation is here regarded as a scientific problem which requires the learner to plan a course of action, carry out the activity and collect the necessary data, organise and interpret the data, and reach a conclusion which is communicated in some form. It differs from other laboratory work because of the planning component and the problem solving nature of the task.

Affective objectives of laboratory work can be divided into two main categories (Gardner & Gauld, 1990), attitudes to science and scientific attitudes. Attitudes to science include interest, enjoyment, satisfaction, confidence and motivation; scientific attitudes refer to styles of thinking such as objectivity, critical-mindedness, scepticism, and willingness to consider the evidence.(Garnett *et al.*, 1995)

Furthermore, Osborne (1993) stated that, in reality, one of the primary purposes of science education is to introduce pupils to a reserved language and range of concepts which have wide-ranging validity and application, and thus we can ensure the development of linguistic and conceptual competency within the domain of science. 75% of the national curriculum is essentially devoted to this aim.

What is more, as a teacher of science you are essentially a teacher of a language that has reserved and specific meanings. For instance, it is acceptable to say in every day language that "*I have bags of energy*" but it is not in a scientific context. Similarly to say "*it is boiling*" in reference to the weather is not a scientific use of the word boiling. The term "*electricity*", as a third example, might be acceptable in such phrases as the "*battery has run out of electricity*" but in a scientific context it is inappropriate. The list of examples is endless where everyday language reinforces misconception of the nature of the scientific concept.

Hence, science teaching is a complex mix of practical and theory, which can be represented by the figure (2.1) below:

(**A**) Represents the current practice where too much emphasis on the link between practical and theory whereas there is an insufficient linkage on developing theory to make sense of practical experiences (**B**). Clearly, the balance between theory and practical needs to be re-addressed so that pupils spend more time interacting with ideas and less time interacting with apparatus.

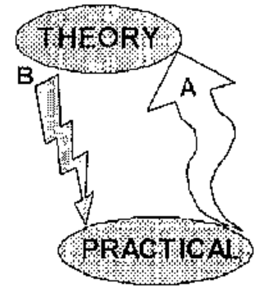


Figure 2.1: The realtionship between theory and practice

Overall, attempts to recognise the objectives of the science lab are hindered because the stated objectives are either so detailed that they can only be of use in specific disciplines or are so general that they can include almost anything one can think of (i.e. imparting information, training basic processes and building up adequate motivation). Kirschner and Meester (1988) have catalogued more than 120 different specific objectives *(see appendix 2.1)* for science practical work.

As a whole, we can divide these objectives and aims into five main categories, which are:

- Motivating by stimulating interests and enjoyment.
- Acquiring laboratory skills.
- Enhancing scientific knowledge.
- Understanding and using the scientific method.
- Developing certain scientific attitudes.

Another way of thinking about laboratory work

As knowledge cannot be transferred from one person to another intact, it must be actively constructed by the learner through interactions with the environment. What does this learning environment look like in the laboratory? Has it different forms of instruction to promote a suitable learning environment?

The following sections attempt to review laboratory instruction styles.

2.3. A Review of Laboratory Instruction Styles

1. Types of practical work:

Learning outcomes it is believed, depend on the teacher as much as it does on the learner. Lock (1990) illustrated different types of practical work teachers and learners can engage in, with emphasis on the teacher-pupil interaction and its influence on the open-endedness and closed-endedness of the work. The following diagram (Figure 2.2) comprises two intersecting axes; the vertical one represents the continuum between open-ended and closed-ended work, whereas the horizontal one represents the continuum between teacher-directed and student-centred approaches.

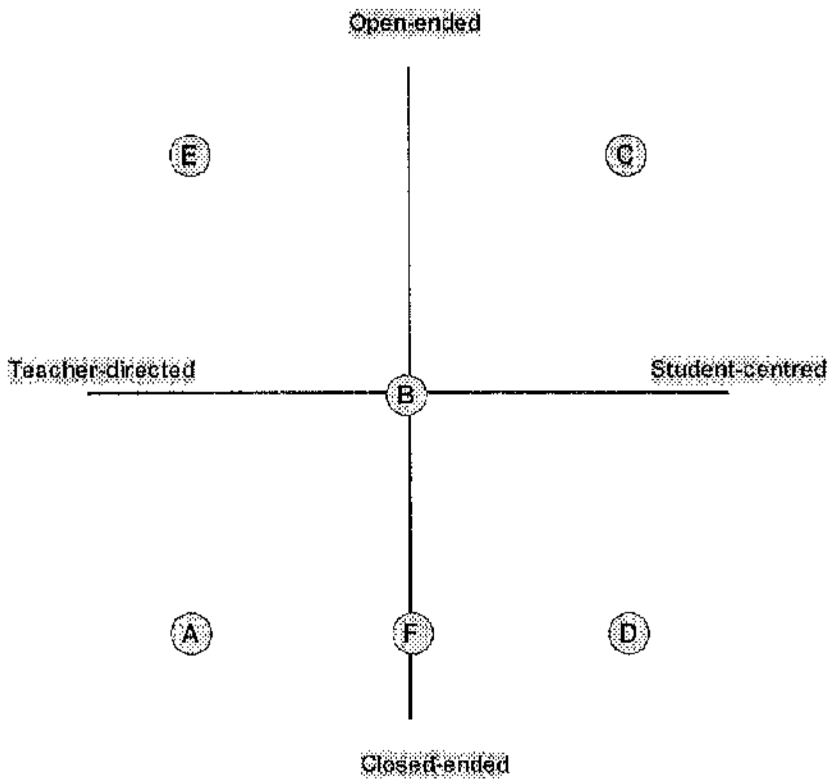


Figure 2.2: Lock's diagram to illustrate types of practical work in relation to teaching style and open-endedness of work.

The six positions shown on the diagram represent different styles of practical work and their relative ranking levels. The type that is located at the bottom half of this diagram refers to that work which is meant to confirm theories and principles learnt in the classroom practically.

1. **Position A**: this kind of practical work is the most popular in school science teaching. The teacher might decide what procedure is to be followed or sometimes carry out the experiment himself (a demonstration). For example, a demonstration experiment entitled 'To show that pure water boils at $100^{o}C$'. In this example, the outcome is determined by the title, there is a single outcome and it is likely that the work would be carried out, if not by the teacher, then in a tight procedure decided by the teacher.
2. **Position F**: in this type of practical work, there is a balance between the teacher's and pupils' input. Pupils would be allowed to do an experiment they have designed but would be advised by the teacher to change to one assumed to be superior and ought to be adopted by the pupils.
3. **Position D**: this kind of practical work is not often used in school science. A teacher may ask his pupils to plan and carry out an experiment or a series of experiments in order to show that for example, snow, ice and steam are all the same substance. The kind of practical work is considered as problem solving since pupils are not told how to carry out such as an experiment. Nevertheless, experiments like this one are located at the closed-ended position on the matrix. For example, student may be asked to design and build a lamp suitable for a bedside table, and this, while it might produce variety in materials and structure, is still providing a single outcome determined by the fact that the problem was posed by the teacher.
4. **Position B**: The practical work involved in this position is the pseudo open-ended work (closed and open-ended investigations). It is sometimes called a guided-discovery approach to practical work. For example, the teacher poses his pupils a problem in which pupils are asked several questions in order to lead them to an interpretation of the results that they have obtained. The teacher knows the outcomes of the problem but his pupils do not. This type of environment is encouraged and believed to be useful in science by the constructivist movement. (Driver and Bell, 1986).
5. **Position E**: This type of practical work is not so often found in school science. It is a practical problem, which is teacher-directed but open-ended. The main reason behind not using such practical work in schools is that teachers do not want an undesirable outcome to emerge where it may be possible. A wide range of solutions could sometimes be obtained from this kind of work. However, such practical work would be beneficial in learning certain techniques or experimental

methods. There are some instances where the teacher gives a problem and at the same time provides pupils with a certain procedure to tackle the problem. Such procedure is called recipe following. Such activities are normally aimed at letting pupils acquire a certain degree of familiarity with the techniques that have been employed. 'In such situations, the collation, evaluation and interpretation of results can be devolved to the students without serious worries of whether misconceptions are being fostered or reinforced'. (Lock, 1990)

6. **Position C**: The practical work in this position is not uncommon in school science. This kind of practical work is considered as an ideal type for open-ended and problem solving principles. It may involve everyday life problems of pupils and may not be novel for them. However, such practical work is not a new element in school science, it has been there since the early 1970s. But, anyone intending to use this type of practical work should be aware of how much care is needed in the design of this type of work compared to others.

These styles of practical instructions can be viewed in another way concerning the whole elements of the communication process; the inputs, outputs (*outcomes*), and the channel (*procedure*).

Throughout the history of chemistry education, our distinct styles of laboratory instructions have been prevalent: expository, inquiry, discovery, and problem-based. Three descriptors can differentiate these styles: *outcome*, *approach*, and *procedure* (Table 2.3). The outcome of any laboratory activity is either *pre-determined* or *undetermined*.

Expository, discovery and problem-based activities all have predetermined outcomes. For expository lessons, both the students and the instructor are aware of the expected outcomes. For discovery and problem-based activities, usually it is only the instructor who knows the expected result.

Expository and problem-based activities typically follow a deductive approach, in which students apply a general principle toward understanding a specific phenomenon. Discovery and inquiry lessons are inductive, by observing particular instances; students derive the general principle.

The procedure to be followed for any lab activity is either designed by the students or provided to them from an external source (the instructor, a laboratory manual, or a handout). Inquiry and problem-based methods require the students to develop their own procedure. In expository and most discovery activities the procedure is given to the students.

Style	Descriptor		
	Outcome	**Approach**	**Procedure**
Expository	Predetermined	Deductive	Given
Inquiry	Undetermined	Inductive	Student generated
Discovery	Predetermined	Inductive	Given
Problem-based	Predetermined	Deductive	Student generated

Table 2.3: Descriptors of the laboratory instruction styles.

Expository instruction:

Expository instruction, also termed traditional or verification instruction, is the most popular type. Within its learning environment, the instructor defines the topic to be investigated, relates the investigation to previous work, and directs students' action. The role of learner here is only to repeat the teacher's instruction or follow blindly the procedure (from the manual) which is stated in detail. Obviously, the outcome experienced is predetermined and already known to both the learner and the teacher. So, as Domin (1999) stated that, "Never are the learners to reconcile the result, as it is typically used only for comparison against the expected result, or confronted with a challenge to what is naively predictable".

Lagowski (1990) stated that within the design of this laboratory (*expository instruction*), activities could be performed simultaneously by a large number of students, with minimal involvement from the instructor, at a low cost, and within a 2-3-hour time span. It has evolved into its present form from the need to minimise resources, particularly time, space, equipment, and personnel.

Expository instruction has been criticised for placing very little emphasis on thinking.

- ❖ Its 'cookbook' nature which emphasises following specific procedures to collect data.
- ❖ It gives no room to the planning of investigation or to interpreting the results.
- ❖ Being an ineffective means of conceptual change.
- ❖ Being unrealistic in its portrayal of scientific experimentation.

Clearly, little meaningful learning takes place in such traditional laboratory instruction. Two reasons can be extracted to explain the inability of this type of laboratory to achieve good learning; firstly, it has been designed so that students spend more time determining if they have obtained the correct results than they spend thinking about planning and organising the experiment. Secondly, it is designed to facilitate the development of lower-order cognitive skills such as rote learning and algorithmic problem solving.

Inquiry Instruction (Open-Inquiry):

As shown in Table 2.3, inquiry-based activities are inductive, have an undetermined outcome, and require the learners to generate their own procedure. They are more student-centred, contain less direction, and give the student more responsibility for determining procedural options than the traditional format, i.e. it effectively gives student ownership over the lab activity, which results in the student's showing improved attitudes toward science instruction.

Student ownership, represented in such activities, requires learners to formulate the problem, relate the investigation to previous work, state the purpose of the investigation, predict the result, identify the procedure and perform the investigation. (Tamir, 1977)

This type is designed to help the learner to construct thinking processes, which if done properly, the inquiry-based lab activities will give students the opportunity to engage in authentic investigative processes. Raths *et al.* (1986) list the following higher-order thinking process as components of inquiry: hypothesising, explaining, criticising, analysing, judging, evidence, inventing, and evaluating arguments. This type could be criticised for placing too much emphasis on the scientific process and not enough on science content.

Discovery Instruction (Guided-Inquiry):

The heuristic method taught by Armstrong, in the early 20th century, can be regarded as the origin of discovery lab teaching in which students were required to generate their own questions for investigation. No lab manual was used and the teacher provided minimal guidance. The student was placed in the role of discoverer.

Similar to the inquiry, discovery approach is inductive but differs with respect to the outcome of the instruction and to the procedure followed. Whereas in the former the outcome is unknown to both the teacher and the learner, in the later the teacher guides learners toward discovering the desired outcome.

The disadvantage of discovery learning (shared with the other non-traditional forms of instruction) is that it is more time consuming than expository learning. Hodson (1996) describes discovery instruction as not only philosophically unsound, but also pedagogically unworkable. He asserted that the learner couldn't discover something that he is conceptually unprepared for. The learner does not know where to look, how to look, or how to recognise it when he has found it.

For pupils making a discovery of chemistry in a laboratory they found that the basic structure of their course is planned discovery and they realise they are following a planned course without 'discovering' but that they are going over a path that has been well trodden. A pupil studies an element such as sodium when it is doubtful whether he will ever meet this metal in the everyday world and then we try hard to make him think of chemistry outside the laboratory –at home and in industry.

Problem-based Instruction:

Wright, (1996) stated that this type of learning is becoming a popular alternative to the other three styles of lab instruction, not only in the general chemistry but also in other chemistry courses. The teacher, in problem-based learning, adopts a more active role by posing questions or problems to the learners, providing the necessary materials, and carefully moving the students towards a successful solution to the problem.

Learners have to create their own procedures to solve a problem and submit a written report describing the procedure, the results obtained, and the conclusions reached. Young (1968) recognised some advantages of expository instruction over problem-based learning (clarity in teaching of principle and techniques, showing how the procedure fits the experiment, and increased student confidence), he however, recognised that its applicability is limited.

In this style, students are presented with a problem statement often lacking in crucial information. From this statement the students redefine the problem in their own words and devise a procedure that will lead them to a solution. The problems are 'open-entry'. That is, they possess a clear goal, but there are many viable paths toward a solution. Wright (1996) emphasises the problems are designed to be conceptually simple. He stated "The students struggle with course concepts in the context of a realistic problem, and this opportunity provides much greater insight into the course material". So students are required to devise a solution pathway, think about what they are doing, and why they are doing it.

Like discovery and inquiry instructions, this style is time consuming and places a greater demand on both the teacher and the learner than traditional instruction. Similar to inquiry instruction it fosters the development of higher-order cognitive skills through the implementation and evaluation of student-generated procedures. It is, however, a deductive approach. Learners must have had exposure to the concept or principle of interest before performing the experiment. Successfully completing a problem-based activity denotes an understanding of the concept. (Domin, 1999)

Implications for teachers:

To understand the effectiveness of each style we should address which style of instruction best promotes the following specific learning outcomes:

- Conceptual understanding.
- Retention of content knowledge.
- Scientific reasoning skills.
- Higher-order cognition.
- Laboratory manipulative skills.
- Better attitude towards science.
- Better understanding of the nature of science.

Real discovery can only come after certain knowledge of facts and practical methods has been gained. The pupil must learn the language of chemistry, its symbols and nomenclature, so that he can communicate his discoveries in a satisfactory manner. Part of his training, as a chemist is to learn the techniques of manipulation of his materials. '*When an artist knows when and how to use his brushes he can be creative. When the chemist becomes skilled in the use of his spatula, he may discover.*'(Jones,1970)

But more than this, a pupil must learn that often the research chemist has a definite design in his work. He researches along a particular line of thought and he examines the literature in order not to retrace the steps of some other chemist. So we do need some method of education in chemistry which cultivates and teaches the recognized scientific attributes of observation; the formation of a hypothesis to explain his observation; the experimentation that tests the hypothesis; and the development of the refined theory which possibly relates several hypotheses.

It is believed that one of the educational objectives of so-called 'chemistry by discovery' is to remove as far as possible the arduous fact learning and to emphasise the ability to understand and to comprehend the subject. In effect, to improve the level of concept attainment and creative thinking of a pupil.

One might expect that understanding of a lab investigation would unfold for learners through their use of process. Interestingly though, in both open and closed investigations, because of their minimal engagement in the task, pupils did not think about the quality of their data and how it relates to the procedure they had chosen.

For the closed investigations, which are structured to encourage pupils to use certain processes at particular points, it is found that many pupils either ignore such instructions or give only superficial responses (e.g. there was a precipitate because a chemical reaction occurred). This is because of the limited mental engagement of pupils during lab work and their main priority is to complete the task.

This is so even for open investigations in that, once the pupils have planned their investigations and designed their own procedure, they would continue to follow their procedure (which they had written in a cook-book style) and when it came to using it they were less engaged than might have been expected.

Berry *et al.* (1999) stated some factors, which contribute to such mental engagement. Factors which improve pupil learning:

Content Knowledge:

To what extent do pupils know the content knowledge assumed by the task? For instance, if pupils have little or no assumed content knowledge, they might be not able to suggest why a solution has changed in colour; they simply made an observation.

The same thing is valid for working out an appropriate procedure. Otherwise pupils may puzzle over their results from their procedure but lack triggers to tell them these results are meaningless because their experimental design was incorrect.

Therefore, teachers have to determine how much content knowledge is necessary for learners to be able to engage mentally with a particular investigation and to what extent pupils have acquired this prior to beginning a task.

Ownership:

When the learner has some input into the design of the task he/she has more interest in its outcome and is more motivated to persist. This is obviously offered by open lab tasks in that they offer greater opportunity for pupils' ownership of work and the truly involved in the process, but this may be offset if pupils do not have sufficient background knowledge.

For practical work to be convincing it requires that the learner becomes a "partisan experimenter". Solomon (1988) argued that *the great experiments of the past were performed in a partisan spirit by scientists who were proving that their hunches were triumphantly right, and that children also were happiest and most successful when they were doing the same.* Cited in: (Solomon,1988)

Time:

Concerning time, the main issue is how learners, when given sufficient time to plan, implement and conclude their work, are able to plan for and use their time appropriately in a managed and accountable style. But allowing an extended period of time to be spent on this kind of individual lab work means less time for other things in the science curriculum.

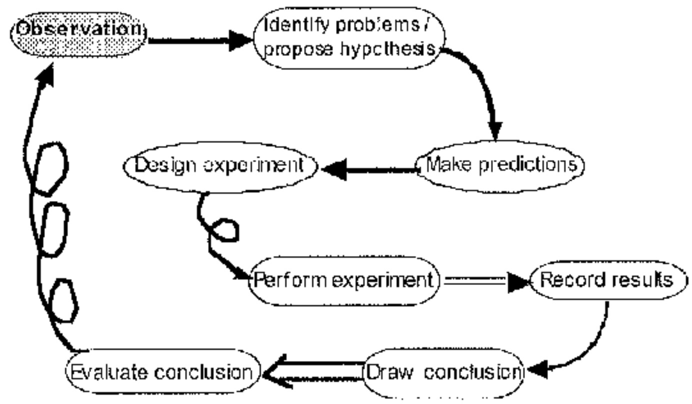
Purpose and Aim:

The aim refers to the scientific reason for a particular investigation and the purpose is the way in which that investigation fits into the work being covered at that point in time.

During the lab session, a pupil may ask himself few queries such as, why are we doing this? What should we be looking at? What do the results tell us? Therefore awareness of aim is important as it helps learners make sense of what they are doing while awareness of purpose can trigger them to seek links between the activity and the rest of their science work.

To motivate, by stimulating interests and enjoyment is one of the reasons given by teachers for engaging in practical work. Hodson (1990) says that 'motivation is not guaranteed by simply doing practical work'; we need to provide interesting and exciting experiments, and allow children a measure of self-directed investigation. He adds that learners need an interest in and commitment to the learning tasks that conventional practical work frequently does not provide. That commitment, he says, comes from personalising the experience – by focusing on the conceptual aspects of the experiment, by identifying for oneself a problem that is interesting and worth investigating or by designing the procedure to be adopted. Pupils are different and therefore, it is unlikely for them all to be motivated by the same things. According to Lock's model there is a variety of practical work that can be employed in the classrooms which might appeal to some pupils and motivate them, while on the other hand it would generally be of no educational value to all.

While it is recognised that problem-solving situations are complex and variable, and they cannot be tackled by a single 'scientific method', science educators have however come to accept that there are certain basic steps that make up a scientific process as outlined in the figure (2.3) below.



(source: Yip *et al.*, 1998)

Figure (2.3): Basic steps of the scientific process

The main idea in this model is that an investigation using the scientific process basically consists of four key steps:

- Identifying a problem for investigation and putting forward a tentative prediction, i.e., a hypothesis.
- Designing an experiment to test a hypothesis.
- Performing the experiment and recording the results in appropriate forms.
- Interpreting the results and evaluating the conclusions with reference to the hypothesis to be tested.

These four steps do not proceed in a linear way but work in a cyclical manner. The conclusion of an investigation is not an end of the problem-solving process, but by posing a new problem, it becomes the starting point for another investigation. However, it should be noted that this model represents only a simplified outline of the scientific process as the actual problem-solving situation is usually more complex, with links and interactions across the different stages such as collecting data or recalling knowledge to predict, and evaluating the design and implementation as necessary in light of the information collected.

At various points in an investigation, there is a need for continual evaluation and refinement on the design and implementation as necessary in light of the information collected.

Most of the available manuals are highly prescriptive and teacher-directed, offering little opportunity for students to pose problems and formulate hypotheses, or to design experiments and to work according to their own design. Students are provided with detailed instruction from the teacher or lab manual, and what they need to do is to follow the given procedure mechanically. This sort of recipe-type practical is primarily used as a means of verifying or demonstrating principles described in textbooks and to prepare the students for the practical examination. They fail to provide experience and training for developing the skills and understanding of the scientific process. Such practicals, being concerned with investigating the teacher's problem and finding the teacher's answer, have little relevance to real life and so fail to promote students a genuine interest and motivation in practical work.

To rectify this situation, a balance must be struck between the content and process dimensions of the curriculum.

Making scientific investigations realistic and meaningful.

To cultivate a genuine understanding and interest in investigative work, teacher-directed 'cookbook exercises' should be replaced by more realistic, open-ended investigations. The first step to work towards this goal is to use practical activities that are set in contexts, which are meaningful and relevant to the learners' personal experiences. Such contexts stimulate students to engage mentally in designing and planning their own investigations, which involves identification of the problem to be investigated and formulation of the hypothesis to be tested.

The main constraint for teachers to carry out this strategy is that most of the available lab manuals are not conductive to such an approach as they, by providing detailed instruction, will deprive students of most of the thinking and challenge of the investigative work

Using projecting experiments or **TOPs** (as they will be called later), there are a number of different strategies that teachers can use to increase pupils' ownership of lab work and enhance their mental engagement. For closed investigations, providing learners with some missing procedure or other information (e.g. title, aim, equipment), translating the given procedure into pictures or a flowchart, or asking pupils to justify why particular questions have been included in an investigation rather than answering them.

Likewise, open activities may include learners predicting the outcome of an investigation based on the class work covered or asking pupils to select the most appropriate investigation from a choice of several and to justify their choice and its suitability before and after the lab task.

CHAPTER THREE

CHAPTER THREE

THE BIRTH OF DEMONSTRATION

3.1. Individual practical work versus Demonstration (Historical Review)

I. The age of demonstration:

It is probably true to say that most science teachers believe that practical work done by the pupils themselves, whether individually, in pairs or in small groups, is an essential part of school science, and that demonstration by the teacher is a second-best forced on him in certain circumstances.

Without doubt, it was necessary that the early school science teaching was mainly done by lectures with or without demonstrations and individual practical work hardly existed. As mentioned before (*Chapter 2 section1*), in the early eighteenth century chemistry was taught only by lectures. It was felt at later stages of the same century that some practical work should be introduced in the form of demonstrations in lectures.

Another man who came under Black's influence was Thomas Thomson (1773-1852), the first occupant of the Regius Chair of Chemistry in Glasgow (1818) at a salary of $100 per annum. Thomson was a chemist who started lab work in Edinburgh (1807) and then brought the idea to Glasgow (1819) when he came as professor of chemistry. His colleagues objected to having "smelly" labs in the university and he hired an old wine shop in Shuttle Street, nearby, to set up his lab in 1831 (Photo below). When the University (Glasgow University) moved from the centre of the city to its present site in Gilmorehill in 1870, labs were allowed, but they had to be built at the east end of the building so that the prevailing west wind would carry the smells away from the main building (*As the sketch below shows*). This lab has now been demolished when the chemistry department moved into new building in the 1930's.

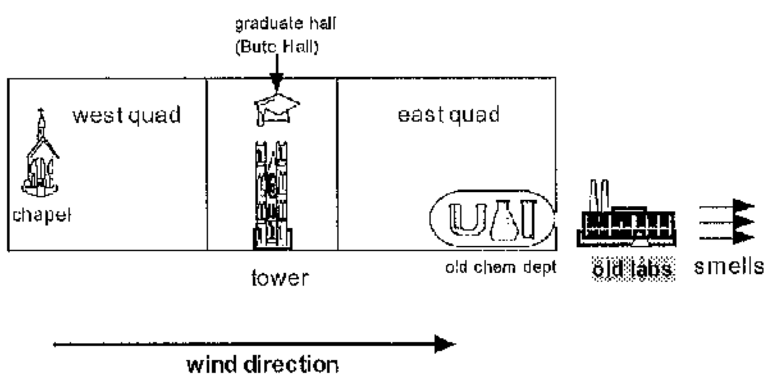


Photo: Shuttle Street labs (Johnstone, 1993)

However, practical lab instruction was here to stay, and undergraduate laboratories sprang up all over Europe and North America. (Johnstone, 1993)

In the later years of the nineteenth century, a rapid introduction for individual practical work had appeared. It owes much to the work of Worthington (mainly in physics), and Armstrong (mainly in chemistry). The latter believed that the pupils should themselves perform all the experiments and discover for themselves all the subject matter in the science course; the heuristic method.

He insisted upon the actual and persistent exercising of individual eyes and hands from the very earliest period in the school career. He stated that the '*use of eyes and hands- scientific method- cannot be taught by means of blackboard and chalk or even by experimental lectures and demonstration alone*'. There seems to be a suggestion here that the 'scientific method' is an activity of the hands and eyes rather of the mind.

These ideas of Armstrong were adopted by some London schools and elsewhere and the first edition of the Board of Education's *Handbook of suggestions for teachers* published in 1905 for the guidance of teachers in elementary schools. This was strongly in favour of individual work, and stressed the importance of complete and accurate recording of all observations, exact expression and inference. Clearly, there is no intention to give the pupils a wide knowledge of the place of science in the world around since the stress is on method rather than subject matter and the content of the course is almost wholly determined by the stress on individual work.

In 1918, the Thomson Report went much farther criticising the limitations of science teachers of the time. It discussed the good and bad effects of the prominence given to individual work pointing out the limitations of the heuristic method. Thomson came to the conclusion that, in many schools, more time is spent in laboratory work than the results obtained can justify. He also reported that insistence on the view that experiments by the class must always be preferred to demonstration experiments leads to great waste of time and provides an inferior substitute. Some diminution in the number of experiments done can gain time which could be used in establishing in the pupils' minds a more real connection between their experiments and the general principles of the science or the related facts of everyday life. Therefore, it had been suggested that in many cases it would be more economical to return to the situation when the teacher performed demonstrations. (Clackson and Wright,1992)

At the same year, 1918, Wiley seems to be the first worker to compare small group work with demonstration and what he calls 'text-book recitation' method. He found that there was not as much difference as is ordinarily supposed in the values of the three methods, as far as imparting knowledge. (Garrett, 1978)

At the 1920 annual meeting of the Science Masters' Association, Sir Richard Gregory endorsed the passage from the Thomson Report just quoted and the British Association warnings about the narrowness of school science.

An article by H.Lowery, 1921, showed the movement of opinion in favour of demonstration. Another writer in strong agreement with the Thomson report is John Brown, 1925 who asked for an effort to reach a position of equilibrium between the previous stage of having too little practical work and the current stage of having too much practical work in science teaching.

The second edition of the *Handbook of Suggestions*, 1927 is clearly influenced by the Thomson Report. It declared that a teacher can often run through a series of easy experiments (using demonstration) in half the time the class would require and nothing valuable will be lost. But it is not clear how the time saved should be used, as there was no corresponding widening of the syllabus.

F.W.Westaway, 1925, discussed the question of demonstration and individual work only briefly. He concluded that a great saving might be effected in science teaching, if the lecture-room method is as good as the laboratory method both as to training and as to knowledge imparted. He did not demand that the demonstration method be proved superior, it is up to the other side, he thinks, to prove that individual work is so superior that its greater expense, time consumption and trouble are justified.

Typical of writings on this subject of that period, all of which favour demonstration, is an article by T.P.Stephenson, 1930, who confirmed the wasting of time upon a series of petty little experiments as the desired object being always to verify well-known scientific facts or to make routine measurements. He maintained that the deplorable results were caused by the judicious use of a textbook, leading to the 'cooked' result. (Connell, 1971)

Barber in 1935, had questioned the effectiveness of the individual laboratory method in physics and chemistry. He maintained that his students mastered the work well, if not better, by the demonstration method and he reduced the number of experiments done by the student to a few which required relatively simple apparatus.

After reviewing the literature, Knox, in 1936, stated that previous investigations had pointed to the superiority of the demonstration method so far as those outcomes can be measured by a written test. (Wham, 1977)

Overall, it appears that in the ten years or so after the Thomson Report (1918) there was a swing of opinion away from an insistence on individual practical work.

The advantages often claimed were that the retention of information in the short and long terms was superior in favour of demonstrations, and it was more efficient in both time and money.

ii. The other side of the story-:

Nevertheless some people were not convinced with the idea above, in that at the 1931 annual meeting of the Science Masters' Association, J.W.Burstall said.

"*A demonstration at the lecture table interests but does not teach. It is better for the student to experiment for himself than to see you do that operation neatly, without breaking anything*". (Cited in Connell, 1971)

Later in 1932 and in Board of Education Pamphlet No. 89, a full discussion of practical work appeared. It repeated the views of the Thomson Report but warned teachers that if demonstration alone be employed, the class tends to become a collection of merely passive absorbers but on the other hand they still found in the schools much laboratory work too remote from the natural and everyday activities of the children.

Another discussion on the relative values of demonstration and practical work appeared in 1934 in N.F.Newbury's *The Teaching of Chemistry* and *The Teaching of Chemistry in Tropical Schools* who stressed that demonstration lessons are not lectures but are developed along the same educational lines as the individual work. He then summarised his findings affirming that demonstration methods are as valuable as individual work in the laboratory.

The next edition of The *Handbook of Suggestions*, 1937 repeated the traditional view saying that ideas the child gets from doing things are better than those gained from seeing things done or hearing or reading about them. On the other hand, the *Handbook* suggested doing demonstration when there is not enough apparatus to allow all pupils to do the same experiment simultaneously.

In 1938, the Spens Report mentioned that practical work carried out more accurately and skilfully will provide more data than is possible where the only, or the main, work is done by the pupils. He ensured that science teachers could stimulate wonder and imagination by a greater use of good demonstration.

S.R.Humby and E.J.F.James, 1942 expressed that the replacement of individual work by demonstration will not correct all the faults; some demonstrations are futile too.

In 1943, the Norwood Committee Report suggested that the lab has become too prominent a feature of school science, and that much good science can be done outside it. A year later, in 1944, the Association of Women Science Teachers recommended different approaches for pupils of different ages, i.e. for 11-13 age-group: individual work + demonstration, but the former should predominate while in the 13-16-age-group more time should be given to demonstration.

iii. The wave of individualisation:

In the same year (1944), the Committee of the Science Masters' Association stated that individual experimental work must, to some extent, be replaced by demonstration in order to cover the wider field.

A moderate view expressed by the National Union of Teachers in 1952 suggested that the teacher should consider the scarcity or cost of the apparatus, the degree of skill and time required, the danger, the size of the class and the room, but recommended that each pupil should have some experience of experimenting himself.

In 1953, *Secondary Modern Science Teaching* revealed the official view of the Science Masters' Association stating that demonstration must be subordinate to, not a substitute for, individual work by the children.

H.F.Boulind in 1957 gave advantages of each method and then listed three things which can be achieved by individual work and that demonstration cannot do, except to a minor extent:

1- 'Pupils find things out for themselves (the heuristic method). No demonstration, however efficiently performed, can be a substitute for 'learning by experience'.
2- Work is provided for fingers as well as brains; pupils obtain practice in the use of apparatus.
3- As every teacher knows after his first weeks of teaching, practical work arouses interest and maintains enthusiasm. Individual work in the lab should therefore be the rule and not the exception'.

In 1952 in America, Kruglak made a comparison of university undergraduate physics classes. One class learnt physics with the aid of individual practical work, for the other practical work was replaced by lecture demonstrations. His study concluded, "neither method of teaching was better at disseminating the facts and principles of the subject". However, individual laboratory work was found to be more effective at 'imparting simple manipulatory skills, measuring techniques, and knowledge of apparatus'. (Connell, 1971)

Besides, Bruner in1961 viewed the discovery method as 'a necessary condition for learning the variety of techniques for problem solving'.

Schwab argued, in 1962, that prior to classroom instruction, students should partake of lab experiences in which the didactic laboratory manual be 'replaced by permissive and open materials which point to areas in which problems can be found'. (Domin, 1999)

In 1962, Michels asserted that the lab should acquaint the student with the 'process of inquiry'. He stated that the laboratory was the only place where a student could experience physics as it developed. He therefore advocated that the laboratory should be open-ended. By open-ended he meant an experiment where the student was posed a problem which he was about to solve. (Wham,1977)

Heafford in 1965 stated that few British teachers will dispute the extreme importance of practical work carried out in the laboratory by pupils. He argued that, in addition to the educational experience involved in the experiment, something genuine learnt as a result of an experiment performed by the pupil is always more firmly understood and remembered than something which is merely demonstrated to him by the teacher, or which he is told or read about. (Garrett, 1978) and (Garrett and Roberts, 1982)

Young.J.A in 1968 proposed that laboratory work should be more than manipulating apparatus and that the failure of practical work was that no one had tried to discover if students were getting anything more. (Wham, 1977)

In school biology, Yager *et al.* (1969) compared three groups namely; a 'laboratory group', a 'demonstration group', and a 'discussion group' in biology. He found that more skills with lab materials and procedure were developed in cases of classes taught with lab demonstrations and classes given practical work compared to classes with no lab experience at all (the discussion group).

Clackson, and Wright (1992) mentioned that a study carried out in 1966 by Sorenson,L.V had observed better critical thinking from practical groups, compared with non-practical classes.

Coulter in 1966 compared the outcomes of three different types of lab practical;

- '**Deductive laboratory**' or the traditional approach where the aim was usually to demonstrate or verify some principles or to determine the value of some constant.
- '**Inductive laboratory**' where pupils design and develop their own experiments to solve suggested problems.
- '**Inductive demonstration**' where pupils designed the experiments and analysed the data, but it was the teacher who physically constructed and carried out the experiments.

Coulter found that all three methods were equally successful at teaching facts, application of principles and lab techniques but the inductive approaches tended to impart a better appreciation of the aspects of scientific inquiry. (Connell, 1971)

Johnstone and Gunning (1976) carried out an investigation in to the relationships between the pupils' sense of achievement and the amount of practical work they did and found that:

1- Pupils who performed experiments themselves felt that they had developed the ability to :

  - *Design experiments to investigate a problem.*
  - *Handle apparatus and chemicals.*

2- Pupils who were used to demonstrations felt that they had not developed the ability to:

  - *Design experiments to investigate a problem.*
  - *Draw conclusions from experimental results.*

- *Handle apparatus and chemicals.*
- *Record observations and results.*

According to Case (1980) the individualised laboratory had a positive effect in improving students' achievement. Solomon (1980) argued that practical work should be done as "a discipline in its own right" not only as a way of teaching theory. Woolnough (1983) also stated that "practical work in schools should be done for its own sake".

Johnstone and Wham (1980b) asserted that it is important to do lab work in a systematic manner, the skills of personal decision, experiment planning, self criticism, evaluation of errors and overcoming practical problems. For this they suggested mini-projects, i.e. small open-ended exercises with the minimum of instruction and maximum of freedom within the limitations of the present state of the student's knowledge with the objective of reinforcing the learnt skills. This was also supported by Pickering (1988) who argued that a puzzle laboratory (of project-type) could provide much more opportunity for creativity and therefore, would be likely to be more successful in the task of lab teaching. They, and Johnstone in 1982, also asserted that practical work reaches its highest form when done by pupils themselves rather than by demonstration, because pupils are then in a position engage in discovery learning (although guided discovery).

Sands (1981) asserted that science teachers in Britain have been encouraged by curriculum developments in recent years to use small groups in their lessons, not only during practical work activities, but also for other activities such as discussion. This method offers a way of coping with shortages of specialised equipment and of teaching mixed ability classes. It gives more opportunity than in a demonstration for students to participate in practical activities. In addition to that, the social benefits as a result of interaction between the students themselves and their teacher are of considerable value and importance.

Driver (1983) emphasises this view when she says that "by doing experiments, pupils will better understand ideas".

Beatty and Woolnough (1982) studied the amount and type of science being taught to the 11-13-year-olds and the aims that their teachers had for doing practical work in it. A questionnaire of four sections was devised and applied to schools. These sections are: 11-13-year-olds teachers background information, organisation of science teaching in the 11-13 range, type and frequency of practical work being done and rating importance of aims of practical work and judging the most appropriate type of practical work to satisfy to each of the different aims.

Overall, schools spend a lot of their science time doing practical work. Teachers from 83 percent of the schools reckoned that they spent between 40 and 80 percent of their time in practical work (45% spending 40-60% and 38% spending 60-80%). 40-60% of the time spent on practical is the median for all types of school, except comprehensives in which the median is 60-80%. 49% of comprehensives reckon to spend this proportion of their science time on practical work.

Teachers also were asked to respond by indicating the frequency with which they used each of the following types of practical work:

'Standard exercises', *'teacher directed discovery experiments'*, *'demonstrations'* and *'project work'*. It was found that schools were using each of the first three types of practical, with standard exercises being used more than discovery experiments and both more than demonstrations. The project work was not commonly used in schools, the majority (79%) spending less than 5 hours on project work per year.

A typical science lesson involves pupils in the laboratories carrying out practical exercises in which they follow instructions and teachers doing demonstrations. In the UK 11-13 year olds typically spend over half their science lesson time engaged in practical work and 16-18 year olds spend more than one-third. A similar practice seems to be occurring, at the same weight, in many parts of the world especially the developed countries.

It has been considered that practical work is preferable to demonstration in the aspects of pupils' enjoyment and picking up hand skills with varying degrees of proficiency.

Denny and Chennell (1986) carried out a study trying to discover what pupils think about science practicals. Results show that pupils regard it to be useful only in the school context. They believe that their teachers' ideas about practical work are similar to their own. This study also found that pupils of the first three years regarded practicals as 'investigatory of theory' whereas of the fourth year regarded them as 'confirmatory of theory'.

In its entirety, and as we have seen from the literature above, perhaps some of the reasons for enthusiasm with which individual practical work has been embraced by the community of science educators, derive from the perceived benefits of such laboratory experiences as expressed by people considered as the main conceptual leaders of the curriculum reform such as Bruner, Gagne, Schwab, Piaget, Ausubel, and Karplus from whose work the following five major reasons (Tamir 1991 and Mapuru1994) which may be offered as a rationale for the school science laboratory were drawn:

1. Science involves highly complex and abstract subject matter. Many students would fail to comprehend such concepts without the concrete props and opportunities for manipulation afforded in the laboratory. Practical experiences are especially effective in inducing conceptual change.
2. Students' participation in actual investigations, employing and developing procedural knowledge often referred to as skills, is an essential component of science as inquiry. It gives students a chance to appreciate the spirit of science and promotes problem solving, analytic, generalising ability. It allows the student to act like a real scientist and develops important attitudes such as honesty, readiness to admit failure and critical assessment of results and of limitations, better known as scientific attitudes.
3. Practical experiences whether manipulative or intellectual,...are essential for the development of skills and strategies with a wide range of generalisable effects. The skills are, in essence, learning tools essential for success and even for survival. Hence, if you help students improve their use of these creative and thinking skills you have helped them become more intelligent and helped them learn how to learn.
4. The laboratory has been found to offer unique opportunities conductive to the identification, diagnosis, and remediation of students' misconceptions.
5. Students usually enjoy activities and practical work, and when they are offered and given a chance to experience meaningful and non-trivial experiences they become motivated and interested in science.

Overall, these two study and many similar studies, as shown above, have insisted on the importance of individual work in its supportive role in confirming the theory taught in classes (or lectures).

However, two important questions could be asked. First, are the pupils really enjoying the practical work the way it is currently done (the cookbook way) in the schools? Second, is it really effective in terms of the expected learning outcomes?

iv. Time for reappraisal :

Most scientists and teachers look back on lab work positively and in reasonable quality, forgetting some major concerns. Students and teaching staff should be aware of the following issues related to the lab work they use: (Kirschner and Meester (1988), Hofstein and Lunetta (1982), Hodson (1993), Kirschner and Huisman (1998)).

- Few teachers in secondary schools are competent to use the lab effectively.
- Too much emphasis on lab activity leads to a narrow conception of science and provides a poor 'return to knowledge' considering the amount of time and effort invested by staff and students.
- Usual work in a lab simply verifies something already known to the students.
- Since too many experiments performed in schools are trivial, having students performing trivial experiments can be regarded as wasting too much time, which could be invested in something else. Similarly, non-trivial ones tend to overwhelm students. Either they require learners to solve problems beyond their comprehension or they allow insufficient time for satisfactory completion.
- Practicals cannot fail. Years of effort have produced foolproof 'experiments', where the right answer is certain to emerge for everyone in the class if the lab instructions are followed. In addition it is seen as isolated exercises, bearing little or no relationship to earlier or future work.
- Lab work is often remote from and unrelated to, the capabilities and interests of the children and frequently, it is found that students have no understanding of the processes and techniques they have used in the lab.
- Since the teacher's role in lab work is to supervise, this process of supervision is often inadequate, in that the teacher is pressed for time, and even then assessed work is usually not marked and returned soon enough to have an effect on learning. Thus, assessment (and penalising) is often arbitrary and has little teaching value; constructive feedback is often lacking.
- Based on the twenty years of teaching and teacher-training experience of Derek Hodson (1990), practical work, as conducted in many schools, is ill-conceived, confused and non –productive. It provides little of real

educational value and contributes little to their learning of science. Nor it does engage them in doing science, in any meaningful sense.

Despite the noble aims for doing lab work, it has not achieved those aims for which it is most appropriate. That is because either it is not undertaken in the right way or those aims are not best achieved by lab work. Instead it may be the case that some aims are better approached by other means.

Meester *et al.* (1995) stated that for laboratory work to be effective and efficient the aims have to be defined in advance and the most suitable instructional method has to be chosen.

Several authors have discussed the relationship between the aims – goals- (sometimes called motives) and the type of practical work appropriate to attain these effectively.

However, what are these aims and purposes that call upon teachers to carry out the practical work?

v. Motives of practical work:

Indeed, a range of justifications are revealed as reasons for getting engaged in this teaching (or learning) strategy. Actually, there are several studies which mentioned these purposes, such as (Kruglak (1951), Kerr (1963), Gunning and Johnstone (1976), Boud (1980), Johnstone and Wham (1980b), Hofstein and Lunetta (1982), Toothacker (1983), Woolnough, (1983), Tamir (1989), Allsop and Woolnough (1985), Kirschner and Meester (1988), Hodson (1990,1992,1993), Osborne (1993), Garnett *et al.*, (1995), Garnett and O'Loughlin (1998) and Kirschner and Huisman, (1998)). In order to discuss these, aims and purposes can be clustered into five major categories:

1- Motivating by stimulating interest and enjoyment.
2- Acquiring laboratory skills.
3- Enhancing scientific knowledge.
4- Understanding and using the scientific method.
5- Developing certain scientific attitudes.

At the commencement, and in order to give a critical appraisal of practical work, we should consider five questions as Hodson, (1990, and 1993) set:

1- Does practical work motivate children? Are there alternative or better ways of motivating them?

2- Do children acquire lab skills from school practical work? Is the acquisition of these skills educationally worthwhile?

3- Does practical work assist children to develop an understanding of scientific concepts? Are there better ways of assisting this development?

4- What view /image of science and scientific activity do children acquire from engaging in practical work? Is that image a faithful representation of actual scientific practice?

5- Are the so-called 'scientific attitudes' likely to be fostered by the kinds of practical work children engage in? Are they necessary for the successful practice of science?

1. Motivation

Hofstein and Lunetta (1982), Arzi. *et al.* (1984), Reid and Tracey (1985), Denny and Channell (1986), Hodson (1990,1993) and Mapuru (1994) have shown that pupils' interests and satisfaction do not always increase when the amount of practical work is increased.

In addition, a survey conducted by Derek Hodson in 1989 for 13-16 year olds in a number of Auckland schools indicated that whilst 57% are favourably disposed towards practical work, some 40% qualify their enthusiasm with comments such as 'like it when I know what I'm doing' and 'do not like it when it goes wrong'. (Hodson,1990 and1993).

Therefore, motivation depends on stimulating the learner's interest and curiosity, so practical work must stimulate them. Although, children are sometimes motivated simply by the opportunity to manipulate apparatus or to make observations, the motivation of older learners often requires a cognitive stimulus, such as the exploration of ideas, the investigation of inconsistencies or the confrontation of problems. It should be noted that enthusiasm for practical work often declines quite markedly with age. On entry to secondary school, pupils first experience the formal teacher-driven, lab-based science lesson, with its reverence for specialised apparatus, its use of strange and unfamiliar language, and its highly conventionalised ways of proceeding. For many, the lab remains thereafter an alien environment of forbidden rituals, with little relevance to every day life.

An instance was reported by Johnstone (1998) whilst conducting a workshop on 'Teaching and Learning in Laboratories' run by the *University of Glasgow* to train probationary university staff. Although it had been attended by a mixture (50) of chemists, physicists, biologists and engineers, only two of these young university teachers admitted to having enjoyed their time in undergraduate labs (and these two were not chemists!).

This is not an attempt to deny that practical work can have motivational value, it is to remind us that it is unrealistic to expect that you can motivate all learners by the same thing (stimulus). Motivation is not guaranteed simply by doing practical work unless we provide interesting and exciting experiments, otherwise, there are other techniques that we can use in science lessons that also may have higher motivational value.

2. Acquisition of skills.

One of the major roles of practical work is to develop certain skills such as observing, checking, measuring, weighing, criticising, interpreting, etc as well as other skills inherent in the scientific mind. Since sub-skills that might be developed by practical work are of a wide range and of the cognitive, affective and psychomotor domains, the principal ones according to Kirschner *et al.* (1998) are: discrimination, observation, measurement, estimation, manipulation, planning, execution and interpretation. Moreover, Bennett and O'Neale (1998) added six more skills; data collection, processing and analysing of data, problem solving, team work, communication and presentation, and laboratory know-how. Their attainment is based on two simple underlying principles – practice and feedback- and presupposes the attainment of relevant skills and knowledge in the cognitive or declarative phase i.e. the practical is not subservient to the theory but is complementary to it.

Hodson (1990) and Millar(1991) divide the skills they feel that can be improved by doing practical work into:

- Practical techniques: such as measuring temperature to a certain limit, separating solutions by filtration or any other 'standard procedures'. These skills are framed in terms of the acquisition of a set of 'content-free' generalisable and transferable skills that are of value for children.
- Inquiry tactics: such as tabulating data, drawing graphs in order to look for patterns, identifying variables to alter, control, etc.

Actually, it is to see whether these skills are of value to all children in confronting everyday problems outside the lab, and if so, in what sense is the ability to use a certain skill successfully transferable to another laboratory and non-laboratory situation in everyday life. How many times will using pipette and burette be re-used outside the lab? The student may have no chance to see it anywhere else but in the cupboard of laboratories.

Furthermore there is evidence confirming that the kind of practical experiences provided in class do not result in the acquisition of skills anyway even after several years of practically-oriented science lessons. They are unable to perform even simple lab procedures accurately, safely and with understanding.

Tamir (1989) stated that even in England, where practical work has always been given great emphasis, it was found that many secondary school pupils have failed to develop basic practical skills such as observation, estimating quantities, designing experiments and making inferences.

The **APU** (1985) report *Science at Age 15* reveals that only 11% of children can read correctly a pre-set ammeter, only 14% can set up an electrical circuit to match a given circuit diagram, and no more than 57% can successfully carry out a simple filtration technique to remove excess copper oxide while preparing copper sulphate. In general, it has been found that girls do less well on these tasks than boys and gains in practical skills made in the early years of science education are not even sustained and may even decline.

Woolnough and Allsop (1985) argued that one reason for the failure of many science courses is the attempt to use the practical lab work for aims to which it is ill suited, such as teaching theoretical concepts, instead of focusing on the real aims, namely the development of basic process skills, a feel for natural phenomena and problem solving skills. Another reason suggested for this failure is the absence of or inadequate use of pre- and post laboratory discussion which is essential for making sense of the lab experiences and relating them to the relevant theoretical concepts.

In fact, it is ethically dubious to require the education of all children to be subordinated to the perceived needs of the few who might study science at an advanced level or gain employment in a laboratory; and hopelessly over-ambitious, requiring teachers to make predictions about future employment opportunities and demands of lab work.

What has been attempted at schools in terms of skill development through doing practical work is like putting the cart before the horse. We then should bear in mind the question; is it necessary to provide children with certain lab skills and are certain skills necessary to engage children successfully in practical work?

Observation of current practices in the laboratories reveals that, learners' function in the lab is similar to that of a lab technician rather than of a practicing scientist. The table (3.1) below gives a clear picture of what the pupil does in the lab in comparison to what the real scientist does.

Activity	Scientist lab	School lab
Identifying problem for investigation	Scientist	Textbook or Teacher
Formulating hypothesis	Scientist	Textbook or Teacher
Designing procedures and experiments	Scientist	Textbook or Teacher
Collecting data	Technician	Student
Drawing conclusions	Scientist	Student and Teacher

(Source: Mapuru, 1994)

Table 3.1: Who does what in the science lab?

According to the information given in the table, the teacher and the textbook (or the lab manual in the high schools) are the main sources of information in the laboratory. Sources which, in most cases, are consulted by students, do not answer questions of what the aim of the particular experiment is or why a certain procedure has been chosen instead of something else they think might work, but ones which tell them what to do and how?

Bennett and O'Neale (1998) remarked that nowadays, only a minority of chemistry graduates make direct use of their chemical knowledge and skills in their work. It seems likely that many learners in chemistry may have no intention of pursuing chemistry as a career. Hence, it is inappropriate to design a program that is specifically and solely directed to the training of the professional research chemist.

Therefore, we should teach only those skills that are of value in the pursuit of other learning and ensure that those skills are developed to a satisfactory level of competence. For maximum effect, skills need to be progressively developed as the learner moves through a particular course. In many courses each lab experience may be valuable and worthy in its own right. However, the next session (or even the next semester) in the laboratory may not take into account the extent of skills developed in the earlier sessions.

On the other hand, for those skills that the child would not need again or for the levels of competence children cannot quickly attain, alternative approaches should be found such as pre-assembly of apparatus, computer simulation or demonstration. Complex skills necessary for further learning could be pre-taught in skills training sessions. Quite obviously, it is too much for a learner to cope simultaneously with both mastering a piece of apparatus or technique for the first time (appreciating what it does, learning how to use it, using it, recognising when the results can be accepted and when they are suspect, and so on) and attending to other aspects of the experiment- and maybe encountering certain concepts for the first time, as well. (Hodson, 1990,1993).

Johnstone and Letton (1989) affirmed that in many labs, learners do not meet skills often enough to master them and add them to their procedural repertoire. So often, "they have to move from topic to topic; each with its own mental and manipulative skill requirements, even before the earlier ones are mastered and stored". Ultimately, this is not an argument against teaching any lab skills. Rather, it is in favour of being more critical about which skills to teach and in favour of making it clear that lab skills constitute a means of engaging in other worthwhile activities.

3.4. Learning scientific knowledge and the methods of science

It is generally agreed that one of the major goals of science education is to bring about an understanding of the processes of science. Certainly, it cannot be argued that practical work is superior to other strategies for learning scientific knowledge and the methods of science. In this context, 'processes of science' does not mean the skills of carrying out particular lab operations (such as using a burette, microscope or potentiometer), but the skills of carrying out the 'strategic' processes of science (such as hypothesising, inferring, designing experiments, and interpreting data), and using them as a vehicle for improving pupils knowledge. In recent years there has been a tendency, in some quarters, to give such priority to the processes of science that content has come to be regarded as relatively unimportant. Underpinning such an approach to the teaching of science are a number of assumptions.

Scientific processes are clearly definable and discrete. They can be used independently of each other.

Processes are content-free. They precede concepts, in the sense that their use leads to the discovery of new knowledge.

Process skills are generalisable, transferable from one context to another and readily applicable in any context.

An American study (Yager *et al.*,1969 and Hodson, 1990) of three teaching styles (lecture/discussion, lab work/discussion, lecture/teacher demonstration/discussion) shows lab work has a significant advantages only in respect of the developing practical skills, but there were no significant differences in respect of conceptual gains, understanding of scientific methodology or motivation.

In a study of practical lessons in a number of British secondary schools, a study to evaluate laboratory instructions in general physics courses carried out by Moreira (1980), and in two other studies by Johnstone (1984) and Johnstone and Letton (1990) found that in many cases, students perform an experiment without a clear idea about what they are doing or about what 'lies behind' an experiment or, at best, with only a rudimentary idea about what they are doing, with virtually no understanding of the purpose of the experiment or of the reasons for the choice of procedure, and with little understanding of the underlying concepts. They are not able to identify that experimentation is a process of making knowledge.

It seems that they are doing little more than 'following recipes'. Students following a recipe are not 'doing an experiment' but 'carrying out an exercise'. At best such activities are a waste of time. More likely, they are confusing and counter-productive, leading to a somewhat distorted and incoherent understanding of scientific methodology.

Moreira (1980) said that many learners are not able to identify the physical concepts, the basic phenomena and even the basic question involved in the experiments. They were also found to use the terms 'scientific method' and 'experimental method' rather loosely, equating them with the mere use of lab equipment and they do not see experimentation as a process of generating knowledge. As a result, lab instruction can hardly contribute towards both the learning of conceptual and phenomenological aspects of subject matter and the understanding of knowledge production in science.

Berry *et al.* (1999) carried out a study where groups of students have been interviewed while they performed a lab investigation about what they did and why.

Many of them did not know why they did lab work. While a number did say that it helped their understanding of theory, some revealed that it verified theory they had previously learnt or gave them a feel for, or an image of, a particular phenomenon.

Although this study focused on investigations into its two types; the closed investigations (where the aim and each step of the task is highly specified by a procedure given to the learner) and the open ones (where the learner makes decisions about such matters as appropriate procedure, and may also be involved in determining the aim), it has been found that in both of them most students tend to focus on completing the task rather than learning from it.

They concluded that laboratory work tends to be "hands-on" rather than "minds-on" and learners' use of process is limited to that required to finish the activity.

On the other hand, the view that science is promoted by discovery is a highly distorted one due to a number of mistaken assumptions about the priority and security of observations.

Observation, as a first step of science methodology, is reliable and unprejudiced. It produces objective, value-free data from which can emerge trends and generalisations, but in the absence of prior theoretical speculation. Prior theorising is strictly not allowed in this model of science. Explanations of these trends to get principles, laws and theories can be extracted from these data. Eventually, these theories and principles can be confirmed by further observations and so on.

In addition to the mistaken epistemology of the discovery methods, they are also "psychologically unsound and pedagogically unworkable". It is absolutely absurd to suggest that children can readily acquire new concepts by engaging in unguided and open-ended discovery-learning activities. Many teachers pretend that "the purpose of such lessons is to engage in scientific inquiry (to discover), when the real purpose is to promote the acquisition of particular scientific knowledge (the established facts)". (Hodson, 1990)

Therefore, to reach the desired goals the teacher has in mind, children should be provided with guidance and deep theoretical understanding.

Furthermore, many experiments give unanticipated results, that may lead children to discover an alternative science, and then usually we just tell them that they have got the 'wrong result'. This may result in both instilling a concern with what 'should happen' and a preoccupation with the 'right answer', and also projecting the picture that teachers know well in advance the results of the experiments they engage in. In addition to that, discovery learning cannot ensure that children have the appropriate conceptual framework. It ignores totally the probability that they may have alternative conceptions, that might lead them to interpret the ensuing events in a somewhat different way from that intended by the teacher.

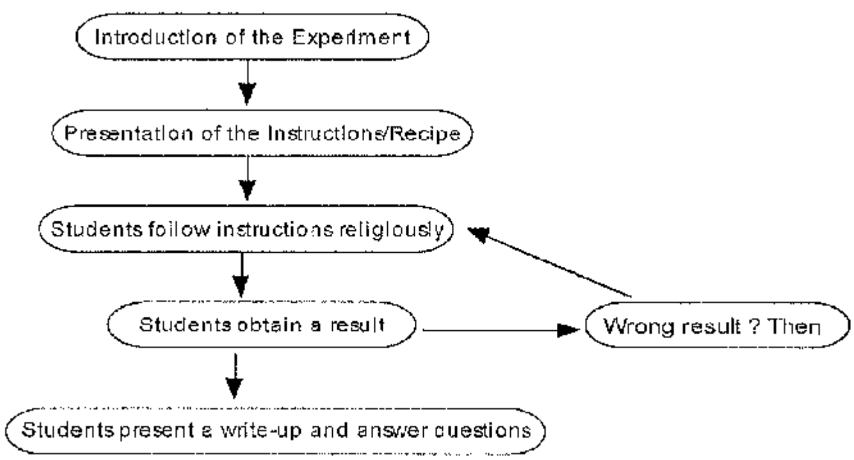
Without doubt, expository knowledge is a prerequisite for attaining the desired ends, in that before one can do something with knowledge (act upon it, act with it, modify it and create new knowledge), one first has to have it.

What has been attempted at schools, placing theory after observation rather than before it, is also putting the cart before the horse.

We need to rethink totally the purposes of the practical work in school science and, in particular, the crucial role of theory in experimentation, if we are to justify its place in the curriculum. Learners therefore must have acquired a broad critical knowledge of the subject matter, the learning of basic competences, prior to successful, productive and useful scientific inquiry. After that, learners need to be placed in situations where they have to use of that knowledge in doing tasks associated with scientific inquiry. Practicals provide an opportunity to develop competence in learning to investigate and to solve problems.

On the other hand, since pupils discussion, reasoning and comparing what have done with others is a necessity for attaining these aims, it also assists them in refining their understanding of problem identification, experimental design, assembling, data collection, analysis, interpretation and reporting of results. (Hodson 1990, 1993 and Kirschner *et al.*, 1998).

In its entirety, a diagrammatic representation of a recipe task is shown in the figure (3.1) below. It is essentially a linear, regimented process with little opportunity for designing, planning, evaluating or decision making. In short, the mind of the learner is only engaged in following the recipe step by step.

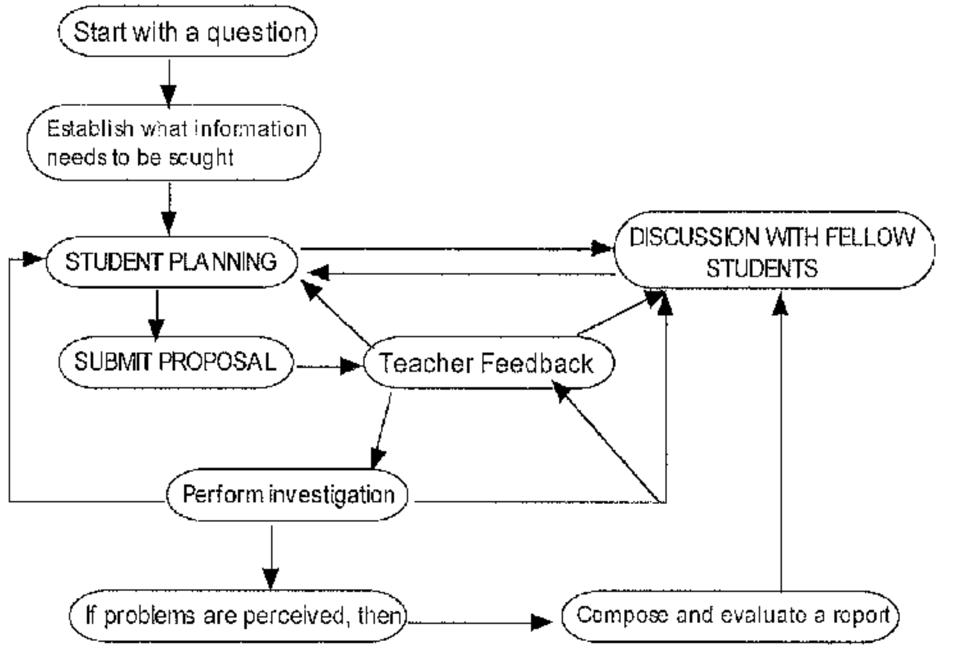


(source Ash and Buchanan, 1998)

Figure 3.1: Recipe task in the laboratory.

However, learning experiences need to be designed more deliberately to develop processes associated with working scientifically. Practical work can play a key role in developing these processes only if traditional practical tasks are restructured to increase the extent of 'openness'.

Such restructuring yields a task that requires learners to plan, design, evaluate, perform and re-evaluate their work. In addition, it more accurately reflects the collaborative nature of real world investigative science by promoting discussion with peers and teacher feedback. A diagrammatic representation is shown in the following Figure (3.2).



(From Ash and Buchanan, 1998)

Figure 3.2: Restructured task in the laboratory

Appendix (3.1) is an example of a recipe task outlined in a structure common to many laboratory manuals. It is followed by a reworking (Appendix 3.2) in which the problem (EFFECT OF CONCENTRATION ON REACTION RATE) is left closed but the 'choosing a method' phase is open. This is done by providing:

- A range of equipment, to force students to consider the suitability and limitations of equipment.
- A series of questions structured as prompts that act to scaffold students' decision making, collaborative and reflective processes.
- Teacher feedback and peer assessment to facilitate a critical analysis of planning, thinking and decision making. (Ash and Buchanan, 1998)

5. Scientific Attitudes:

Generally, it is believed that learners will better appreciate the activities of scientists through adopting a position of value-free and theoretically unprejudiced objectivity, open-mindedness and willingness to suspend judgement.

The substantial increase in the amount of practical work during the Nuffield-inspired curriculum innovations of the 1960s did not lead to increased uptake of optional science or more positive attitudes towards science. Whilst many children enjoy the kinds of activities provided in class (or lab) and develop positive attitude to science as a consequence, there are also many who do not and there is a significant minority who express a dislike for practical work. Many of them regard practical work as 'a less boring' alternative to other methods, rather than as something to be enjoyed in its own right.

It is widely believed that such qualities are both desirable in themselves and transferable to other areas of concern, outside science. Hodson (1990 and 1993) poses three questions:

1- Is the kind of practical work that we provide in schools likely to promote these attitudes?
2- Is this the kind of image that is likely to encourage children to choose science as a career?
3- Do real scientists possess these characteristics?

While experimenting, pupils are striving for the correct answer and are concerned with what ought to happen. This characterises so much lab work in schools and, as a consequence, will not promote scientific attitudes of the learners and that of course shift to answer the first question negatively.

Likewise, children need to see that scientists can be warm, sensitive, humorous and passionate as well as diligent and persistent, not only specific and limited people with particular personality and attributes can become scientists. Obviously, this idea of shifting from real life and suppression of individuality would be unfavourably received by many children and tend not to encourage them to approach science and things related to it.

Concerning question three, scientists probably do not possess these characteristics. Few studies mentioned by Hodson (1990,1993) confirm this commentary. Firstly Roe (1961) suggested that although scientists think they possess these particular characteristics, they do not. Then in 1974 Mitroff and Mason distinguished two kinds of scientists:

- ❖ Extreme speculative scientists: those who do not hesitate to build a whole theory of the solar system based on no data at all.
- ❖ Data-bound scientists: those who are not able to save their own hide in case of fire next to them because they have not enough data to prove that the fire was really there.

Mahoney(1979) also declares that scientists are frequently illogical in the way they work, especially when defending their own view or attacking a rival one.

As a whole, and as Gardner and Gauld (1990) remark "merely being in the lab and doing lab work there do not, by themselves, foster scientific attitudes: it is the quality of the experiences that students have there that crucial".

vi. Reasons for doing practical work now and their limitations:

Wellington (1998) carried out a study asking 48 science graduates embarking on a teaching career to write down why we do practical work in school science. He inevitably received a wide range of answers to such an open question. Some ideas offered were "to make learnt things easier to remember", "learning some skills and shifting from routine theory", "something else to do apart from lessons", "keep kids quiet", "make lessons more interesting", "they break up lessons to keep the kids entertained", "nice change"; etc...

To sum, all these reasons and the rationales put forward in the last thirty years (such as, Kerr (1963), Buckly and Kempa (1971), Thompson (1975), Beaty and Woolnough (1982), Millar (1987), Hodson (1990), and others) can be grouped into three main areas: one relating to knowledge and understanding (the cognitive domain); one relating to skills and processes, often deemed to be transferable (the psychomotor domain); and a third relating to attitudes, enjoyment and motivation (the affective domain).

The following lines give brief summary of arguments in each area and counter arguments to them:

1- *The cognitive arguments*: it is argued that "practical work can improve learners' understanding of science and promote their conceptual development by allowing them to visualise the law and theories of science. It can illustrate, verify or affirm theory work". (Willington, 1998)

Practical work, however, can confuse as easily as it can clarify or aid understanding (especially if it 'goes wrong') and this might be affirmed by the well-known aphorism ' I do and I become confused', not the other way round. Theory should come first and is needed in order to visualise. Unless, we instil theories in the first place, practical work is still not a good tool for teaching theory- "theories are about ideas, not things". Likewise, Leach and Scott (1995) stated that learners would not develop an understanding through observations since the theoretical aspects of science are not there to be seen.

2- *Affective arguments*, it is argued that practical work can motivate, excite and generate interest and enthusiasm of the learner. It also helps him to remember things and make it stick. Though this is not the case for all pupils – some are 'turned off' by it, especially when it goes wrong or they can not see the point of doing it.

3- *Psychomotor arguments*. In addition to manipulative or manual dexterity skills, practical work can also promote higher level, transferable skills such as observation, measurement, prediction and inference which are valuable to future scientists and to possess general utility and vocational value.

This can be argued that in spite of some manipulative skills, which can be promoted to some extent, there is still little evidence that skills learnt in science are indeed general and transferable or that they are of vocational value.

In a slightly different area of skill, it has been claimed that the teamwork, which projected experiments or **(TOPs)** involved, can develop such skills as communication, interaction and co-operation. Again, and even in case of group work, this might be argued as Willington (1998) stated "when group work is closely observed and analysed it often reveals domination by forceful members".

> The counter-argument to this, whilst carrying out a **TOPs** practical session, the instructor can spread out the roles among pupils and ensure that all learners get engaged in discussion. Of course, not all learners would participate in handling apparatus but instead, and the most important, mental engagement, could be offered to all. Using this strategy, lack of physical engagement for some which may leave one pupil simply recording results or drawing out a neat table without even seeing, let alone touching, any apparatus. (Willington, 1998)

Eventually, there is a notion common amongst teachers - and often expressed by learners too, that 'what you do for yourself, you understand'. Indeed, the early Nuffield schemes used the (allegedly) ancient Chinese proverb, "I am told and I forget; I see and I remember; I do and I understand" to support the case for the widespread use of practical work. Nevertheless, there is much evidence that many children cannot say what they did, why they did it or what they found although they have just completed the practical exercises. It is more likely a case of "I do and I am even more confused". This state is justified by Tasker (1981) who identifies the following six reasons:

1- Lessons are perceived by pupils as isolated events, not as part of a related series of experiences.
2- Usually teachers do not state the purpose, so the pupils' purpose is different from that of the teachers. Even when they do, they do not ensure that pupils understand it. The situation that pupils may construe either "following the set instructions" or "getting the right answer" as a purpose.
3- Failing in understanding relationship between the investigation purpose and the design of the experiment they carry out.
4- Pupils lack prerequisite knowledge assumed by the teacher.
5- Pupils are unable to grasp the 'mental set' required.
6- Pupils' perceptions relating to the significance of the task outcomes are not those assumed by the teacher.

vii. Individual practical work & Demonstrations: In the balance

Wham (1977) and Viarna (1991) reported that during the first three decades of the twentieth century, the literature recorded some 50 studies related to individual versus demonstration laboratories. Of these, 45 were applied to high school and five to college classes; 23 dealt with chemistry instruction, 7 investigations of the debate were conducted by means of questionnaires, and 13 were reviews of findings of previous investigations. Four papers expressed the opinions of the authors on the relative merits of the individual laboratory versus the demonstration method. Those who were against the individual method of laboratory instruction, argued that it was a waste of time and money and concluded that they were used inefficiently in the laboratory. Kapuscinski (1981) stated that Hunt in 1935 argued that demonstrations could be done in 5-40% of the time required for individual labs and the students would be less likely to be victims of overzealous instructors who required them to stay after hours and do extra experiments. Demonstration methods would also make more efficient use of faculty time, not only because they required more concentrated effort but also because the teacher who tended to neglect laboratory supervision would be forced to take on a more active role.

The demonstration method, on the other hand, offered the advantages of keeping the entire class together and preventing poor students from becoming discouraged. It also offered students a greater opportunity to think because of instructors could call attention to every point and ensure that certain principle would not be overlooked. Demonstration thus exposed students to a broader experience of chemistry by introducing them to methods, apparatus, compounds, and uses of chemistry which could only be accomplished by spending long hours in the laboratory over one experiment.

Supporters of the demonstrations method also contended that most laboratory manuals of the day were quite useless as far as the scientific method was concerned; yet many students gave evidence of their genuine interest in science through their thoughtfully and independently written notebooks.

The arguments used by those who supported individual lab instruction were that it facilitated the learning and retention of chemical facts and principles discussed in the classroom by providing contact with actual materials. It was further suggested that individual practical work gave the students some basic insight into elementary laboratory method and left them with a feeling of the reality of science thus increasing their interest and enthusiasm, resulting in increased enrolment for chemistry courses.

All sort of arguments, including economic, educational and philosophical ones, have been used for or against both methods. These arguments tend to favour demonstrations over individual methods. (Vianna, 1991).

As a **conclusion,** there has been a wide range of debate and studies attempting to evaluate the teaching procedures in science concerning the two instructional approaches of the demonstration and the individual (or small group) practical work. The following table is attempting to survey studies investigating pupils' achievement from teaching using those two methods. For the purpose of brief discussion, these studies are split into four historical phases.

For Phase 1 studies (1900-1926) –no statistical treatment			
	Results		
Learning outcomes	**Demonstration Favoured**	**(individuals) or Small group favoured**	**No difference favoured**
Immediate recall	11	0	0
Delayed recall	2	8	1

For Phase 2 studies (1926-1946)						
	Results					
Learning outcomes	**Demonstration Favoured**		**(individuals) or Small group favoured**		**No difference favoured**	
Statistically	significant	Not significant	significant	Not significant	Significant	Not significant
Immediate recall	1	7	0	4	6	2
Delayed recall	1	4	0	1	2	2

For Phase 3 studies (1946-1960)			
	Results		
Learning outcomes	**Demonstration Favoured**	**(individuals) or Small group favoured**	**No difference favoured**
Immediate recall	0	0	5
Performance	0	1	2

For Phase 4 studies (1960-19--).			
Researcher(s)	**Study dimensions**		
	Heuristic- guided discovery	**Cook-book**	**Didactic with demonstrations**
Heaney ,S (1969 and 1971) (teaching tactics)	More successful in improving problem solving skills.		High order cognitive skills when being taught concurrently with learning
	Dependent	**Independent**	**Neutral**
Garrett,R.M (1978) (the need of lab work) (Ph.D. Research)	No significant differences between attainment of the demonstration and the small group pupils after isolating pupils scores.		
Garrett,R.M and Roberts,I.F (1980) (Teaching both groups within guided-discovery strategy)	**Small group work**		**Demonstration**
	No significant differences between the demonstration and the small group pupils even after isolating scores of boys and girls.		
Palmer,C.R (1971) **Kempa,R.F and PalmerC.R** (1974) (Effectiveness of video-taped demonstration)	Little difference between student performance in relation to the cognitive aspects of skills being taught. Marked differences in manipulation skill performance. Those receiving video film were more competent in completing the manipulative skills than were those who had merely given written instructions.		
Ben-Zvi, *et al.* (1976) (effectiveness of filmed demonstration)	Filmed demonstrations were an effective substitute for individual lab work and pupils were not affected adversely in the problem solving situations.		
Beatty and Woolnough (1982) (Time in the curriculum allocated for lab. work)	Teachers in lower secondary schools spend between 40% and 80% of their curriculum time on practical work.		
Gayford,C(1992) (five main styles of group behaviour)	Groups with more "democratic" or "negotiated" styles of working often have higher motivational levels and gain greater all-round understanding than those in which an individual student assumes a leadership or directive role		

(Source: Garrett and Roberts, (1982) and Hodson, (1993))

Table 3.2: Studies evaluated individual experimenting & demonstration since 1900

In fact, most of these studies came from the USA and were in the fields of chemistry and physics. Only about three involved biology classes and some of general science. The majority of them were carried out in schools and few in the universities or colleges.

Clearly, almost all phase 1 studies indicate that demonstration was superior to individual or small group work for short-term retention while the reverse was true for longer-term recall. However, discussion at that time centred on the importance of lab work as compared with textbook recitation work rather than with the type of lab class to be provided.

At the time of phase two, chemistry and physics were enjoying particular popularity; experimental inquiry was important and was bringing about a more fundamental understanding of these subjects. Phase two studies also show that only four out of twenty indicated that small group work might be superior for immediate recall, but none of these produced significant results, while eight found demonstration to be superior although only one found it to be statistically significant. Although there is no overall superiority of one teaching method over the other, at what may be called the micro levels of investigation we should mark that the group method resulted in longer retained more-understanding type of learning and also in greater individual differences in such learning with more able pupils, but the lecture demonstration resulted in greater expression of individual differences and in longer retained more-understanding learning in less able pupils. In addition, lecture demonstration resulted in greater expression of individual differences in longer retained recall-recognition type learning in the less able three-quarters of the pupils. (Garrett *et al.*,1982)

Examples of scientists in phase 1 are Wiley, 1918; Philips, 1920; Cunningham, 1920; Hunter, 1920; and Cooprider, 1922. For phase 2, Anibal, 1926; Knox, 1927; and Johnson, 1928 whereas Kruglak, 1952; Ward, 1956; Novak, 1958; and Kruglak and Wall, 1959 are examples of this area scientists for phase 3.

However, there is abundant research evidence that even directly after completing a conventional practical exercise, many children cannot say what they did, why they did it, or what they found. So much for understanding!

Because of poor lab design, inadequate facilities, lack of technician support and insufficient curriculum time, teachers are unable to run practical work as they wish. Besides, overly directive lab texts and the restrictive demands of practical examinations are other constraints on teachers.

In its entirety, although practical work depends on specialised facilities and materials, good facilities do not guarantee good practice and favourable learning outcomes; they can militate strongly against them.

On the other hand, the consensus view is that much practical work serves only to develop manipulative skills to a limited extent and is not very effective in helping learners grasp concepts, because the laboratory is a "noisy" place in terms of information (Johnstone, 1984).

One problem that has been identified as a possible source of so little learning taking place in the laboratory is the gross information overload experienced by the pupils there.

Thus, under this circumstance, is it reasonable to expect learning to take place in the laboratory?

To find some answers to such a question, we have to examine how learning takes place. The proposed model (Figure 3.3) for science education based on information processing, makes predictions about how input information is dealt within the human mind so that meaningful learning can take place.

3.2. Learning Situation In The Laboratory

i. The information processing model and practical work:

According to the information processing model (Figure 3.3) for science education stated by Johnstone and El-Banna (1986), input information in the practical science lessons in the laboratories like instructions, apparatus, observations and skills passes in to a limited space called working space (**WS**) where it is held temporarily to be organized and shaped in order to enter the long term memory (**LTM**) store.

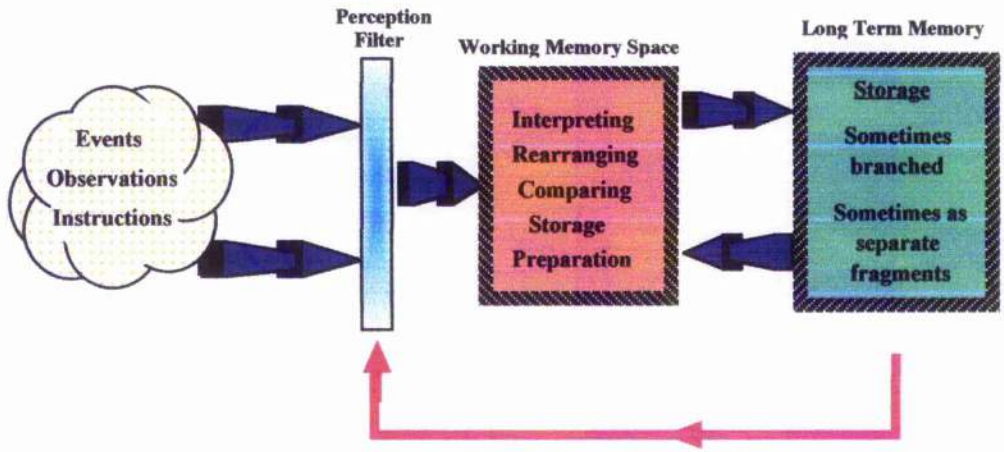


Figure (3.3): Information Processing Model

To explore this path bit by bit, the first step in human processing and learning is ***perception***; in other words, before the input information enters the working space for processing, it has to go through a filter. In the filter, relevant materials are selected for processing in the **WS**. This is a selective process in that experts do not attend to all of the incoming stimuli, but choose what is of interest or of importance or of greater impact. For a novice, on the other hand, to try to respond to all stimuli would be an instant recipe for confusion. However, "the selection process must be driven by criteria which are already available in the mind of the expert, his previous knowledge, interests, misconceptions. In other words, our previous learning has an influence on new learning". (Johnstone *et al.*, 1994 and Johnstone*, et al.*, 1998)

The filtered material now passes in to Working Space (WS), where processing takes place. Relationships are sought, fits between old and new are found, patterns are established or enriched and ideas are prepared for storage or rejection. Johnstone (1997b) stated that Working Space has two functions which operate simultaneously in a limited, shared space which is used for the temporary holding of material while it undergoes various operations of matching, transforming and organising. If a lot of information has to be held, there is little space for the operations, and vice versa. With nothing familiar in the long term store; processing becomes difficult due to the **selection** problem; no appropriate connections can be made for long term storage and this may result in loss of such information or forgetting.

Since a learners' working space capacity is finite, this would place an excessive load on the working memory space of the learners who are unable to organise the recalled and new information in order to decide the point of an experiment, what is important and what is not and which new principles and concepts are emerging.

If the learner is concerned about details of weighing, filtration, pouring, adding, obtaining spectra, etc..., less working space is available for the thinking skills which laboratory work is supposed to foster. If it is to master manipulative skills, they have to be met frequently and have to be taught consciously.

Farmer and Frazer (1985) have shown that often basic skills are met infrequently and so are not reinforced to the point of mastery.

On the other hand, learners are put into the position where they have to understand the nature of the problem and the experimental procedure, assemble the theoretical perspective (with only minimum assistance from the teacher), read, comprehend and follow the experimental directions, handle the apparatus, collect the data, recognise the difference between obtained results and expected results, interpret those results, write an account of the experiment and all the time ensure that they get along reasonably well with their partners. The learner should also recall skills, theory and apparatus at the same time as absorbing new skills and written (and perhaps verbal) instructions. Johnstone and Wham (1982) and Hodson (1993).

Johnstone and Wham (1982) stated that the incoming information may have no apparent structure, so the learner cannot discern what is important and what is incidental since the working space is in a state of unstable overload. They indicated that during practical work, the learner's limited memory is flooded with information of various kinds (<u>Figure 3.4</u>) such as:

1. Written instructions (manual, textbook or worksheet)
2. Verbal instructions.
3. New manipulative skills.

4. Unfamiliar or unnecessarily complex labelling of reagents.

To these are added from the long term memory (LTM).

5. Recall of manipulative skills.
6. Association of names for apparatus, reagents, ..etc.
7. Recall of background theory.

There is also input from the experiment itself:

8. Visible changes.
9. Audible changes.
10. New smells.
11. Gases given off.

In addition, learners are working against the pressure of time to follow the experimental procedures and instructions from the work sheets (or manuals) at the same time as recalling theory and techniques, observing phenomena, learning new hand skills, reading instruments, recording data, processing data and making sense of the message of the laboratory.

As an example given by Johnstone and Letton (1989b, 1991) and Johnstone (1997a), to make the point a few lines from a lab instruction book:

' the student has just synthesised a copper(1) thiourea complex and is about to analyse a portion of it for copper.

> *"Weigh out 1g of your white complex and add x ml of 50% nitric acid. When the reaction dies down, evaporate the solution to dryness, cool and add y ml of water. Now add ammonia solution drop by drop until the solution just becomes cloudy. Add acetic acid dropwise till the solution becomes clear. Add 1g of potassium iodide and titrate the iodine released with standard thiosulphate".*

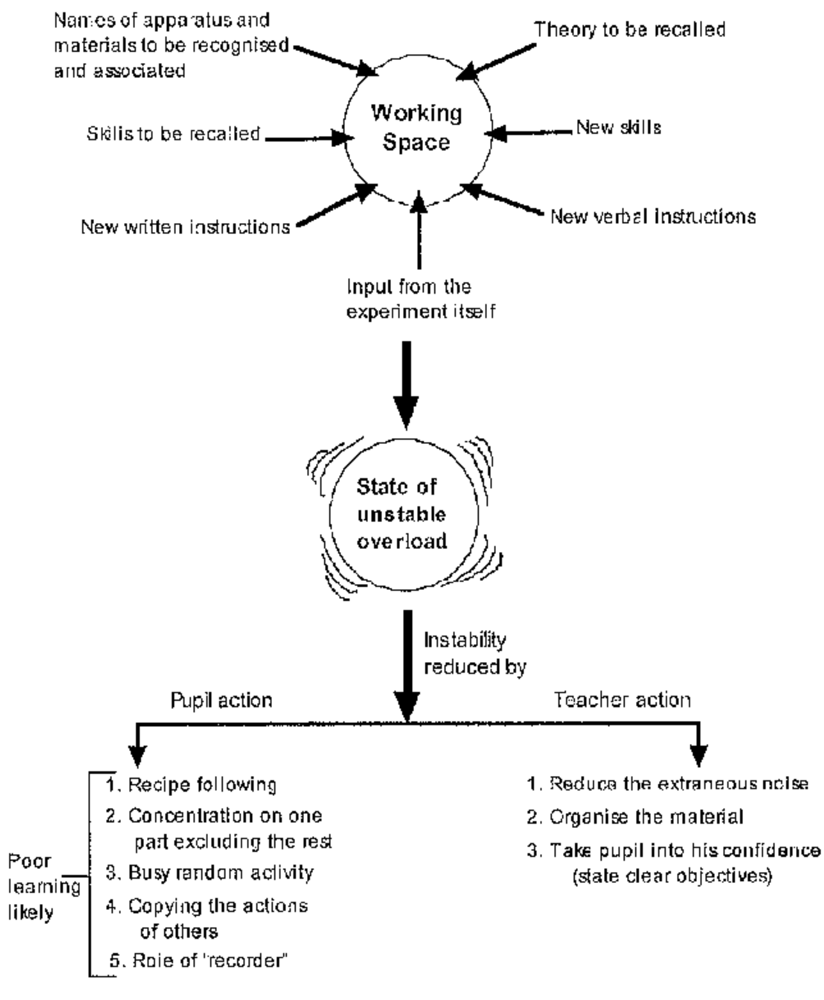
ii. Lab work and memory Overload:

The '**Working Space'**, the conscious part of the brain where we hold and manipulate information, is of very limited capacity. Into this finite space comes information from the outside world and information retrieved from **long term memory** (LTM). External information going into the learner's working memory consists of the instructions from the lab manual: "Add concentrated nitric acid; evaporate almost to dryness; take up in water; adjust pH by adding ammonia solution till a precipitate forms; add acetic acid till the precipitate just disappear; add excess potassium iodide; titrate with thiosulphate; calculate copper content".

The experiment also contributes sensory information: "Brown fumes; blue solution; white anhydrous residue; blue again when water added; pale precipitate becoming deep blue if too much ammonia is added; return to pale blue when acetic acid added; brown colour when the iodide is added; disappearance of brown (or purple with starch) on titration; white milky suspension".

Next comes recognition that the brown material released with the potassium iodide is iodine. "This is an oxidation, therefore there must be a reduction. What is being reduced?". Recall copper (II) to copper (I). At the end of the thiosulphate titration (procedure recalled) there is still a milky solution. "Should the titration continue till it disappears?" Either recall that copper (I) compounds are white or recall similar titration from perhaps many weeks ago.

All of this represents an overload that completely swamps the working memory in which the learner is subjected to an amazing array of input information as illustrated by figure (3.4) below:



(Source: *Johnstone*, 1997b)

Figure 3.4: Unstable overload in practical work.

What should be coming from **LTM** into the working memory to make sense of the external input? "Brown fumes, probably NO_2, therefore nitric acid is being reduced. There may also be blue appearing, probably copper (II). How do I evaporate almost to dryness safely? (Request to procedural memory for a match with a similar situation in store). Why do I need to adjust pH? Why ammonia? Why the deep blue? Cuprammine complex? The pH adjustment has to be done carefully". Once more an appeal to procedural memory is required for a match on how to do it. (Cited in Johnstone and Letton, 1989b)

For the example above, the analysis in the following table (3.3) revealed that for the majority of students, columns one and two were processed and recorded, but a consideration of column three was absent; and yet column three is essential for any understanding to take place. The sheer load of experimental instructions and observe that column three was often ignored.

Column 1 **Instructions from manual**	**Column 2** **Observation**	**Column 3** **Interpretation**
Weigh out complex	White powder	Cu(I) compounds often white
Add 50 per cent HNO_3	Can't find any bottle labelled 50% HNO_3	Equal volumes of conc. HNO_3 + Water
Allow reaction to proceed	Brown fumes and a blue solution	NO_2 is the reduction product of HNO_3 and the blue colour is hydrated Cu(II), the oxidation product
Evaporate to dryness	White solid	Has it gone back to Cu(I) or is it anhydrous?
Add water	Blue returns	Yes it was anhydrous
Add ammonia	Can't find NH_3, will NH_4OH bottle do? Turns cloudy	NH_4OH label really means $NH_{3(aq)}$. Cloudiness may be $Cu(OH)_2$
Add acetic acid till clear	No matter how much acid I add, the solution remains blue and does not go clear (colourless)	Puzzled
Add solid KI	Turns brown with a precipitate	I_2 released by oxidation of I^-, therefore Cu(II) must be reduced to Cu(I) (white and insoluble in water)
Titrate with thiosulphate	Brown disappears but milky solid is left. Is this the end point or does the solid disappear?	End point occurs when I_2 is reduced completely to I^-. The white solid is a Cu(I) compound

(Source, Johnstone and Letton, 1991)

Table 3.3: An analysis of six lines from three pages of experimental instructions.

If the things the learner has to do; number of observations (colour changes, gases evolved, etc...) and recalling theoretical ideas to make sense of these observations and instructions and knowing that this part is less than one-tenth of what student had to process in three hours (lab session), the total is staggering!

Thus, 'conventional practical work causes severe overload and drives the pupil to mindless recipe-following in which no learning takes place. The flood of information has to be severely controlled to allow room for thought'. (Cited in Johnstone (1997a))

This confirms the Johnstone's commandment 4 (Johnstone, 1997a) (**The amount of material to be processed in unit time is limited**), as in practice and to avoid this overload, learners would blindly process only the instructions and seldom record or interpret the observations. They will resent probing questions from the instructors and maintain their thinking brains in neutral. It is possible to reach the end of the lab period having learnt nothing except some hand skills that may decline after a while and which might be acquired at home while dealing with normal households duties. It is even possible to obtain 'the right answer' or good crystals (as products) without knowing why and without getting satisfying understanding of what happens in between the reactants and products.

Suffering information overload, the learner finds himself incapable of perceiving the "learning signal" clearly. Consequently, he may engage in one of a number of strategies: - (Johnstone and Wham (1982), Johnstone and Letton (1989a+b, 1990), Hodson (1993))

1- Adopt a "recipe approach", simply following the instructions step-by-step.
2- Focus on one aspect of the experiment, to the virtual exclusion of everything else.
3- Exhibit random behaviour, in which they are 'very busy getting nowhere'.
4- Look around them in order to copy what others are doing.
5- Become 'helpers' or 'assistants' to a group organised and run by others.

Subsequently, since "**what we have already known and understood controls what we learn**" (commandment 1: Johnstone, 1997a), pupils minds should be prepared to recognise the expected changes, to be surprised when something different occurs. This preparation should include revision of theory, reacquaintance with skills, planning the experiment to some extent and discussion with others. Otherwise the learner will not be in a position to process the laboratory experiences with understanding. It does not matter if we use bucket-scale or micro-scale, the same fundamental problem of overload remains. (Johnstone, 1997c)

iii. Rebirth of demonstration and reconciling of the paradox

Therefore, something should be done in advance both to reduce the load in the laboratory and organise the learner's thinking. So towards learning new facts, principles and concepts as well as manipulative skills, "signals" must be enhanced while "noise" must be reduced.

In experiments, noise can arise in a number of ways:

1- *Experiments become more sophisticated and the 'noise' creeps in almost unnoticed.*

   To introduce acids and bases, for instance, pupils used to be given litmus paper to try on a variety of household materials such as vinegar, ammonia, salt, baking soda and so on. So on the basis of very simple rules, pupils could establish categories into which these substances fell.

   Later and when pH paper became more common, teachers introduced it instead of litmus forgetting that they add even more to the load, i.e. It gives a variety of colours, which have to be judged against a colour scale to translate them into magic numbers. Pupils now should note that numbers less than 7 corresponded to acids and numbers more than 7 to bases. They also have to learn that the **smaller** the number, the **more** acid is the substance. Moreover, the intelligent pupils want to understand the meaning of the strange symbolism pH (**p** =power, **H** =hydrogen ion concentration). The less inquisitive settled for pH, a meaningless symbol. Therefore this welter of information will obscure the point of the experiment and that has happened because of simply using pH papers. Undoubtedly, replacing pH paper by litmus paper would cut the noise and enhance the signal.

2- *Manipulative skills demanded by an experiment can obscure the point of it.*

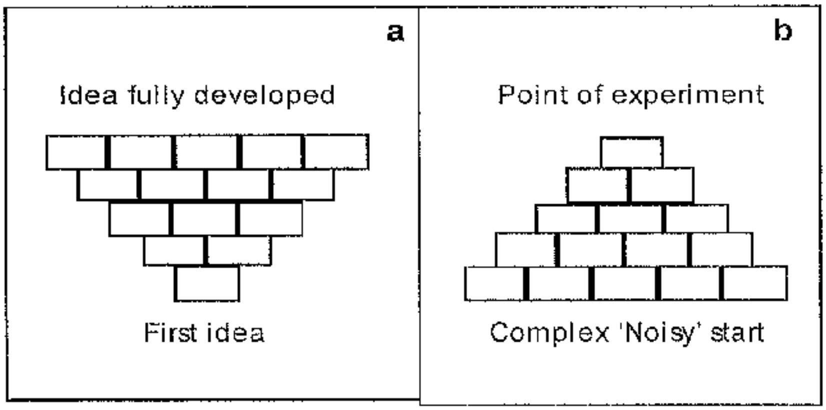
   As an example, if we consider the reaction between thiosulphate and acid, this reaction is based on diluted acids. Hence, instead of letting pupils pay attention to this part of experiment (dilution), which may detract from the rate measurement, pre-diluted solutions allow their attention to focus on the rate measurement; the point of the experiment.

3- *Unconscious noise. Regarding labelling, sometimes it becomes an unnecessary part of the load.* For example, confusion is caused by a surfeit of information. The teacher might be unaware until a pupil asks, "What does 0.1M mean?" referring to 0.1M HCl. Besides, using of unnecessary terms is another labelling problem. Another example is, when dealing with redox reactions involving iron, pupils meet ammonium thiocyanate as a test for Fe^{3+}. The point of the lesson is that, under certain conditions, Fe^{2+} is oxidised to Fe^{3+} while some other reagent is reduced! The thiocyanate turning red indicates the presence of Fe^{3+}. When pupils were asked how did they know that Fe^{3+} had formed, they repeat "the ammonia went red" or "the thio stuff turned red". The name ammonium thiocyanate was not forthcoming. It might have eased the situation by labelling the reagent 'Detector for Fe^{3+}; turns red'.

4- *Calculation and pre-cautions 'noise'*

For instance, in an experiment reported by Johnstone and Wham (1982) to determine Avogadro's number, acid is electrolysed using a constant current source and a clock to measure the amount of charge required to release 11.2 litres of hydrogen at stp. Measurements of temperature, atmospheric pressure, saturated water vapour pressure and time are taken. Pupils then have to relate current, time, volume, temperature, pressure and water vapour pressure and most of the pupils are lost long before Avogadro's number emerges, if ever. But, we can settle for only two measurements; time in seconds and volume in litres instead of worrying about the 'noise' of measurements of temperature, atmospheric pressure, water vapour pressure and time, which do little to improve the final value of Avogadro's number obtained. 6×10^{23} is good enough for most purposes.

When teachers are developing a general concept in class they often begin with a single idea and elaborate it with examples and develop connections (figure 3.5.a). But in practical work, the pyramid is often reversed (figure 3.5.b) with the complex and numerous at the start leading to (or obscuring) the main point we are trying to make.

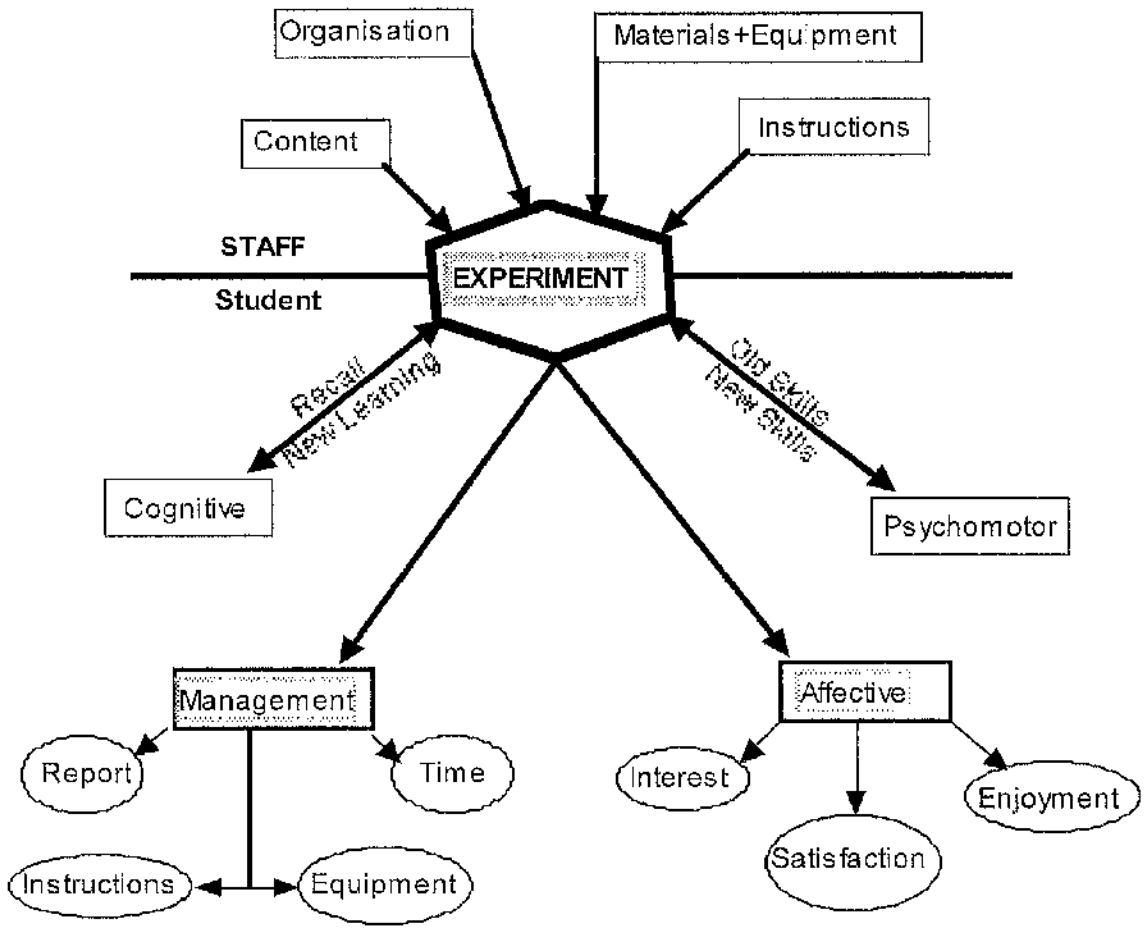


(Source: Johnstone and Wham, 1982)

Figure 3.5.a+b: Two teaching strategies for connecting between elaborating ideas and concept.

We, as teachers, can cope because we designed the experiment. By years of practice and experience, we can group large interrelated 'chunks' of information and thus control the load at any time in the working space. Johnstone and Kellett (1980c) argued that the ability of 'chemistry masters' and 'chemistry novices' to recognise structural formulae depends on their ability to 'chunk' the information. They recommended that it is good practice in teaching to operate in low-information situations while a concept is being developed. Where a high-information situation is inevitable because of the nature of the science, the teacher ought either to postpone the introduction of new concepts or provide students with efficient strategies to allow for 'chunking' and the development of confidence at the temporary expense of understanding. Finally, they advise that teachers keep redundant information well out of the way during the development of concepts. Pupils at a low development stage may see redundant materials as essential and so overload their capacity.

Letton (1987) illustrated in the following diagram (Figure 3.6) the different aspect of practical work which were all present in the laboratory, with regard to the staff and the students.



(Source: Letton, 1987)

Figure 3.6: Aspects present in the laboratory with regard to staff and student

To the staff (*expert*), the lab represented the result of a well-organised exercise where the content of each experiment had been planned and the corresponding equipment and materials made available within the management of the laboratory. The instructions were compiled in a compact manual, which included any relevant theory, which they thought was necessary.

The students (*novices*) were presented with this book of instructions in an unfamiliar lab setting with possibly hitherto unknown partners. The method of organisation for the equipment and materials in this lab could also be new for them. In addition, they had to cope with the written instructions for each experiment. While following and understanding these, they were expected to remember relevant theory in order to work out what should be happening, as well as either learning or perfecting new techniques or remembering old ones. All this had to be accomplished within a pre-ordained time restraint and with the production of an acceptable report.

Because of their previous knowledge and experience, the staff who had planned the experiments had well-organised ideas, concerning the content and the outcomes of these experiments. The student did not have the benefit of these pre-organised ideas and were put into this multi-variant situation in the lab where they found it difficult to determine what was important and what was incidental. The situation was one of 'noise' in which the student had difficulty to in determining the 'signal'. This situation can be illustrated by the following figure (3.7):

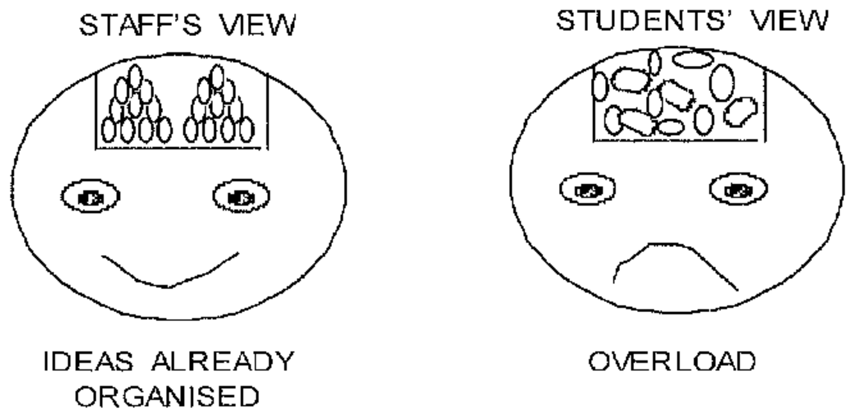


Figure 3.7: Situation of how ideas organised mentally by staff and student

Back to our example we set previously, the behaviour of nitric acid under various conditions is a chunk of information, and iodine / thiosulphate chemistry is another chunk. In addition to practical techniques, mental techniques for problem solving and data manipulation are the chunks teachers have as a distinctive feature.

Whereas the learner is not in such a happy situation and has not yet developed this mental tool kit; how then does he survives?

iv. Lessening the load:

Lessening the load during the learning period by the way in which the manual is written and presented is an approach that has helped the learners. Since the student is at the learning stage, he or she is not in a position to distinguish between what matters and what does not- between the 'signals' (important information) and the 'noise' (unimportant information). With careful preparation, one can reduce or eliminate the 'noise' and enhance the 'signal'.

Noise reduction in the laboratory:

Part of the learner's working space can be occupied by many distractions in the laboratory. They take on board the irrelevant as easily as they take on the relevant. Due to their previous experiences, teachers (the experts) can easily decide which is which, but the students (the novices) cannot. For first-time learners, the slightest surfeit of information (intended or not) makes them overload and become very irritated with the exercise. If the manual or the procedure is not clear, overload occurs because irrelevant information has been taken in.

Back to the example of copper (I) complex. There are several pieces of 'noise':

- Firstly, "*50 per cent nitric acid*" as it is unnecessary digression. If it is needed, why not supply it in an appropriately labelled bottle?
- The second occurs at '*ammonia*'. Instead, the manual should say, "*Use the solution marked ammonium hydroxide*".
- Thirdly and the more semantic 'noise' comes in at the mention of '*clear*'. The young pupils may think '*clear*' means '*colourless*' and not just '*transparent*'.
- The '*titration*' comes as the fourth piece of 'noise'. The previous experience of a thiosulphate-iodine titration had an end point in which brown (or blue with starch) gave a colourless, transparent solution. In this case, without warning, the end point leaves a milky-white solid.

One way to cut out this 'noise' is by exposing the manuals (procedures) to a group of students for 'pre-shredding' and many of the problems of noise could be eliminated before the whole class was exposed to it.

Noise reduction in the manual:

Manuals can be redesigned in an appropriate way to reduce noise by keeping in mind the following features:

- Make the layout more open and less daunting. This might be done by splitting the manual into separate steps with clear statement of the point of the experiment. This would not make the layout seem to be over-crowded with information and steps.
- Wherever there is any doubt or possibility of misinterpretation in the text, a picture or icon could be displayed in the margin to clarify the point. For example, diagrams of types of balance (rough or analytical) indicate the

precision of weighing required. A term such as 'a little' is shown by the amount on the spatula. To minimise students wandering about looking for things in a large, unfamiliar lab, the numbering in the manual margin can refer to the lab map where specific items can be found. Signs of safety hazards will alert student to risks. When unusual or new glassware is specified, a picture of it can be displayed to help the students to identify it. This definitely is effective in reducing the 'noise' which may arise from the 'silly' students' questions.

Practice makes perfect:

The new manipulative skills required by the experiment will overload the working space leaving less space for the 'thinking kills' which lab work is supposed to foster. In this way, the 'novice' becomes the 'master'. We now have a basic skills laboratory followed by a graded set of experiments using these skills with increasing sophistication.

Think before acting:

One way of reducing the load in the lab, is to do something in advance to organise the students' thinking, so that some tasks have already been thought through. One of the easy places to start is with the quantitative. The original manual would have said: "weigh out x g of substance A and y g of substance B. Dissolve them in z ml of water...". The new manual says: "you are asked to prepare w g of substance C, beginning with substances A and B. allowing for an 80 per cent yield, work out how much of A and B you will need". (Johnstone and Letton, 1989b, 1991)

The learners must do the relevant preparation before the lab session and show their calculation to the instructor before beginning the experiment. They are also asked for equations, reaction pathways and suggested methods.

Johnstone and Wham (1982) have suggested that less "noisy" practical work can be developed and the instability of overload can be reduced. They recommend:

1. Giving a clear statement of the point of the experiment.
2. Stating clearly what is preliminary and peripheral.
3. Making sure that the experiment has not acquired irrelevant or confusing aspects.
4. Making sure that involved skills have been already acquired.
5. Controlling the complexity of language.

These calculations might be required before beginning of the experiment by asking learners to do them before the lab session (pre-lab). The effective pre-lab is not just "Read your manual (instructions) before you come" nor is it "Do a few calculations in advance". We can also ask for equations, reaction pathways and suggested methods, bearing in mind a few relevant questions such as:

'What theory do I need to put in place? What instruments will be used? Do I need to get practice using X again? Do I understand the terminology? How will I recognise the product? What maths do I need? And what planning am I expected to do?'

This strategy will help learners, before attempting the laboratory, to understand the experiment, give them more confidence, force them to think about the experiments and prepare them to follow procedures with a greater understanding and sometimes to familiarise them with procedures and variables. (Johnstone and Letton, 1991).

Correspondingly, experiments can be made simpler by cutting out some of the less crucial steps and by using simpler apparatus and simpler techniques. Many children struggle to set up complex apparatus and have 'done enough' before the conceptually significant part of the activity has got underway. A similar case can be made for the pre-weighing and pre-dispensing of materials. Avoiding complex language in experimental directions extends to the labelling of materials (e.g. *Fe (III) indicator* rather than *ammonium thiocyanate*). Re-calibration of apparatus, as Johnstone and Wham (1982) advocate, can reduce the number of chunks of information that have to be processed or the number of measurements that have to be taken.

Furthermore, Letton (1987) put forward the following suggestions for reducing the 'noise' in existing laboratories:

1- Giving a clear statement of objectives.
2- Giving clear instructions, on the requirements for the laboratory report.
3- Identifying which instruction matter and which are peripheral and make this obvious in the material.
4- Redesigning the experiment with regard to the content.
5- Dividing the written material into sections, which are easily managed by the students.
6- Making the management of the lab efficient and giving a map of the layout of the laboratory with location of all equipment and material.
7- Ensuring that relevant skills are taught separately from the actual experiment in order that the student should gain confidence.

In Summary:

1- Much of what goes on in our science classrooms under the name of practical work is muddled and without real educational value.

2- Much of traditional practical work should be replaced by theoretically more sound and pedagogically more useful learning methods.

3- Our conception of 'practical work' should be expanded to include other active-learning methods (such as **TOPs**).

4- We should identify much more clearly than in the past the goals of particular lessons- in terms of individual goals related to learning science, learning about science and doing science- and select active learning methods specifically suited to those individual goals.

5- All lab work (indeed, all practical work), including the identification of problems, choice of experimental procedures and interpretation of results, should be preceded by theoretical considerations.

6- A major goal of practical work should be the engagement of students in holistic investigations in which they use the processes of science both to explore and develop their conceptual understanding and to acquire a deeper understanding of (and increased expertise in) scientific practice.

7- We should encourage students to regard practical work as personally worthwhile, in that enables them to study phenomena, explore issues and solve problems that interest them.

Conclusion:

In the first three decades of the 20th century, there were several investigations comparing individual practical instruction with the demonstration method. They were mainly in favour of demonstrations due to lack of facilities and the costing constraints. However, almost all the major science developments of late 1950s, 1960s, 70s and early 1980s promoted hands-on practical work as an enjoyable and effective form of learning. It is claimed that individual laboratory work allows development from concrete situations to abstract ideas and it is considered to be the 'vehicle for arousal of curiosity and appreciation of aesthetic aspects of the subject' (Hodson, 1990). It (individual practical) is an essential ingredient of chemistry education and an important element in the teaching of school science

Nevertheless, because the classes in educational institutions are becoming much larger and the cost of practical courses is escalating, space becomes at a premium and the learning effectiveness of the available courses is being questioned. Demonstration experiments could be seen as a feasible and efficient alternative.

Also more sophisticated alternatives to individual lab work are considered. Film, video experiments, and also computer simulations can be also tried.

However, two important questions could be asked; first, are the pupils really enjoying the practical work the way it is currently done (the cookbook way) in the schools? Second, is it really effective in terms of the expected learning outcomes?

We have seen so far that learning in the laboratory situation may result in a state of working memory overload because of the large amount of information given at once. The overload also occurs when the learner is incapable of discriminating between the 'noise' and 'signal' in the laboratory instruction. Also overload arises due to the incidental information given by the teachers and demonstrators which contributes to an increase in 'noise' and becomes difficult for the learner to recognise the 'signal'. Further some laboratory manuals introduce unnecessary amount of information for the learner to cope with, thus adding to 'noise'.

The key, which the student needs to organise this flood of incoming information, is the very thing he is trying to learn. If only he knew this, he would be in a position to decide a) what was important and what was trivial; b) which measurement should be done accurately and which roughly; c) which observations were essential and which could be ignored; and d) what was vital relevant information and what was merely 'noise'. In a discovery situation we can borrow the language of the physicist and say that the 'signal' to 'noise' ratio can be very poor. The thing to be discovered is the essential technique, which is needed to reduce the 'noise' and enhance the 'signal'.

The previous argument has sought to question the notion that *learning* science itself is best approached by *doing* science in a laboratory. An *education* in science, rather than *training* in science, would see practical work and the 'doing' of science as only **one** element of the process of learning science, and a minor element at that. Yet the learning of science is not dependent on a practical offering for every lesson and there is much that can be done in a normal classroom with no or few facilities. Perhaps then it is time to think the unthinkable "*only radical surgery will do for a re-examination of the cultural sclerosis that predominates in the teaching of science where the adherence to the laboratory blocks progression in our pedagogy*". (Osborne, 1993).

So, let us re-think old ways!

CHAPTER FOUR

CHAPTER FOUR

EDUCATION IN THE SULTANATE OF OMAN

4.1. Development of education in Oman:

In Oman, before 1970 most children went to Qu'ranic schools, held under a tree, or in the local mosque. Pupils were taught Arabic and some numeracy in mixed classes and when they could recite the entire Qu'ran they left school. Although there was a school for girls for a brief period in the sixties, only boys - and just a privileged few of them- were able to attend one of the three formal primary schools in existence then. Because of the shortage of teachers and resources, after seven years of schooling the boys became infant teachers themselves. (The Scotsman, 2000).

Oman's renaissance beginning in 1970, led by H/ Majesty Sultan Qaboos Bin Sa'eed, saw the Sultanate launch a plan to develop the people's potentialities, abilities and trends of thinking, in order to prepare future generations. The people are now in the process of becoming aware of their potentialities in all areas of life.

Therefore, Education is the axis of this preparation and its main pillar. After just five years of this renaissance the following figures appeared in Oman:

- Number of schools had multiplied 70 times.
- Number of pupils had multiplied more than 60 times
- Number of student scholarships was 273.

The Omani curricula were first implemented in 1978/79 in the elementary and preparatory levels. The implementation was completed in the secondary level in 1983/1984. Nowadays, beside the Sultan Qaboos University, there are several colleges of different scientific areas (6 Colleges of Education, 5 Technical and Industrial Colleges, and a number of Health and Nursing Institutes) in addition to few private colleges for higher education.

Likewise, the number of public education schools has grown rapidly as the number of pupils has increased.

The language of numbers will not be denied, and the following table (4.1) is affirming this situation:

	94/95	95/96	96/97	97/98	98/99	Annual Growth %
Schools	926	935	967	958	968	1.1 %
Pupils (M)	243586	252466	259103	264573	271286	2.7 %
Pupils (F)	226263	236332	243571	249742	257071	3.2 %
Total Pupils	469849	488798	502674	514315	528357	3.0 %
Teachers	22740	24271	24646	25172	26104	3.5 %

(Source: Ministry of Education, Oman, 1998/99a)

Table 4.1: Development in numbers of schools, pupils and teachers in public Education between the academic years 1994/95 to 1998/99.

Just as the population of the schools in Oman has grown, so this has had a 'knock-on' effect on the demand of more school facilities and their use. Indeed the same can be said of the rest of other country education communities.

For example, Omani secondary schools have seen a rise in total numbers from 135 in 1994/95 to 177 in the academic year 1998/99 (annual growth 7.0%). Similarly, for the secondary level has seen an increase in pupils numbers of just over 67.5% in the same period of time (1994/95: 59714 pupils, 1998/99: 88453 pupils at annual growth 10.0%) Figure (4.1) below shows the changes in the total number of pupils studying in Omani schools over the last five years, while figure (4.2) shows the change in the schools in the same period of time:

Academic year	1994/95	95/96	96/97	97/98	98/99
Primary	293642	297488	300707	300270	301281
Preparatory	116493	122457	125399	132918	138623
Secondary	59714	68852	76568	81127	88453

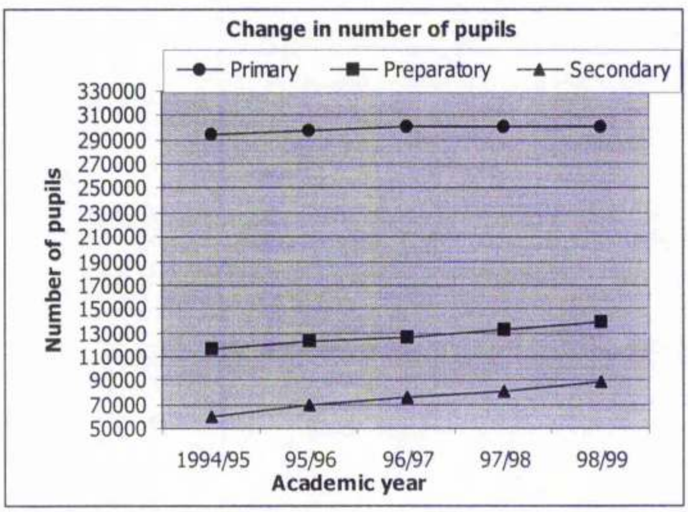


Figure (4.1) Change in number of pupils

Academic year	1994/95	95/96	96/97	97/98	98/99
Primary	356	347	338	318	294
Preparatory	435	458	470	472	497
Secondary	135	148	159	168	177

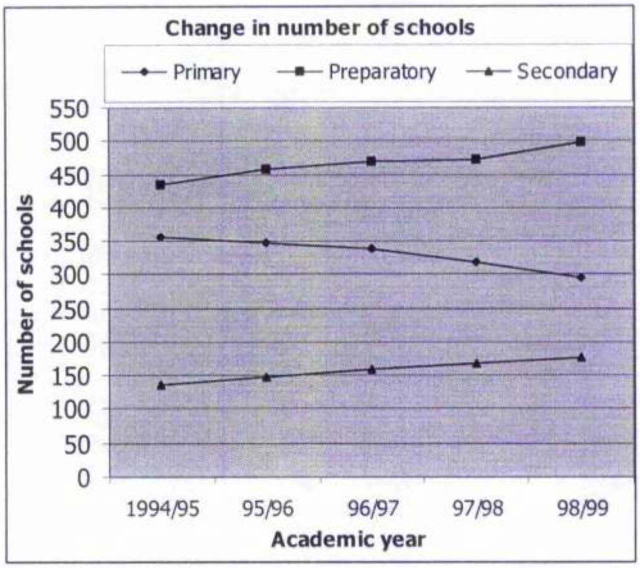


Figure (4.2) Change in number of schools

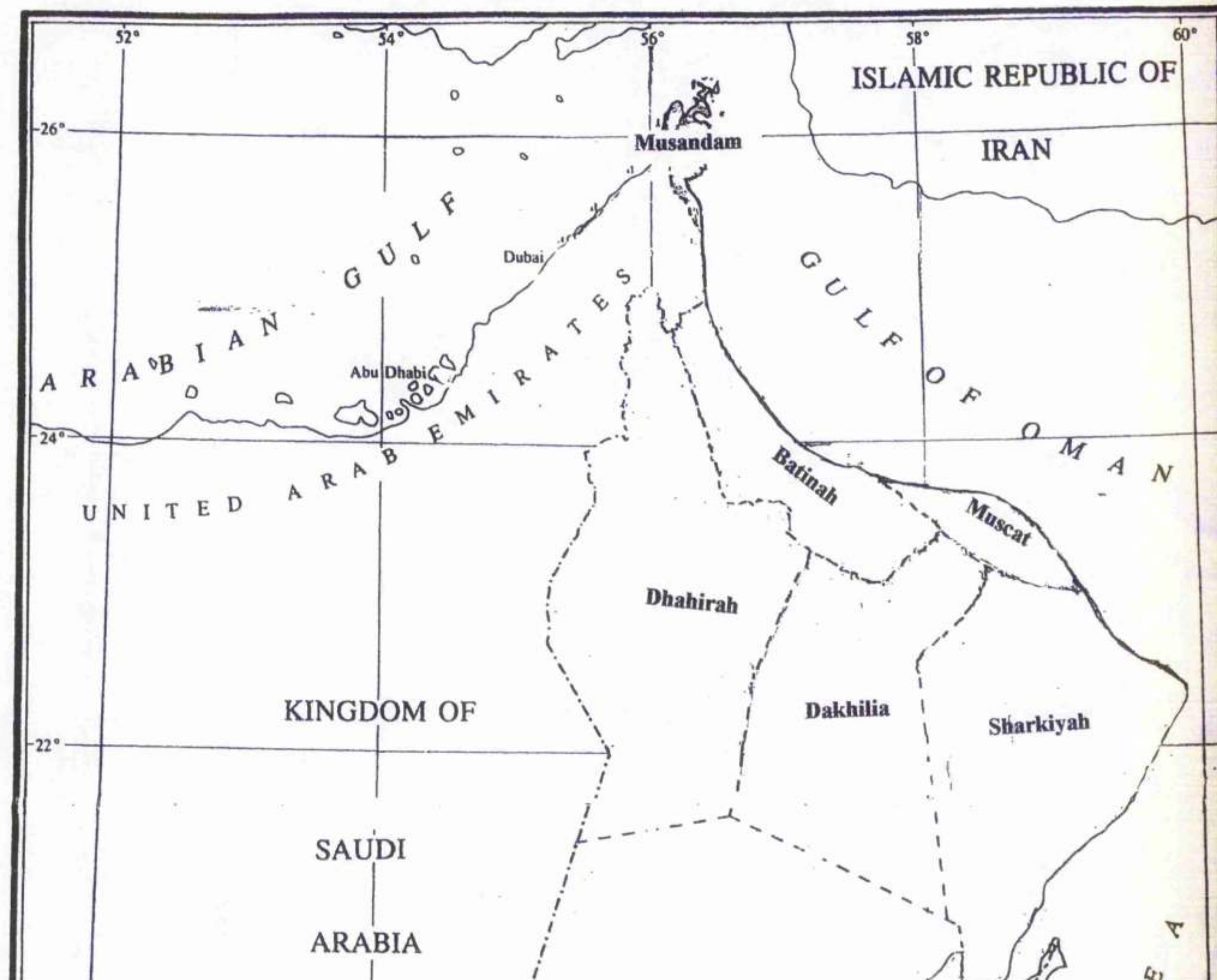
The reader may observe a gradual drop (annual growth = -4.7%) in number of primary schools during this period. That is because primary school is the one with years 1-6, and if the school open a class for year 7, it will shift to preparatory level. So under the continuous increase of pupils, schools will increase their classes to cover as many pupils as they can and to many different studying years as possible (the annual growth for preparatory schools is 3.4% and for secondary schools is 7.0%).

This change has led to an obvious problem; a strain on the school resources by the increased numbers entering the system, which was, originally intended for many fewer.

4.2. Educational Authorities in Oman

Geographically and in respect of Education, Oman has been divided in to eight regions (*County of Muscat, County of Dhofar, County of Musandam, Dakhilia, Batinah, Dhahirah, Sharkiyah, and Wusta*). The map provided (Figure 4.3) might give a simple impression of these educational authorities, which have been acted on by a general director. These authorities are responsible for the public schools in the area and their relevant academic and administrative issues.

SULTANATE OF OMAN



Produced by the Ministry of Information, September 1994

Based on National Survey Authority OR 1, edition 6 dated June 1994

This map is not an authority on international boundaries

4.3. Secondary School Science

Before going to the position of science in the Omani curriculum, it is worth looking at the structure of the educational system in Oman.

The Omani current educational system is similar to that adopted by many Arab countries, and, indeed, the majority of the Gulf States. Three years of preparatory education and three years of secondary education follow six years of primary education (Figure 4.4).

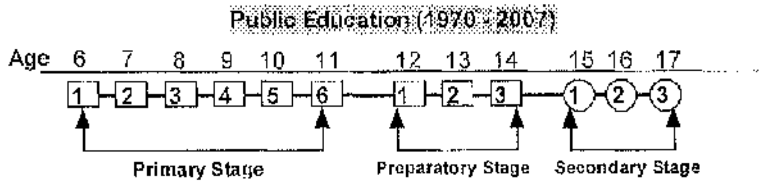


Figure (4.4): The present Omani Educational system

In the secondary school, a student may opt, after successful completion of the first year, to enter either the Arts stream, where the emphasis is on social and literacy studies, or the science stream where the sciences and mathematical subjects are taught. Students normally enter primary school at the age of six and complete the preparatory level at the age of 15. The first secondary year sees the first, and for many students the last, opportunity to study science as three separate disciplines (biology, chemistry and physics). Whether a student chooses the Arts stream or the Science stream determines the kind of science to which the student will be exposed in the final two years of school. The Arts stream studies a general science course while, in the Science stream, science continues to be taught as three separate subjects. (Al Busaidi, *et al.*, 1992)

The present situation of Education is relatively long in that, unlike many developed countries, pupils finish their secondary level at age 18. This system also allows pupils not to carry on studying and leaving schools searching for an employment. Therefore, Oman has adopted a new educational system, which started in the academic year 1998/1999 in 17 schools scattered in different parts in Oman. Figure (4.5) shows the studying levels in this Compulsory Education.

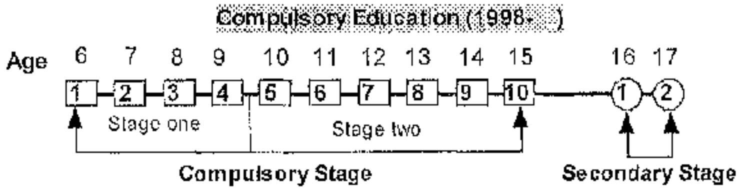


Figure (4.5): The Future Omani Educational system

Each one of the science syllabuses is split into chapters, which consist of specific topics according to the class level (Appendix 4.1).

The weight of science in the Omani curriculum is very light. For the preparatory stage of public Education pupils study five 40-minutes periods out of 30 periods (16.7%). At the secondary stage, the time allocated for each period is 45 minutes and the weight of science in the Science stream is as follows:

- Biology (4 lessons out of 34 lessons)(11.8%)
- Chemistry (4 lessons out of 34 lessons)(11.8%)
- Physics (5 lessons out of 34 lessons) (14.7%)
- Science in the Arts stream (2 lessons out of 34 lessons)(5.9%)

In addition to that, science is still suffering a deficiency of native science teachers so that the ministry of Education has to use expatriates. The table (4.2) below presents the number and ratio of science teachers distributed according to their gender and whether they are Omanis or not.

Nationality	Gender	Biology (%)	Chemistry (%)	Physics (%)
Omani	Male	21 (6.5 %)	9 (5.4%)	7 (1.3%)
	Female	96 (29.9%)	46 (27.7%)	54 (9.7%)
Expatriate	Male	138 (42.9%)	68 (41.0%)	276 (49.8%)
	Female	67 (20.8%)	43 (25.9%)	217 (39.2%)

(Source: Ministry of Education, Oman, 98/99a)

Table (4.2): Secondary science teachers for the year 98/99.

4.4. Practical work in secondary school science:

According to the ministerial legislation, there is a strong emphasis on doing practical activities in spite of some deficiencies schools might suffer from. Teachers are asked to use laboratories as much as they can. They are provided with a "teacher's guide book" which illustrates their plan in teaching at any particular level. Besides, pupils are provided with a separate laboratory manual stating materials, equipment, and procedures to be involved for each experiment. The manuals also contain questions to be answered (mainly in the form of gap filling questions, which ask the learner to write down a word or a simple sentence concerning their observations).

Since these manuals provides all required steps and procedures in the form of instructions, the pupils' role is only to follow blindly this recipe line by line and word by word to achieve an expected result which is pre-stated by either the textbook or the 'cookbook' manual.

What is more, many school experiments implicit in these manuals involve materials or equipment which schools lack or which exist in limited amount since the supplying of all materials and equipment depends mainly on the Ministry of Education with the exception of a few laboratory aids such as models, figures or charts which can be produced by the teachers or pupils in co-operation with teachers.

Besides this shortage of lab facilities, the huge numbers of pupils is presenting an obstacle for each learner to undertake experiments individually.

As we will see later, many schools have no room allocated for laboratory or this room, if found, might be used as a normal teaching room since there is a shortage of classrooms.

Over and above that, teachers are wilting under the heavy load and encumbrance of both academic and administrative duties and liabilities.

CHAPTER FIVE

CHAPTER FIVE

Methodology (I)

Establishing a base-line

5.1- Perception of practical work in Oman

5.1.1. Introduction:

In the last chapter, we glanced briefly the situation of practical work in Omani schools and noted the emphasis of the ministerial legislation in spite of some constraints on carrying out individual practicals.

But, how do both poles of the instructional process (the teacher and the learner) channel, perceive and comprehend practical work? What are pupils' views about it? How has it been carried out and how frequently is it achieved?

Such questions can be answered through questionnaires.

5.1.2. Aims of the survey:

This field research is attempting to investigate the following:

- ❖ To establish a base line on how the science teacher and the learner perceive practical work.
- ❖ To determine how often teachers carry out practical work in schools.
- ❖ To pinpoint any relevant constraints on doing practical work.

5.1.3. The Method of Research

A- Teachers'/Pupils' Questionnaires:

The method used here is a survey based on questionnaires. Two types of questionnaires were used to collect the data: a teachers' questionnaire and a students' questionnaire. The data to be collected from the latter are the opinions of students on practical work in their school science while the former is asking teachers about the way they carry out practical work and whether they are faced with any difficulties.

The researcher designed those two questionnaires using the following steps:

- ❖ Searching the literature related to the theoretical background of attitudes, opinions and views towards practical work as a main ingredient in science teaching.

- ❖ A few scales and attitudes measurements (both in Arabic and English) were compared to inform the designing questionnaires' statements.
- ❖ Then the first drafts of both questionnaires contained some statements presented positively and some negative statements were included to minimise guessing and careless responding.
- ❖ These drafts were then submitted to colleagues, in the Centre for Science Education, Glasgow University, for their comments.
- ❖ Specialists who gave some suggestions in adding, neglecting or redesigning of some statements then rechecked the questionnaires.
- ❖ The final drafts eventually appeared and were ready to apply and administer in schools. (Appendices 5-1a and 5-1b)
- ❖ The researcher translated both questionnaires into Arabic. (Appendices 5-2a and 5-2b)
- ❖ With each questionnaire there was a preamble or preface, requesting co-operation and assuring that results would be confidentially treated to encourage unbiased responses. For that no names or numbers were requested.

Teachers' Questionnaire:

This questionnaire consisted of two parts (Table 5.1). Those who were involved in practical work filled in part (A). It asked them to determine whether they agreed with some activities teachers may do before, during and after a demonstration to make it effective. On the other hand, those who were not involved in practical work were told to ignore part (A) and go to part (B) to describe and justify reasons and difficulties for not doing laboratory work in their schools. Part (B) categorises difficulties in the laboratory itself, the school, the curriculum and the science teacher himself.

Table (5.1): Teachers' Questionnaire

Dear Teacher:

This questionnaire intends to survey the nature of practical work and demonstration and how they have been carried out in schools in the Sultanate of Oman. Please note:
1) If you are involved in practical work, please fill Part **A** only (ignore part B)
2) If you are **not** involved in practical work, please fill Part **B** only (ignore part **A**)

School: .... **Taught Classes:**..........................

Part A

To make your demonstration effective, there are some things you may do before, during and after.
A few are listed below. Please give your response.
We are interested in statistical aggregate, all information will be confidential and for research purposes only.

I- <u>Before Demonstration</u>, it is important to:

	Agree	Disagree
1. Give pupils the purpose of experiments and how they relate to the topics	☐	☐
2. Highlight the concepts pupils should pay attention to in experiments	☐	☐
3. Prepare in advance all required chemicals and apparatus to be used in experiments	☐	☐
4. Pre-test the experiments before starting laboratory sessions	☐	☐
5. Ensure that laboratory arrangements will allow pupils in the class to observe what is going on in experiments	☐	☐

Any additional comments
....

II- <u>During Demonstration</u>, to make it effective, it is necessary to:

1. Ensure that all pupils can follow and understand the experiments' procedure	☐	☐
2. Re-demonstrate when necessary and when pupils need further help or feel confused	☐	☐
3. Ask pupils to write their observations about the experiments	☐	☐
4. Allow pupils to participate in the experiment when possible	☐	☐

Any additional comments
....

III- <u>After Demonstration</u>, to make it effective, it is necessary to:

1. Ensure that the experiments have achieved the planned objectives	☐	☐
2. Create questions and discussions to promote understanding	☐	☐
3. Summarise the experimental results to help understanding	☐	☐
4. Encourage pupils to conduct some experiments themselves when possible to explore the real life of chemists	☐	☐

Any additional comments
....

Part B

You have indicated that you do not perform demonstration or practical.
This may be because of difficulties in your schools.
Give us your views by responding to the questions below.

We are interested in statistical aggregate, all information will be confidential and for research purposes only.

Difficulties:

1. Related to Laboratory

	Agree	Disagree
a) No laboratory is available in our school	☐	☐
b) There are inadequate laboratory materials (apparatus, equipment, chemicals) for experiments	☐	☐
c) Safety precautions are poor (ventilation, fire apparatus, first aid kits)	☐	☐
d) There is inadequate technician's support	☐	☐
e) The laboratory does not have adequate supplies of:		
I) Gas	☐	☐
II) Water	☐	☐
III) Electricity	☐	☐

Any additional comments ....

....

2. Related to School

a) The school does not have funds to finance laboratory requirements	☐	☐
b) There is no encouragement from the administration to make use of the laboratory for teaching	☐	☐
c) There is a deficiency in practical training programs for teachers	☐	☐
d) Classes are too large for laboratory work	☐	☐

Any additional comments ....

....

3- Related to Curriculum

	Agree	Disagree
a) Practical work marks have been disregarded in the final exams	☐	☐
b) Time allocated by school for teaching the subject is limited,	☐	☐
there is no extra time to run laboratories	☐	☐
c) There is no timetable allocated for the laboratory	☐	☐
d) Teachers are too busy teaching to have time to run laboratory sessions	☐	☐
e) Practical experiments are not compatible with what pupils have learnt or what they should comprehend	☐	☐
f) There is no emphasis by the curriculum on doing chemistry at the laboratory	☐	☐
g) Practical works gets in the way of theory and causes confusion	☐	☐

Any additional comments ....

....

4- Related to you as Science Teachers

a) I believe that the laboratory will not help my teaching of chemistry	☐	☐
b) I have not been trained to use apparatus or equipment in the laboratory	☐	☐
c) Since there is little emphasis on practical work, I lack experience in performing chemistry experiments	☐	☐
d) Unlike normal classes, I feel that pupils could get out of control in laboratories leaving little room for learning	☐	☐

Any additional comments ....

....

Thank you for co-operation

Pupils' questionnaire:

This questionnaire (Table 5.2) contained 18 statements of which twelve positive and six were negative statements (4,5,6,8,10 and 13). It was set out as a Likert scale of three fixed responses (agree, uncertain, disagree).

Teachers' sample selection:

These questionnaires were implemented in the *Dakhilia* Educational Region (*Chapter 4, Figure 4.3*) and the sample was selected to cover almost all secondary schools in that area in April in the academic year 1997/1998.

The initial teachers' sample consisted of 100 teachers, who were selected randomly, from those who are using, or are supposed to use, the laboratory in science teaching. However, 7 returns were rejected as they were either not complete or contained careless responses leaving 93 completed questionnaires (59% male). 70 of them answered part (A) while 23 teachers addressed part (B) of the questionnaire.

Students' sample selection:

- This sample contained 997 pupils from 20 different schools and were selected randomly from both genders who are studying in 3rd preparatory, 1st and 2nd secondary (year 9,10 and 11 respectively).
- The questionnaire was applied in the presence of the researcher himself to clarify any ambiguous points or answer any query which may arise. In addition, the chemistry teachers (or the headmaster) did not to attend the class at the time of answering the questionnaire in order to eliminate any bias in favour of the teacher or the school administration.
- The time allocated was 15-20 minutes, which proved to be ample for all pupils.
- 20 questionnaires were discarded as they were answered in a frivolous way. The yield was 977 questionnaires.

Table (5.2): Pupils' Questionnaire

Dear Pupil:

This questionnaire intends to identify your opinion about practical work and to what extent it would meet your curiosity. Please answer as many statements as you can.

Your answer will never affect your school work or exams in any way.

The questionnaire's results are for research purposes only.

School : .... **Class :** ....

Statement	Agree	Uncertain	Disagree
1- The teacher explains in advance the general purposes of each experiment	☐	☐	☐
2- The teacher marks my lab book after lab sessions	☐	☐	☐
3- Teachers use a variety of equipment in the laboratory (e.g. OHP, TV, Video, etc) to promote our understanding	☐	☐	☐
4- The teacher solely controls laboratory sessions leaving no rooms for us to participate	☐	☐	☐
5- Laboratory work never helps my understanding of chemistry topics	☐	☐	☐
6- I prefer a revision session for any chemistry topic, rather than attending a laboratory session about it	☐	☐	☐
7- Laboratory sessions assist me to understand complicated topics in chemistry	☐	☐	☐
8- I feel that laboratory requirements (e.g. measurements, manipulations, etc) are difficult to cope with	☐	☐	☐
9- Laboratory discussions (pupil-pupil, teacher-pupil) are helpful and could enhance my understanding	☐	☐	☐
10- School examinations disregard any laboratory experiments (marks)	☐	☐	☐
11- I believe that the laboratory is a vital part in learning chemistry	☐	☐	☐
12- I feel more interested in chemistry when doing practical experiments in the laboratory	☐	☐	☐
13- I feel that I gain little from experiments since they are higher than my school level	☐	☐	☐
14- Laboratory sessions are well organised and well prepared	☐	☐	☐
15- We made numerous laboratory sessions this year	☐	☐	☐
16- I feel that the laboratory is the means for verifying the theory	☐	☐	☐
17- The laboratory shows me how chemists deal with real life scientific problems	☐	☐	☐
18- The laboratory teaches me how to go about solving problems	☐	☐	☐

Comments :

Thank you for co-operation

B- School visits:

The researcher, to identify the situation of the laboratory and the limitations of carrying out lab activities in schools, had visited 21 schools. Besides, several technicians from both genders were met and asked to indicate any compulsion and restriction related to undertaking laboratory activities and they were also encouraged bring out any suggestions or hints they wished to appear. The researcher also had a look at the equipment, chemical and safety precautions available in schools. Moreover, he ensured the availability of an overhead projector (OHP) and the possibility of building the proposed device (*Next chapter*).

5.1.4. Surveying the aims of practical work

Introduction

Chapter 3 Section 3 has given a wide range of aims for doing practical work in science teaching. These aims cover the three areas of the Bloom taxonomy, which are the cognitive, affective and psychomotor domains. Some writers suggest that the essential ingredient of practical work is to allow pupils to learn how to conduct an investigation. This survey covered three groups of people involved in Science Education (Teachers, Teacher Trainers and Inspectors).

Aims of the survey:

This survey based on questionnaires was trying to investigate:

- the opinions and views of teachers, teacher trainers and inspectors towards a list of aims of doing practical work
- to what extent it is been achieved by the teachers in schools.
- to what extent these aims are considered in pre-service training.
- whether teachers are assessed in achieving these aims.
- the existence and the nature of work which allowed pupils to do investigative activities.

Questionnaires:

These three questionnaires (appendices 5-3a, 5-3b and 5-3c) consisted of two sections; the first section contained a series of statement about practical work gathered from a large sample of teachers who had previously responded to researcher in the Centre for Science Education, Glasgow University. It asked the respondent to give his view on them in the first column. In the second column, teachers were asked to indicate if they are achieved in practice in their classes while teacher trainers were asked to determine if they let teachers practice them. Inspectors were asked to decide whether they assess teachers on achieving them in schools or not.

The second section, however, is an open statement where the respondent could justify doing investigative work, not doing it or even disagreeing with it as principle.

Sampling:

Teachers' sample selection:

The sample was 115 teachers of both genders from the schools of *Dakhlia* region where the research was localised.

Almost all responses were accepted despite the fact that a few teachers ignored the second part of the questionnaire.

Teacher trainers' sample selection:

This sample covered the entire teacher training institutions in Oman (The 6 colleges of Education in *Salalah, Sohar, Sur, Ibri, Rustaq* and *Nizwa* and the College of Education at Sultan Qaboos University in the capital *Muscat*).

The respondents were those who teach science education syllabuses in these colleges and are responsible for providing pre-service training for future teachers. They total 23.

Inspectors' sample selection:

With the exception of *Musandam* and *Al Wusta* regions, this sample covered the whole area of Oman. All of this required the researcher to travel a lot using both land and air to reach the remote areas such as *Salalah*. These efforts resulted in a total number of 51 inspectors.

5.2. Analysing, Interpreting and Discussing the Data

5.2.1. Introduction

In this section, results of all previous instruments and research methods used will be analysed and discussed. We will go through them in the order they were described above and will be interpreted in general as a whole with light details where necessary.

5.2.2. Perception of the nature of practical work in Oman.

To identify how practical work is perceived by the educational institution members in Oman, several methods were employed.

What should be mentioned here is that, due to the country's philosophy, Oman has school of only a single sex. But, for the purpose of aggregate statistical analysis, we will ignore the gender and treat data as a whole since examinations of responses from both genders showed no differences.

Teachers' Questionnaire

Firstly, and in order to determine how practical work is carried out in Omani schools, a questionnaire (Table 5.1) of two parts was applied for 93 teachers of both genders. Part (A) was answered completely by 70 of them and 23 sheets addressed part (B). Results of both parts (A and B) were calculated as frequencies and then converted to percentages indicating to what extent teachers agree or disagree with certain statements.

Responses for part (A) of this questionnaire can be concluded as follows:

Number	Statement	Agreement %
1. Before demonstration, it is important to:		
1.1	Give pupils the purpose of experiments and how they relate to the topic	96
1.2	Highlight the concepts pupils should pay attention to in experiments	94
1.3	Prepare in advance all required chemicals and apparatus to be used in experiments	100
1.4	Pre-test the experiments before starting laboratory sessions	89
1.5	Ensure that laboratory arrangements will allow all pupils in the class to observe what is going on in experiments	90
2. During demonstration, to make it effective, it is necessary to:		
2.1	Ensure that all pupils can follow and understand the experiments' procedure.	96

2.2	Re-demonstrate when necessary and when pupils need further help or feel confused	81
2.3	Ask pupils to write their observations about the experiments	100
2.4	Allow pupils to participate in the experiment when possible	100
3. After demonstration, to make it effective, it is necessary to:		
3.1	Ensure that the experiments have achieved the planned objectives	100
3.2	Create questions and discussions to promote understanding	93
3.3	Summarise the experimental results to help understanding	91
3.4	Encourage pupils to conduct some experiments themselves when possible to explore the real life of chemists	97

Table (5.3): Teachers' responses to part (A).

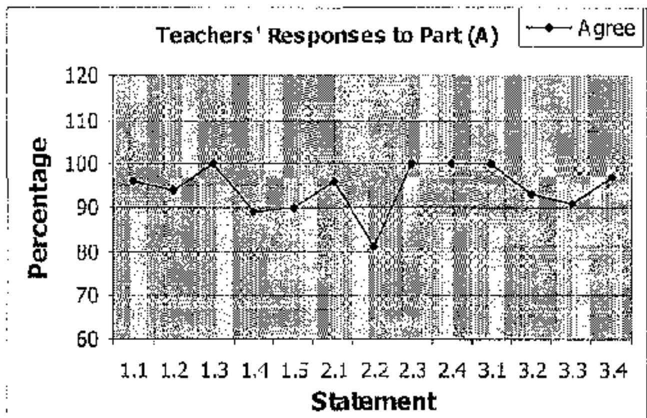


Figure (5.1): Teachers' responses to part (A)

From the figure (5.1) above, it can be seen that almost the whole sample agree with the all statements describing activities teachers should be put into practice whilst demonstrating. Four statements meet with full agreement and become first in their ranked order, as these are either obliging teachers to do, or teachers might exaggerate their work since this is the way they are expected to do.

These four statements are:

- ❖ preparing in advance all required chemicals and apparatus to be used in experiments.
- ❖ asking pupils to write their observations about the experiments.
- ❖ allowing pupils to participate in the experiment when possible.
- ❖ ensuring that the experiments have achieved the planned objectives.

However, there is still some slight disagreement with those statements. They could be traced to the lack of timing and materials required for doing such activities such as pre-testing, re-demonstrating or re-arranging class.

Overall, this leads to the fact that demonstration is widely accepted by most teachers in Oman, and is being carried out in the way existing conditions allow regardless of some weakness associated with it, which TOPs (the method which will be explained next chapter) may overcome up to a point.

On the other hand, Part (B) of this questionnaire concerning difficulties related to practical work showed that some teachers do not do any type of practical work, confining themselves to lecturing. 23 returns were answering this part, 4 females and 19 males. They indicated that they perform neither individual experimenting nor demonstration.

Likewise, the following table (5.4) and Figure (5.2) show total responses of these teachers as a whole.

Number	Statement	Agreement %
1. Difficulties related to laboratory		
1.a	No laboratory available in our school	30
1.b	There are inadequate laboratory materials for experiments	87
1.c	Safety precautions are poor	39
1.d	There is inadequate technician's support	17
1.e.i	The laboratory does not have adequate supplies of	13
1.e.ii	The laboratory does not have adequate supplies water	13
1.e.iii	The laboratory does not have adequate supplies electricity	17
2. Difficulties related to school		
2.a	The school does not have funds to finance laboratory requirements	30
2.b	There is no encouragement from the demonstration to make use of the laboratory for teaching	4
2.c	There is a deficiency in practical training programs for teachers	52
2.d	Classes are too large for laboratory work	74
3. Difficulties related to curriculum		
3.a	Practical work marks have been disregarded in the final exams	61
3.b	Time allocated by school for teaching the subject is limited, there is no extra time to run laboratories	43
3.c	There is no timetable allocated for the laboratory	65

3.d	Teachers are too busy teaching to have time to run laboratory sessions	74
3.e	Practical experiments are not compatible with what pupils have learnt or what they should comprehend	26
3.f	There is no emphasis by the curriculum on doing chemistry at the laboratory	26
3.g	Practical work gets in the way of theory and causes confusion	26
4. Difficulties related to the science teachers		
4.a	Teachers believe that the laboratory will not help their teaching of chemistry	6
4.b	Teachers have not been trained to use apparatus or equipment in the laboratory	13
4.c	Since there is little emphasis on practical work, teachers lack experience in performing chemistry experiments	30
4.d	Unlike normal classes, teachers feel that pupils could get out of control in laboratories leaving little room for learning.	17

Table (5.4): Teachers' responses to part (B)

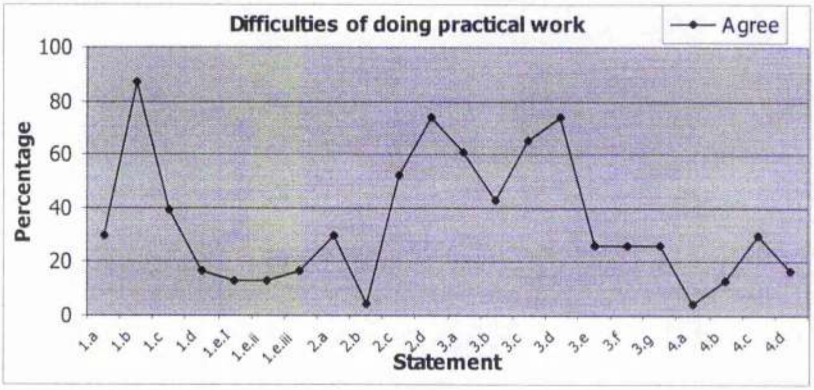


Figure (5.2): Teachers' responses to part (B)

According to the results above, difficulties can be categorised into four groups:

1. Difficulties reported by 60% or more include:
   - *inadequate laboratory materials (87%)*
   - *classes which are too large for laboratory work (74%)*
   - *teachers are too busy teaching to have time to run laboratory session (74%)*
   - *no timetable allocated for the laboratory (65%)*
   - *practical work marks have been disregarded in the final exams (61%)*

2. Difficulties with moderate reporting 35-59% include:
   - ❖ *time allocated by schools for teaching the subject is limited and so there is no extra time to run laboratories (57%)*
   - ❖ *a deficiency in practical training programs for teachers (52%)*
   - ❖ *poor safety precautions (ventilation, fire apparatus, first aid kits) (39%)*
3. Difficulties reported by fewer than 35% include:
   - ❖ *no laboratories are available in the schools (30%)*
   - ❖ *schools do not have funds to finance laboratory requirements (30%)*
   - ❖ *teachers lack experience in performing chemistry experiments (30%)*
   - ❖ *prescribed experiments are not compatible with what pupils have learnt or what they should comprehend (26%)*
   - ❖ *no emphasis by the curriculum on doing chemistry at the laboratory (26%)*
   - ❖ *practical work gets in the way of theory and causes confusion (26%)*
   - ❖ *inadequate technicians' support (17%)*
   - ❖ *lack of pupils control in laboratories leaving little room for learning (17%)*
   - ❖ *laboratories do not have an electricity supply (17%)*
   - ❖ *laboratories do not have a gas supply (13%)*
   - ❖ *laboratories do not have a water supply (13%)*
   - ❖ *teachers have not been trained to use apparatus or equipment in the laboratory (13%)*

The final two difficulties teachers indicated were that:

- ❖ teachers believe that laboratory work will not help their teaching of chemistry (9%)
- ❖ the school's administration does not encourage the use of the laboratory for teaching (4%)

Pupils' Questionnaire

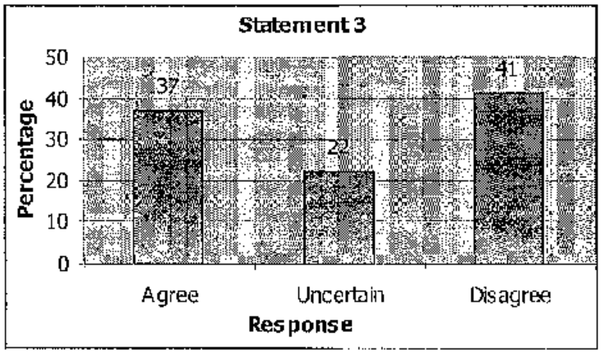
This 18-statement questionnaire was given to about a thousand (997) secondary pupils studying in the year 1998/1999 to give their responses of three options, i.e. they were asked to determine whether they agree, disagree or are uncertain about each statement. 977 sheets (56% male) were analysed and frequencies were plotted as percentage. The results are shown in table (5.5) below.

Number	*Statement*	*Agreement %*
1	*The teacher explains in advance the general purpose of the each experiment*	89
2	*The teacher marks my lab book after lab sessions*	76
3	*Teachers use a variety of equipment to promote pupils' understanding*	36
4	*The teacher solely controls laboratory sessions leaving no room for pupils to participate*	36
5	*Laboratory work never help pupils' understanding of chemistry topics*	11
6	*Pupils prefer a revision session for any chemistry topic, than attending a laboratory session about it*	25
7	*Laboratory sessions assist pupils to understand complicated topics in chemistry*	73
8	*Pupils feel that laboratory requirements are difficult to cope with*	34
9	*Laboratory discussions are helpful and could enhance understanding*	90
10	*School examinations disregard any laboratory experiments (marks)*	38
11	*Laboratory is a vital part in learning chemistry*	91
12	*It is an interesting thing to do practical experiments in the laboratory*	74
13	*Pupils gain little from experiments since they are at a higher level*	18
14	*Laboratory sessions are well organised and well prepared*	56
15	*Pupils made numerous laboratory sessions that year*	42
16	*Laboratory is the means for verifying the theory*	84
17	*Laboratory shows how chemists deal with real life scientific problems*	60
18	*Laboratory teaches how to go about solving problems*	51

Table (5.5) Pupils' opinions about practical work

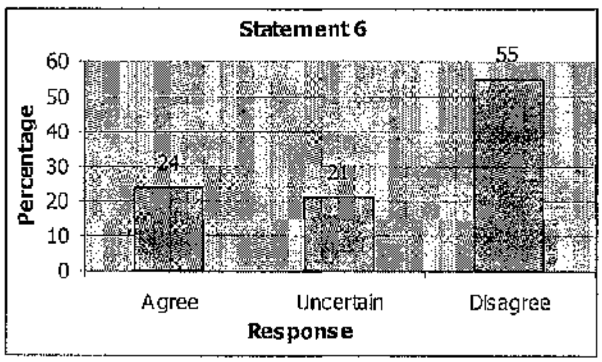
Responses indicated that pupils regarded practical work as one of the main ingredients in science, and as the vehicle of verifying theory. However, they did not express concern over some things teachers do whilst doing practical work, such being as dominant or not allowing any pupil participation. They also disagreed that experiments were disregarded in school examinations. A few statements meet with ambivalent responses spread between agreement, being uncertain and opposition. These responses need closer examination.

Statement 3: teachers use a variety of equipment in the laboratory to promote pupils understanding.



This depends to equipment available at schools. The location of school may affect that. Urban schools usually have different instructional equipment, OHP, coloured overlays, videos, TVs whereas rural schools mostly have none of this technology with the exception of normal OHP with manually produced overlays.

Statement 6: pupils prefer a revision session for any chemistry topic, rather than attending a laboratory session about it.

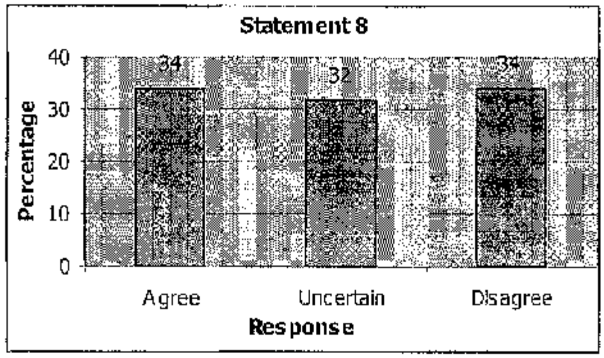


This statement might be justified in two ways:

- Unlike the situation in Britain where one room can do both jobs of lecturing and be as a laboratory, the classroom in Oman is used to teach all subjects and the teacher moves between classes and there is a special theatre devoted for practical activities. Some schools have not got a room allocated for a lab, which means their classroom is used for both lecturing and lab sessions, so there is no difference. They might prefer to stay on their chairs rather being asked to share in the activity or answer a question in a discussion during and after the activity.

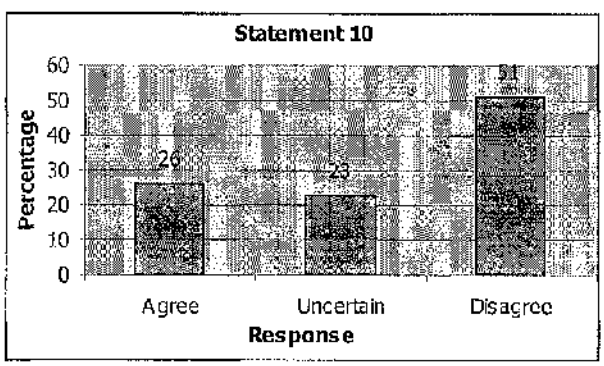
- ❖ Some teachers mainly choose particular pupils (pupils in the front row or star pupils those with higher school grade) to participate whereas some pupils have to stay passive during lab session.

Statement 8: pupils feel that lab requirements (e.g. measurements, manipulations, etc.) are difficult to cope with.



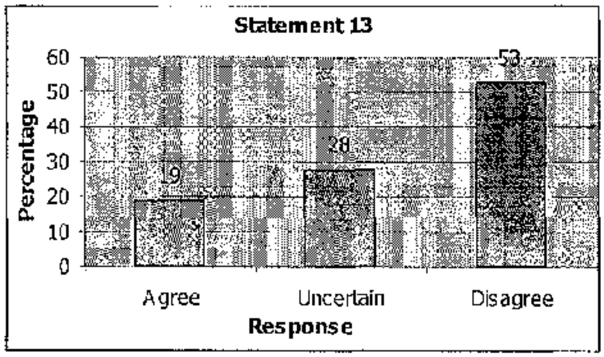
Despite being explained by the researcher while applying the questionnaire, this statement might be still difficult to be understood by the 15-16-year-olds pupils. Lab requirements might be interpreted as planning, designing and following experimental procedures, and pursuing conclusions and findings. Some pupils have never been to any lab to deal with its requirements. Even when they visit the laboratory (statement 15), there is still no participation for the pupils (statement 4) and teachers, only, control lab sessions. Those pupils who get a chance to deal with lab requirements can cope with them since most basic requirements are met at home such as reading balances, weighing, adding, mixing, pouring water and so on.

Statement 10: school examinations disregard any laboratory experiments (marks)



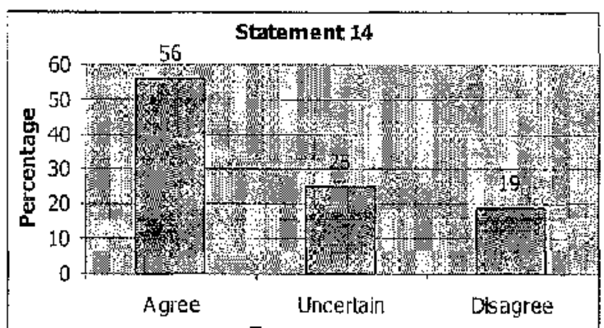
Although there is 5% of the chemistry total mark devoted for practical work, some teachers (about one quarter in this study) use this percentage in unfair ways. They allocate the marks for being polite and silent whilst the teacher is conducting the activity, or teachers run theoretical lab examinations assessing pupils knowledge in experiments they did.

Statement 13: pupils feel that they gain little from experiments since they are higher than pupils school level



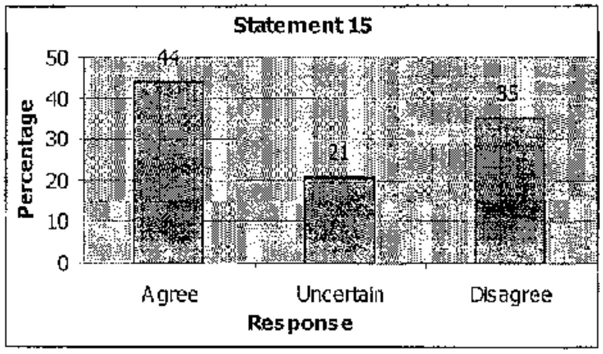
About one half of the pupils are uncertain or agree about gaining little from experiments since they are pitched higher than their school level. This is due to the lack of a laboratory or because of carrying out lab sessions in the way which does not engage the learners or because teachers throw off this responsibility because of the other duties which teachers have to perform (teachers' questionnaire, part (B))

Statement 14: laboratory sessions are well organised and well prepared



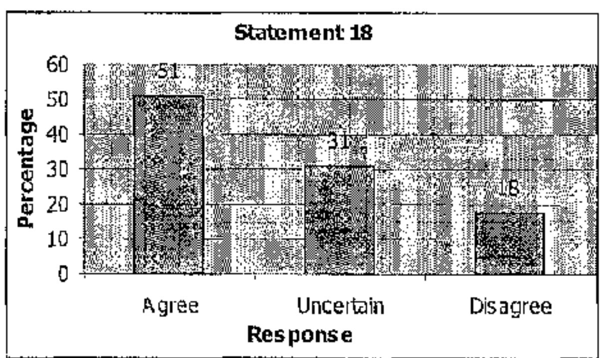
If we consider uncertain pupils to be those who have not been to any lab, we still have about one fifth of all pupils not happy about lab arrangements and organisation. This is because of numerous teachers duties and encumbrances and the heavy demand on the lab each day (quite often there is only one room devoted as a laboratory and allocated for about 25-30 classes in a school)

Statement 15: pupils made numerous laboratory sessions that year



Based on the previous statement, we expect a shortage or even absence of lab visits especially in male schools. Furthermore, there are some external reasons why pupils do not go to lab. One of them is that chemistry syllabuses are mainly theoretical due to insufficiency of experiments available. Secondly, where a laboratory exists there might be a deficiency in chemicals and equipment (see teachers' questionnaire part B). In addition, the many duties of teachers force them to deprive pupils of practical work. Finally, and as a consequence of the difficulty of controlling boys in a laboratory, teachers skip laboratory to avoid class anarchy.

Statement 18: the laboratory teaches pupils how to go about solving problems.



Again, it might be difficult for pupils to understand the meaning of this statement clearly. This may explain why 31% of the sample are uncertain. In addition, some pupils disagree with this statement because lab sessions do not include the way to go about solving scientific problems. That is because laboratory sessions might not be well prepared (statement 14) or experiments maybe pitched higher than pupils school level (statement 13).

Generally, whereas this questionnaire contains both positive and negative statements, the negative responses should be turned to be positive in order to present results into one figure (5.3), which give a general picture of the responses to the questionnaire statements.

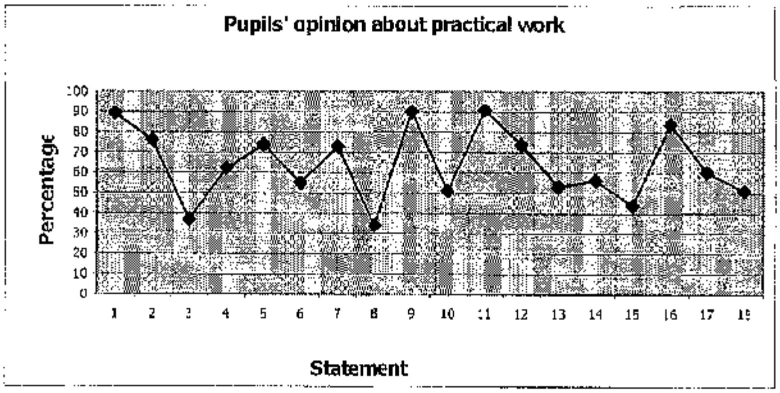


Figure (5.3): Pupils' opinions about practical work

Likewise, we can categorise responses into three main groups:

1. Strong agreement (60% and more) and this includes:
   - ❖ that the laboratory is a vital part in learning chemistry (91%)
   - ❖ laboratory discussions are helpful and could enhance understanding (90%)
   - ❖ the teachers explain in advance the general purposes of each experiment (89%)
   - ❖ laboratory is the means for verifying the theory (84%)
   - ❖ the teachers mark lab book after lab sessions (76%)
   - ❖ pupils feel more interested in chemistry when doing practical experiments in the laboratory (74%)
   - ❖ laboratory work never help pupils' understanding of chemistry topics (74%) [negative statement, response turned]
   - ❖ laboratory sessions assist pupils to understand complicated topics in chemistry (73%)
   - ❖ the teacher solely controls laboratory sessions leaving no room for pupils to participate (62%) [negative statement, response turned]
   - ❖ the laboratory shows pupils how chemists deal with real life scientific problems (60%)
2. Moderate agreement (35-59%) on the following statements:
   - ❖ laboratory sessions are well organised and well prepared (56%)

- ❖ pupils prefer a revision session for any chemistry topic rather than attending a laboratory session about it (55%) [negative statement, response turned]
- ❖ pupils feel that they gain little from experiments since they are higher than their school level (53%) [negative statement, response turned]
- ❖ laboratory teaches pupils how to go about solving problems (51%)
- ❖ school examinations disregard any laboratory experiments (marks) (51%) [negative statement, response turned]
- ❖ pupils made numerous laboratory sessions that year (42%)
- ❖ teachers use a variety of equipment in the laboratory to promote pupils understanding (37%)

3. low agreement (35%) with the following statement:
   - ❖ Laboratory requirements are difficult to cope with (34%) [negative statement, response turned]

5.2.3. School visits

Whilst visiting school laboratories and talking to **technicians**, the following points arose:

- ❖ Most schools have a room allocated as a laboratory. The few, which do not (3 out of 21), were constructed at the beginning of the Oman renaissance (1970) or the laboratory is used as a classroom.
- ❖ Some secondary schools have two laboratories whereas some of them have only one.
- ❖ Most schools are of two daily sessions (morning 7.30 – 13.00, and afternoon 13.15 – 17.30). The same school operates on two shifts i.e. some pupils are morning only and some afternoon only. These two sessions usually share one technician and sometimes one laboratory theatre. For instance, only one lab theatre (recently two) and one lab technician served a school of about 900 pupils in the first session and 1100 pupils in the second.
- ❖ The lab theatre has a capacity of 35-45 pupils and has 4-8 benches. Each bench commonly has a supply of :

  i- 4 gas points.

  ii- 2 water supplies (2 sinks)

  iii- 2 electrical sockets.

- Most labs have a fume cupboard, 1 fridge, 2 air conditioners, 2-5 fire extinguishers (2-3 water and 1-2 powder) and infrequently a first aid kit and all this with no regular maintenance.
- Gas points are supplied from gas cylinders since there is no central gas supply.
- Almost all schools have an overhead projector OHP (HP-L14).
- Nearly all laboratories lack chemicals and apparatus required for various experiments.
- Supplying of chemicals, equipment or apparatus seldom occurs during the term with the exception of the beginning of the academic year. This supply is subject to sending a letter requesting in details the amount (quantity) of each item while enclosing another report about the amount of any chemical used during the past year.
- In case of breaking an apparatus or spillage of a chemical, the teacher is requested to fill in a form of explanation.
- Technicians can informally borrow deficient chemical and equipment from nearby schools for a certain period of time.
- Teachers usually carry out practical activities in the form of demonstration mainly in the lab theatre and sometimes in the classroom.
- 25-30 classes (per time session) share not more than two laboratory theatres. This makes the technician (generally one) fully occupied for the whole day and the lab, consequently, has to be booked 2-3 days in advance.
- Since it is the largest room in the school, the lab theatre can be used for meetings or lecturing by a visitor (mainly health visitors) as this require as many pupils as possible to attend. And thus no lab session is available for 2-3 hours.

5.2.4. Perception the aims of practical work

Introduction

This survey covered three groups of people involved in Science Education (School Teachers, Teacher Trainers and Inspectors). It addressed the views and opinions of respondents as to how practical work seemed to them.

The questionnaires

The following table (5.6) summarises results obtained from these groups for the first section of the questionnaire (the fixed-response-closed statements).

Table (5.6): Responses upon statements describing the aims behind doing practical work

Inspectors (n=51)				Teacher trainers (n=23)				Statement	Teachers (n=115)			
Agreement		Assessment		Agreement		Training			Agreement		Achievement	
Agree %	Disagree %	Yes %	No & No Response	Agree %	Disagree %	Yes %	No & No Response		Agree %	Disagree %	Yes %	No & No Response
94	6	75		78	22	74		To instill confidence in science	97	3	96	
100	0	94		96	4	96		To learn basic practical skills	100	0	91	
92	8	92		87	13	83		To familiarize with important standard apparatus and measuring techniques	99	1	93	
100	0	98		100	0	100		To illustrate materials taught in lectures	100	0	98	
100	0	98		100	0	100		To train in observations	100	0	98	
100	0	96		100	0	100		To train in making deductions from measurements and interpretations of experimental data	100	0	97	
94	6	78		96	4	96		To use experimental data to solve specific problems	92	8	90	
65	35	57		70	30	65		To learn some theoretical materials not taught in lectures	66	34	59	
80	20	78		83	17	83		To foster a critical awareness (e.g. extraction of all information from the data; the avoidance of systematic errors)	79	21	76	
100	0	96		100	0	100		To help bridge the gap between theory and practical	100	0	98	
98	2	86		91	9	91		To stimulate and maintain interests in science.	99	1	97	

In this table (5.6), there is a series of statements describing some aims of practical work. Alongside each statement, there are two columns for each group, in the first column, the respondents were asked to indicate whether they agree or not with each statement. In the second column, teachers were asked to indicate if they achieved them or not, inspectors should also indicate whether they assessed teachers on achieving these aims whereas the trainers were questioned if they trained future teachers on how to achieve these aims.

From the researcher's point of view, through observation and frequent site visits to schools, the reality of achieving these statements is just wishful thinking. This is idealism since it may not even be attained in Scottish schools. This is attested by the researcher who attended many practical lessons and saw the real situation. So, we can affirm that these results contain an element of exaggeration. It is not easy to carry out these noble aims and fulfil them in such circumstances and situations fully, with so many stumbling blocks in the way of practical work. Self-reporting is not always true and valid, unless it is associated with another assessment or evaluation by an independent party. However, this does not preclude discussion and interpretation of the data.

In order to compare, the mean scores of the agreement percentages were computed for each statement. These means were then subtracted from the agreement percentage that each group gave for each aim. Paired data points for each aim were then plotted for paired sets of data, teachers against teacher trainers, inspectors against teacher trainers and teachers against inspectors. The results are shown in Figures (5.4, 5.5 and 5.6).

Teachers and teacher trainers groups:

Statement	1	2	3	4	5	6	7	8	9	10	11
Teachers	7	1	6	0	0	0	-2	-1	-2	0	3
Trainers	-16	-3	-10	0	0	0	2	3	2	0	-5

Table (5.7): Standard deviation of the total mean score (Teachers & Trainers)

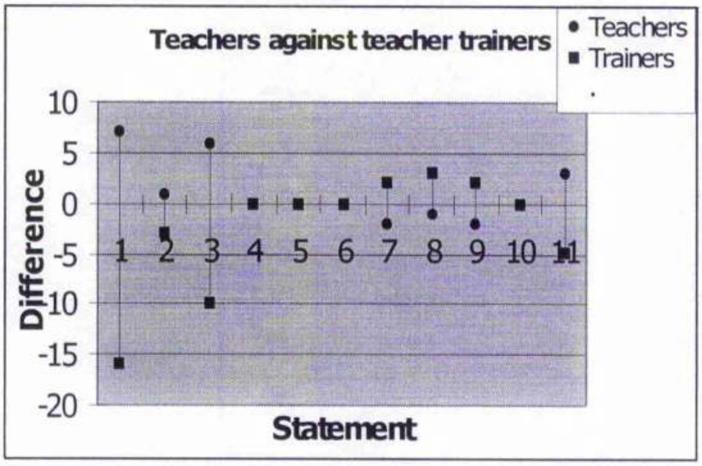


Figure (5.4): Standard deviation of the total mean score (Teachers & Trainers)

In spite of statements 4,5, and 6, there is some difference between the agreement of school teachers and teacher trainers group to the statement. The teachers group tends towards importance and "nobility" of doing practical work. They also reported that they achieved these aims to a large extent. Unlike trainers, they believed that practical activities could efficiently instil confidence in science and familiarise pupils with important apparatus and measuring techniques. They also highlighted the importance of practical in stimulating interest in science perhaps forgetting some other significant aims of practical works. The trainers group broadly agreed, in using experimental data to solve specific problems and learning some theoretical materials not taught in lectures.

Inceptors and teacher trainers groups

Statement	1	2	3	4	5	6	7	8	9	10	11
Inspectors	4	1	-1	0	0	0	0	-2	-1	0	2
Trainers	-16	-3	-10	0	0	0	2	3	2	0	-5

Table (5.8): Standard deviation of the total mean score (Inspectors & Trainers)

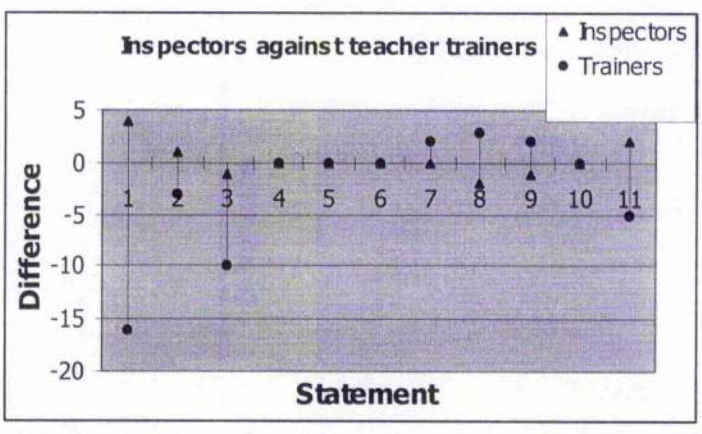


Figure (5.5): Standard deviation of the total mean score (Inspectors & Trainers)

Again for statements one and three, there is a difference between these two groups, but the variation between this pair 5 less than in figure (5.4). They are almost agreed in the rest of the stated aims with exception of the idea that practical work stimulates interest in science, teachers trainers have some objection and are more sceptical.

Teachers and inspectors groups

Statement	1	2	3	4	5	6	7	8	9	10	11
Teachers	7	1	6	0	0	0	-2	-1	-2	0	3
Inspectors	4	1	-1	0	0	0	0	-2	-1	0	2

Table (5.9): Standard deviation of the total mean score (Teachers & Inspectors)

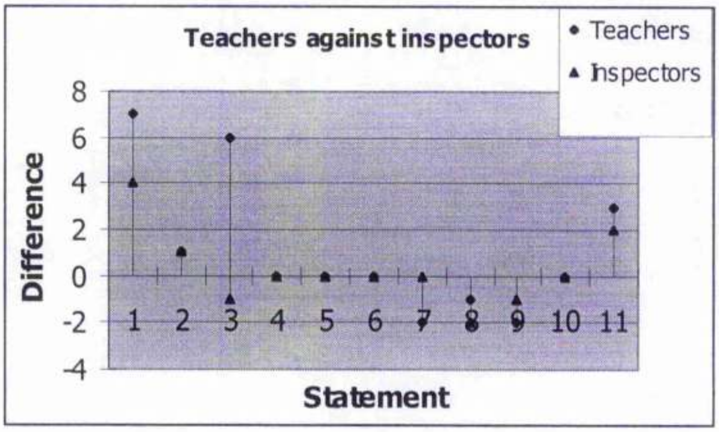


Figure (5.6): Standard deviation of the total mean score (Teachers & Inspectors)

Since members of these two groups have more interaction than other pairs, their responses would be anticipated to be the same to a considerable extent. With the exclusion of "*practical work familiarises learners with important apparatus and measuring techniques*", which teachers largely agreed on, all aims met almost the same degree of agreement in this group. Their responses reflect their similar ideas about practical work and this could be justified in that the inspectors group is the authority responsible for in-service training for schools teacher whereas trainers group is the body for preparing future teachers and offering pre-service training. It could also be that teachers are dominated by inspectors and have to "follow the party line".

However, the data presented above has focused on the differences between the agreement on some stated aims of practical work as seen by school teachers, teachers trainers and teacher inspectors. It is now important to turn to some similarities between the aims expressed by the three groups. The four aims given the same response and with no difference from the percentage mean are as follows:

- ❖ To illustrate materials taught in lectures
- ❖ To train in observations
- ❖ To train in making deductions from measurements and interpretations of experimental data.
- ❖ To help bridge the gap between theory and practical.

Conversely, few respondents gave negative responses in the second column for some statements. Teacher trainers did have some objections when asked whether they achieve each statement independently since there is no designated laboratory for this purpose in the Faculty of Education. Chemistry labs are in the Faculty of Science only, where chemistry teachers are shown how to conduct laboratory activities. These trainers might attempt to instil these aims in their lectures and by allowing student teachers to practise them in forms of microteaching or teacher training activities. Inspectors, on the other hand, stated some restraints on assessing some statements, such as "to familiarise with important apparatus and measurement techniques" or "to learn some basic skills". These constraints are time and lack of materials allowing teachers to carry out frequent experiments to investigate whether learners can grasp these aims or not. These constrains also apply for not achieving such aims such as instilling confidence in science or stimulating and maintaining interests in science. Obviously, the assessing process focuses attention on the theoretical content, and completion and fulfilment of the assigned topics in the allocated time according to the pre-designed annual plan.

5.2.5. Investigations:

The three questionnaires also contain an open statement asking respondents about their views, ideas and actions towards investigations as an essential ingredient of practical work. Most respondents indicated that they fully agreed with this concept. However, several responses stated some difficulties concerning it.

Teachers' Group:

School teachers listed the following barriers:

- ❖ The heavy academic load teachers required to claim (20-24 or more 45-minute-lessons a week)
- ❖ Too much syllabus work to cover in a term.
- ❖ Other administrative tasks, teachers are asked to do (being head of a class, pupil's activities, neatness and discipline, etc…)
- ❖ Absence of the laboratory or the heavy demand on its availability and issues related to conducting such a practical activity.
- ❖ Several teachers stated that they never came across this method in their pre-service training.
- ❖ The weakness of pupils' theoretical background (especially in the primary classes) since they are too crowded and they are under pressure of various heavy loads.
- ❖ There is no lesson allocated as a practical lesson and the examinations do not consider practical work.

Teachers are dissuaded by these obstacles and are being asked to confront simultaneously various academic and administrative tasks. If teachers are trained badly, it is not surprising if they teach badly. Teachers should be regarded as the corner stone of the teaching process and hence they should be encouraged to create a good learning situation in their classrooms and not to let them wilt under non-educational duties.

Nevertheless, teachers still do their best to carry out some investigating activities within the resources available. Their scattered responses in this matter can be summarised as follows:

- posing a problem related to the theme
- proposing with pupils some suggested hypotheses
- carrying out experiments to test hypotheses (this is mainly done in groups or by the way of demonstration)
- determining the results and introducing discussions as time allows.
- coming to a conclusion.

Inspectors' Group:

Likewise, teachers' inspectors consider learning through investigation as a vital part of the educational process, but they raised a few limitations on doing such investigations at schools:

- Although improved recently, science syllabus design is still getting in the way and not easing the teacher's load.
- Most teachers are unqualified and untrained to carry out this type of activity.
- Investigations (in general) require a sufficient source and supply of material, which are not affordable.
- Besides lack of in-service training, there is a deficiency of libraries and teaching and learning resource centres at schools. This situation deprives teachers of an awareness of teaching strategies not usually employed in their level of study.

However, some inspectors do encourage teachers to use this strategy of teaching. They provide them with guidance, suggestions and instructions on how to conduct it. They also ask teachers to keep away from rote learning and avoid spoon-feeding in their practical sessions and lectures. Few inspectors stated that they held workshops for beginner teachers on carrying out experiments in the proper way to achieve such aims and objectives to a greater extent. They stated that the proper way to investigate is to pose the subject in the form of a specific problem, asking for solutions and suggestions, determining the required materials and substances, forming a procedure, doing the activity and then, in light of results, determining if this solution works. If not, other suggestions will be tested till we result to a conclusion. A few inspectors argued that it is better not to give or even to hint at the specific detailed objective of the activity since that would expose the main idea and reveal the conclusion.

Teachers' Trainers' Group:

Again, trainers pointed out a few difficulties concerning encouraging and training future teachers to carry out such investigating activities. Some of these are:

- Science education courses do not require student teachers to use real world examples of what they have been taught. Their role is to give a clear way to conduct a particular teaching method.
- Microteaching laboratories lack facilities required for any such practical activity (*the one in the Sultan Qaboos University has no water or gas supply*

and it looks like a normal room with few chairs and desks). So, the student needs to borrow from other laboratories the materials and chemicals required.

- Teaching time allocated for each student in the microteaching lab is less than 20 minutes, to cover as many students as possible and give feedback in a session. This discourages them from addressing this type of teaching.
- Teacher trainers are busy lecturing, supervising and correcting written tasks since each one is responsible for more than 40 student teachers at different schools and about 30 students practising in the microteaching labs in the college.
- Student teachers at schools are novices in this area, so they will avoid any open-ended activity for fear of class anarchy.
- Current textbooks and laboratory manuals dissuade teachers from addressing this type of activity since they give all the details of the topic leaving no room for learners to investigate and experiments are given in a direct cookbook style requesting pupils merely to follow blindly the written several-step recipe.

However, teachers' trainers do not simply skip the word "investigation" from their lectures and feedback knowledge which they give to future teachers, but they explain how it should be carried out and clarify its importance. Few trainers ask their student teachers to plan out and achieve a lesson in this way and conduct it in front of their colleagues either in the college in the microteaching lab or at schools during their teaching training. Closed investigations are educationally unsound. Open investigations may not be possible and directed investigations are the best solution.

Conclusion:

Consequently, the situation regarding the use of investigations is weak and flabby as the existing conditions and circumstances discourage teachers from using investigations.

This type of teaching involves specific facilities designed to present topics in the form of a problem (question) facing the learner and challenging his contemplation and thinking in order to encourage a scientific way of thinking. It also requires teachers to take into account the individual differences of the learners to suit the ability and learning pace of each one in the class (individualised learning). This doubtlessly demands a longer time to cover the whole course. It also involves presenting the course in the form of headlines of topics, leaving room for teachers to formulate their own teaching ways without being confined to a particular textbook which the teachers have to cover in a certain period of time. The current textbooks present all the facts related to the topic. The learners come already knowing all this and thus the purpose of the investigation is destroyed.

We need to regard the learner as a small scientist undergoing preparation and training who should find out solutions, original at least for him, for such challenging problems as he may face. Therefore, he should be given as much freedom as possible to think about the possible solutions for his puzzle and design the suitable experimental to test his solutions. He then will be able to present his findings in the proper way and outline conclusions in an acceptable form. Thus the learner has encountered both the science subject and method.

For instance, iron corrosion can be stated as a worrying phenomenon converting iron to another crumbly useless substance. The pupils are then in a situation to find out theoretically AND practically, the conditions and circumstances (not only the reaction formula) for this case. It is quite easy for a pupil to recall these issues after being taught theoretically, but after leaving school these will be quickly forgotten. Another example is when determining the relationship between resistance, current and the voltage (Ohm's law). Given ammeter, voltmeter, rheostat, resistance, battery and wires, connect the circuit as shown in the board and find out a relationship between V, R and I (teacher has obtained and drawn a sketch after discussion with pupils). Despite being given some hints and information, pupils are still required to think about how to transform the drawing into reality, how to connect wires and appliances in either series and parallel, how to change and specify current flow on wires (I) and voltage (V) each time they adjust the rheostat. Learners should also draw a graph representing the relationship between V, and I and deduce a relationship between V, R and I.

However, when describing counter-intuitive events, their testing and checking could be left to the learners to do at home. Not all experiments have to be done in a formal laboratory. For example, to assert that a tray of hot water will freeze sooner than an identical tray of cold, can be tested by pupils at home. There would be enough time to discuss, in class, the procedures and factors affecting the experiment: "Did you use identical trays? Same amount of water?, did the placing of the trays matter? etc...". this would improve the learners' confidence and motivate them as well as involving them in learning much science.

Problem-solving investigations may have the disadvantage in that because they are real problems, once they are solved they are solved forever and each year the teacher has to come up with a new one. On the other hand, they have the very powerful advantage of showing that science is directly important to people's lives.

It is recommended that investigation be continued in their life outside the classroom. This will add reality to their lives and make life more interesting. For example, measuring the pH of streams or of household chemicals such as oven cleaner, washing soda, detergent or any such activities teach that science is not a "*dry abstraction*", but a way of thinking about and **investigating** the world.

CHAPTER SIX

CHAPTER SIX

FIELD RESEARCH (II)

6.1. Conversion of bench demonstration using the OHP.

6.1.1. Introduction

As we have seen from the figures stated above (Chapter 4), a teacher can expect to have to teach to as many as 40-50 pupils. There are also several cumulative constraints on doing individual practice. If the lesson (or the topic) demands carrying out such a practical activity, the teacher has no choice **but** to turn to demonstration. Then he / she is faced with three options.

Firstly, he / she can carry out the experiment on a normal scale and hope that the pupils at the back rows of the classroom (or the laboratory theatre) have 20:20 vision or have the use of telescopes. Secondly, he can scale the experiment up. This can become hazardous and it also would be impossible, as it is prohibitively costly. Or thirdly, the teacher can forget about it. The first one is the usual option chosen.

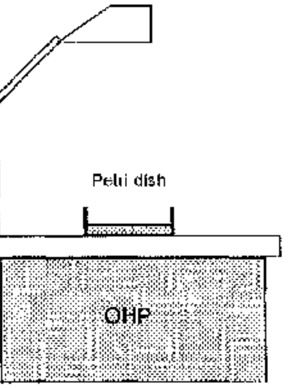
There is, however, a fourth option; that is for the experiment (less than the standard scale or possibly even smaller) to be projected on to a screen, therefore increasing the size many times without increasing the amount of chemicals used.

6.1.2. The OHP "attachment" for demonstration

The evolution of a "new" attachment for OHP to be used in demonstration came through the following modes:

Mode (1): The normal orientation

An overhead projector (OHP) can be used in its normal orientation (Diagram below) but only a limited number of experiments can be done this way. It is good for "flat" projection to see colour changes or ionic migration or bubble rafts or ball bearing or mini-models and things which do not have shadow problems. However, things involving layers, gas production and collection, electrolyses, liquefaction of gases, etc… cannot be done.



Flat projection

Mode (2): Johnstone and Kinloch gadget

This mirror method allows images to be projected the right way up and hugely magnified. Johnstone and Kinloch (1987) designed a very simple and cheap gadget on which a practical demonstration can be done on a normal or even smaller scale. This was achieved by doing the demonstration on an overhead projector and projecting it to a screen.

The normal vertical beam strikes one mirror, passes horizontally through the specimen, strikes the second mirror and passes to the head and is focused in to the screen. The following sketch can illustrate this.

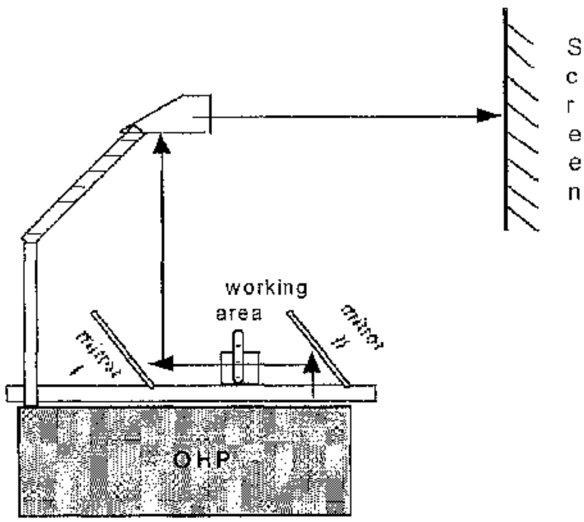


Figure (6.1): Johnstone's and Kinloch's gadget

However, despite the advantages of this simple gadget, there are weaknesses related to it:

1- It is relatively difficult to set up, in that the two mirrors should be, one at 45° and the second at $> 45^{\circ}$ as shown above.

2- The working area, in which we put the set of apparatus and chemicals (the reaction vessel or cell), is small and very narrow allowing for use of no more than 3 test tubes beside each other.

3- It is risky for the OHP Fresnel lens in case of spillage of any solvent.

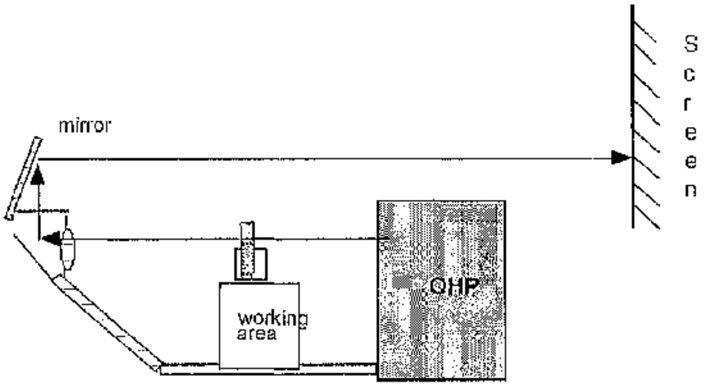
4- Not all OHP's are suitable for the use of this gadget, since some of these projectors have the light source in their heads and are not illuminated from below.

5- Since the area, to work in, is small and this gadget is set on the projector, this attachment suits some experiments **but** is not suitable for others. For instance, experiments involving heating, titration, or any with strong acids or bases can not be carried out easily.

Consequently, there is a need for another overhead projector attachment, which avoids these limitations, which is cheap, easily constructed, fitted and maintained and that will not have adverse effects upon the projector itself.

Mode (3): Tilted set-up

A new gadget has been devised based on an attachment to the head of the projector. It can be easily fixed by clipping a mirror on to the head after tilting the projector through 90° in order to allow the beam to go through the working area and then be deflected by the mirror onto the screen which is in front of the projector as shown in the following diagram:



This new gadget has advantages over the previous one.

It is:

1- simpler to build and design as it is just a normal plain mirror (tile-size) stuck in a wooden frame to fix on to the front head of the projector.

2- easier to carry in between classes, easier to store in a normal teacher drawer, easier to fix to the projector and the projector can still be used normally with no need to take this attachment off.

3- safer for the Fresnel lenses in case of solvent spillage.

4- visible to a large number of people at once.

5- providing a working area more than four times wider, so it gives room to carry out more experiments and even those, which require much apparatus at the same time such as titration, ammonia fountain, etc...

6- possible to project nearly all experiments with almost no exception; i.e. experiments involved Bunsen burner, water tap and things such as these.

7- capable of being used in nearly all OHP's, and almost all OHP's in Omani schools are suitable for this gadget. Besides, the OHP can be used without making any adjustment for normal projection so that the lesson can carry on without any interruptions.

However, two main issues can be regarded as faults for this new attachment. **Firstly**, a tilted projector might obstruct the ventilation path of some few projectors such as "3M-five sixty six" projector in which its ventilation fan would be below- the base (but not the ones in Oman). This can be easily overcame by raising the projector up on two parallel sticks to allow ventilation to take place. **Secondly**, as these attachments are based on using test tubes as reaction vessels, this gadget, and the previous one, have a problem of "convergent" test tubes.

6.1.3. Solving the problem of "convergent" test tubes:

If an empty test tube is placed within the beam of the projector, a clear, sharp focused image is obtained (the glass being so thin means that there is little refraction of the light). However, if a solution is poured into the test tube, it will act like a cylindrical lens (Figure 6.3) and produce an image with only a line showing the colour of the solution surrounded by dark bands on either side.

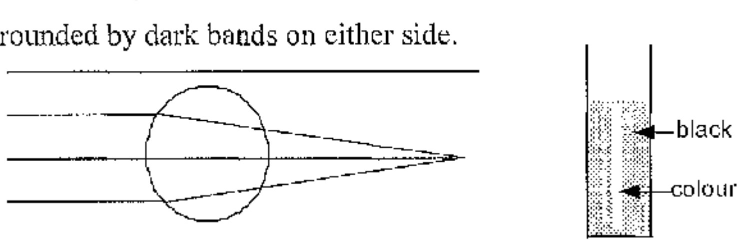


Figure (6.3): Convergent test tube (cylindrical lens) effect

The cylindrical lens properties of the full test tube can be overcame by placing the test tube into a flat walled transparent container containing a clear substance with refractive index almost identical to that of the test tube; i.e. water (Figure 6.4).

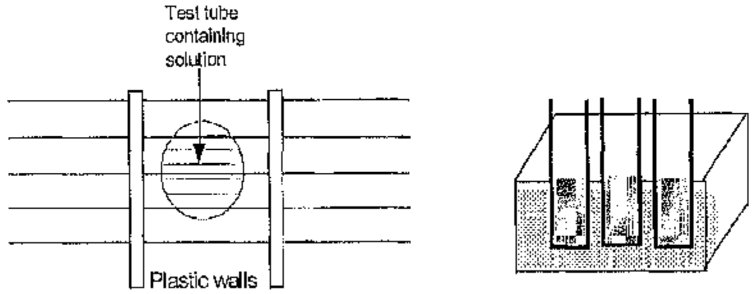


Figure (6.4): Solving the problem of cylindrical lens

A convenient plastic container turned out to be the plastic box in which litmus (or pH) papers are supplied. These are cheap, easily available and produce excellent results.
The attachment when used for demonstration can give every pupil in the class (or the laboratory theatre) a front seat view. See Appendix (6.1)

6.1.4. Developing TOPs experiments

Thousands of experiments were published by Hubert Alyea in the monthly "*Journal of Chemical Education*" in the period from 1962 to 1970 and summarised in 1971 **84**(1), and 1978 **55**(1) entitled: *(Tested **Overhead** Projection series)* **TOPs.** (Appendix 6.2)
Plenty of experiments are available to be selected from those given by Alyea or extracted from different sources. We could design and outline some examples of projectable experiments in the light of the following issues:

- Availability of apparatus, chemical and equipment (see next section 6.1.5).
- Matching experiments to Omani syllabuses using textbooks as the set course.
- Length of each experiment to ensure that we can offer room for discussion before, during and after the demonstration takes place. (Allocated time for the whole laboratory session is 40-45 minutes).
- Pupils' theoretical background since what we already know determines what we learn.

Thus for this purpose, experiments were designed and adapted for this gadget.
Experiments found to be projectable and suitable for the resources available in Oman have been collected into a manual (**Inside back cover**) which can be used later for both the researcher and other chemistry teachers (as we will see later).
The experiments can be broadly categorised into five main groups:

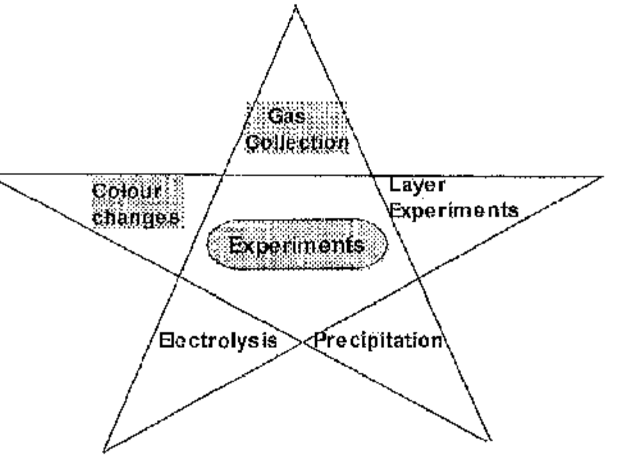


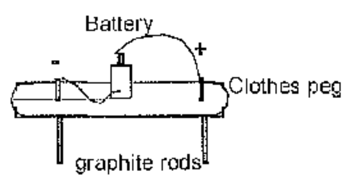
Figure (6.5): Categorising experiments into five main groups

In light of this categorisation, a teacher package (tool kit) has been proposed covering almost all experiments which a teacher may need to do.

6.1.5. Apparatus and chemicals:

Most of the apparatus, used in the previous package, can be easily constructed from local materials with the exception of a few things such as a transparent ammeter (or voltmeter) and a small amount of chemical substances and solutions.

The following chemical examples may show a typical pedagogy of running a lesson using this method. For instance, for this electrolysis experiment, a mini-set of a 6-volt battery connected to two graphite rods (pencil leads) fixed in a small wooden strip or on one half of a clothes peg as the diagram shows:



(This could be used for many such activities related to this topic (*Electrolysis*)).

Example (1): Electrolysing salt solutions. (Electrolysis)

Salts are compounds that contain a metal and a non-metal group. When salt solutions are electrolysed, two different chemicals can be formed at each electrode. Here are some salts to electrolyse. What is formed at each electrode?

Start to discuss pupils about the electrolysis of pure water and what gases given off and at which electrode they evolve. But before that, make sure that they know which electrode is the cathode and which is the anode.

Let a pupil give an example of a salt solution and another one predict the chemical at cathode and the chemical at anode when electrolysing. Start the experiment with say "copper (II) sulphate" and get pupils first to name ions present in this chemical and then to discuss what they see at each electrode. Now let a pupil try "potassium nitrate", another one "zinc sulphate", "sodium bromide", "magnesium chloride", "potassium iodide", etc...

Now a teacher can start a wide discussion of what is happening at each electrode:

At anode, "did the liquid change colour?", if it is red "bromine formed" or if it is brown "iodine formed". What if there was no change in colour? "test gas with pH paper", then if it bleached it would be "chlorine" otherwise the gas is "oxygen".

At cathode, "was much gas given off?" if so then "test with burning splint" if not " a metal must have been deposited".

In conclusion, discuss with the whole class. "which gas is always given off at the cathode?", "which metals were formed at the cathode?". Now get them to write a rule for deciding what is given off at (a) the anode and (b) the cathode?.

Example (2): Investigating the reactions of chlorides, bromides and iodides. (Precipitation)

Using the materials and chemicals available, work out how halides react with silver nitrate solution and chlorine water.

2 test tubes, stopper, Bunsen burner, sodium chloride, sodium bromide, potassium iodide, hexane, distilled water, solutions of ammonia, chlorine and silver nitrate.

The teacher would begin questioning with the word "halides, what does it stand for?" "the salts of halogens", "another word of halogens" or similar responses that may pupils think. "the first one is right", "so is the table salt a halide?", "yes, of course, it is the salt of chloride".

The teacher can start with this salt (NaCl) by dissolving few crystals of it in half a test tube of distilled water and then divide the liquid into two. To one of them a pupil would add 2 drops of silver nitrate solution and the class will observe what happens. "there is a precipitation", a pupil says. "what is it? And where has it come from?" the teacher should ask. "Ok, see, your friend will add ammonia solution until the tube is nearly full and notice the precipitation and record what you observe, could you explain what happens?"

Similarly, another pupil will add an equal volume of chlorine water to the other sample of sodium chloride, then 2mL of hexane and shake gently whereas the class will be watching if there is any colour in hexane layer.

Now get pupils to predict what is happening if we repeat these experiments using other halides available (sodium bromide and then potassium iodide).

Example (3): Iron Rust (colour changes)

Having the following materials and chemicals, find out factors needed to make iron rust.

Test tubes, test tube holder, stopper, iron wool, Bunsen burner, 4 nails, cooking oil and anhydrous calcium chloride.

Start to discuss pupils' knowledge about the meaning of rust and why iron rusts. They might say: "water", "air", "material the nail made of", "temperature", etc.... Write all of these probabilities in the board. Now how we can address and investigate such this problem. Ask for suggestions.

Now you can start the experiment by putting a nail in each test tube, but before that ask a pupil to clean the nails with the iron wool explaining why. Then label them A-D.

Let a pupil put some lumps of anhydrous calcium chloride in test tube A, and cork tube B after putting a nail in it (Discuss why to stopper the second tube whilst leaving the first one open).

Another pupil will heat 3mL of water in tube C, then drop in a nail and pour in 1mL cooking oil. (Discuss the point of boiling and adding a layer of oil).

In tube D, just place a nail. Add some drops of indicator to tubes B-D, leave for few minutes and then compare and justify the results. (If there is no ferroxyl indicator, then you need to leave the nails for a week)

Now get pupils to predict in which tube the nail will rust giving their reasons.

And then ask a pupil to put the four test tubes in order and put the one with the most rust first. What do they found?

What does the anhydrous calcium chloride do in tube B, and why was oil put on top of the water in tube C. Now which factors are needed to make iron rust? What can pupils suggest to protect against rusting?

Example (4): The halogen displacement rule (Layers)

Using the materials and chemicals (all solutions) provided, work out the rule for predicting what will happen when the halogens are reacted with sodium chloride, sodium bromide and potassium iodide solution.

4 test tubes, stoppers, chlorine, bromine, iodine, sodium chloride, sodium bromide, potassium iodide and hexane.

The teacher may start asking pupils why were solutions of the halogens used in the experiments. A pupil could ask "Why is fluorine not mentioned in this experiment?", the teacher may reply: "It is usually not available at school laboratories".

The teacher now can let a boy put 2mL of NaCl, NaBr and KI into separate test tubes, and ask others what will happen if add an equal volume of chlorine water to each test tube. What do you expect if we add 2mL of hexane to each, stopper and shake tubes gently. Some would say "solutions will mix together" whereas others may say "hexane does not dissolve, so a layer could happen".

"Now let us find out what does happen". "Yes, there is an upper hexane layer, what is its colour in each tube". "Ok, boys could you anticipate what will happen if we add bromine water instead of chlorine? What if we add iodine solution?"

now the teacher with pupils can put chlorine, bromine, iodine into order with the most reactive first and find out a trend within this group (VII). Thus they can state the displacement rule in halogens and predict if there will be a reaction between chlorine with sodium fluoride, fluorine with potassium iodide and even between astatine and sodium bromide.

6.1.6. The learning situation during a demonstration:

Recalling the class sizes, demonstration is inevitable and is the only way to carry out practical activities. Bearing in mind information processing load, there are many instances in which this technique (so-called TOPs) can be used to ease the load of teaching as well as of enhancing the learning process.

Since the normal class size in Oman is in range of 35-50 pupils, and there is a scarcity of laboratory rooms, the teacher, instead of forgetting about any kind of practical activities, can use the idea of making concrete a theoretical point when teaching a topic <u>in a normal classroom</u>. This would provide some more concrete evidence to pupils. It is easy to say, "changes in oxidation state change colour", but when it is demonstrated to the pupils and they observe it <u>clearly</u> happening, the fact becomes real, as the saying goes, "seeing is believing".

Besides, a teacher, either in the classroom or in the laboratory, can establish a theoretical base before consolidating it practically. He can reshape the activity or interactive demonstration, following the scientific method in learning, to suit the time and resources available. Pupils can participate by both hands and minds. Their hands are not fully engaged in manipulating apparatus or chemicals (individual practical) nor are they left unused while watching in a big theatre passively (normal bench demonstration). They can be used to assist the teacher in carrying out the experiment.

A study carried out by Roth, *et al.* (1997) revealed six dimensions describing a number of influences that mediated learners' descriptive and explanatory discourse relative to the demonstration. The influences, however, cannot all be separated entirely, because they interact and overlap. Some influences that mediate what and how students learn from demonstrations are:

(a) **Separating signals from noise**: Students have difficulty in separating "signal" (important things) from "noise" (unimportant things). They do not know which aspects of the display they need to focus on in order to understand, the teacher's accompanying or subsequent theory talk. For demonstrations to work at all, students need to see what the teacher intends them to see so that his "canonical explanation provides a plausible explanation". If we consider TOPs through Information Processing Theory, we find that, in normal laboratory work (discovery) pupils may not discover what the teacher wants them to do, or they may discover something different from what teachers intends them to do. On the other hand, in TOPs, teachers can control the input to the perception filter and can link them to pupils' previous knowledge. For instance, saying "*this idea is the same as what we saw yesterday,... this is confirming ...., .. it can be explained in light of....*etc...", these phrases make sense to the novice learner rather facing a load of new information in the form of both "noise" and "signal" and not knowing which is which. The conscientious pupil may try to cope with both and overload.

(b) **Different experience background**: When students come to see a particular demonstration, they bring with them different experience backgrounds that affect their descriptions and explanations, which may be inappropriate for and even interfere with the development of new ideas suitable for the situation in hand. Again, in TOPs, the teacher can minimise the influence of these factors as he can frame the lesson in the way he recognises it suits learners' different backgrounds.

(c) **Interference from other demonstrations**: Other demonstrations students have seen may interfere with their development of a new idea because of superficial similarities between the previous knowledge and the new knowledge. They used mental images as resources in their predictions, interpretations, and explanations. However, these images and the predictions students derived from them were often inappropriate. This interference will occur if the learner fails to link new knowledge to his previous knowledge (which TOPs can do). He may accept that some thing is important at the time, he may hold it for a while but it will not be long until it is lost.

(d) **Switching representations**: Students may not be able to connect the different representations that are implicit in the teacher's theory talk to other aspects of their knowledge. Clearly, TOPs, under the control of the teacher, can match knowledge and connect representations through giving pupils the opportunity to engage their mind in identifying the problem, hypothesising, suggesting solutions, planning procedures, carrying out some hands-on skills, and drawing conclusions. Besides, by asking pupils to use a balance to weigh a substance, measure a certain volume using a measuring cylinder or a pipette, standardise acids with bases, preparing 2M HCl, read ammeter or thermometer, blow in limewater, etc…pupils can get hands-on in such a demonstration.

(e) **Larger context of demonstrations**: Low priority may be given to constructing ideas and understanding phenomena compared to being able to get the correct results on numerical tasks. This affects students' engagement with the demonstration. Through TOPs, teachers can let learners engage by both hands and minds. They can shift easily from cookbook styles to the interactive one where pupils are active and feel some ownership in the activity.

(f) **Lack of opportunities to use scientific language**: A lack of opportunity exists for students to engage in a discourse about the demonstration and to describe, construct ideas and explain phenomena. As stated above, the ownership of pupils lead them to engage actively in the experimenting process.

Moreover, in TOPs, the noise of frustration (which is a result of not being able to see) is reduced, since phenomena here are more observable than that in bench demonstration. Not being able to see what is going on makes the learner irritated with the activity and then become frustrated.

Without doubt, there are dangers when teachers start to misuse demonstration if they are merely keeping the learners busy and learners become just observers or even grasp nothing.

An example given by Johnstone (Johnstone, 1980a) may illustrate the danger inherent in a bench demonstration if it goes solely by a teacher-directed approach in which the teacher decides what procedure is to be followed or sometimes carries out the experiment himself/ herself alone (Position A in *Roger Lock*'s diagram in chapter 3). Appendix (6.3) is a video script of a normal demonstration session attempting to portray how a set of instructions for a chemistry practical lesson must sound to a pupil. How many thousands of times a day must such situations occur in schools, colleges and universities? The teacher is not trying to be obtuse, but he is so familiar (expert) with the work that he forgets the first-time learner (novice). The point of the experiment may be simple, but what is forgotten is that the welter of preliminaries, precautions, new skills and new language can completely obscure the point of the experiment from the learner. The pupil does not know what is vital and what is trivial because the experiment is being used to develop the very concept the pupil needs in order to unravel the experiment. This is a vicious circle, which must be broken if the lesson of the experiment is to come across clearly to the pupil.

Demonstration, however, can be designed interactively to serve many ways, styles and methods of teachings. It should be planned in a proper mode not in a cookbook style. For instance, it can be directed to facilitate problem solving as shown in the following example that provide learners with only a problem or a main question. They are then asked to **design** their own procedure to **solve** this problem and **write** their own conclusions:

Limewater

Problem:

An experiment has been done and found that when breathing in limewater, it turned milky (cloudy). But when we kept on blowing, the water turned clear again.

- Recalling solubility property, expose reasons make water turns cloudy and then clear.
- Find out how water can become cloudy once more without blowing in it?
- Describe your procedures, draw some conclusions and write the appropriate equations.

This is really a revision experiment with a thought providing end-piece.

Lesson:

You know that limewater turns milky when you breath into it. Let us do the experiment again, but with a difference. I need a volunteer to blow into the limewater.

Now blow and the class will watch the effect. *{It turns milky as expected}*

Now keep on blowing and blowing and blowing !! *{milkiness disappears}*

Here is a problem. What has happened to the limewater?

What was the milkiness? {$CaCO_3$}

Write the equation to refresh your memories. {$Ca(OH)_2 + CO_2 \rightarrow CaCO_3(milky) + H_2O$}

Now we have $CaCO_3$ in water and keep on adding CO_2 {$CaCO_3 + H_2O + CO_2 \longrightarrow$ }

What could the product be? (Take suggestions)

{Arrive at $CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$ *(dissolves)*}

How could we check this and reverse it? {*Remove extra* CO_2}

How {*Heat*}

Try it and see the milkiness returns.

6.2. The growth of the new baby

6.2.1. Introduction

As seen previously, because of limitations and inadequacy of facilities, individual practical work is unlikely to occur and demonstration seems to be the usual option. And if this is the case, it is more common for the learner to be presented with a demonstration. However, it may not be an effective way of learning.

Therefore, it is time to check our hypotheses that this method (TOPs) is one of the best alternatives, and provides a way in which a learner can learn even more effectively.

TOPs is not just a demonstration in another jacket, but it is a new strategy for interactive and effective practical activity. The teacher mainly conducts and controls it, but the learner would be engaged both physically and mentally.

6.2.2. TOPs in Trial

To investigate the effectiveness of such a method of instruction, a teaching process had to take place adopting this method, checking its productiveness and efficiency in the light of pre-stated objectives.

The researcher, consequently, administered this process according to the appropriate research method. A Null hypothesis was assumed for this test which is "*There is (are)* *no significant difference(s) in the academic achievement between the control and the experimental group(s) at the 5% level".*

A. Research method

After completing and fulfilling the required formalities in getting the relevant and applicable letters and correspondence from all relevant authorities to get access to schools (Appendix 6.4), the researcher selected a secondary school to apply this project in.

Autumn term

Pre-tests (Appendices 6.5a+b+c) were applied to all class-sections existing in this school. After analysing and contrasting the results, two groups were selected from each year (six sections in total). These two matched groups were chosen because of their similar achievement results in the pre-test. Then one was named as the control group (which would be taught in the normal way existing in school), while the second group called the experimental group would be taught using TOPs.

Table (6.1) clarifies this process. The number **(n)** in brackets indicates number of pupils in each group. Bold numbers are groups and bracketed numbers are pupils.

Age	**Control Group (n)**	**Experimental Group (n)**	**Total (n)**
Year 9 (15)	1 (28)	1 (30)	**2** (58)
Year 10 (16)	1 (30)	1 (31)	**2** (61)
Year 11 (17)	1 (34)	1 (33)	**2** (67)
Total	**3** (92)	**3** (94)	**6** (186)

Table 6.1: Description of control & experimental groups

These groups both the control and experimental were taught for seven continuous weeks by the researcher himself in order to eliminate factors such as the variation between teachers style, experience, etc.... Groups encountered the same topics using the same objectives, but while the control groups performed experiments using mainly conventional bench demonstration (with a few small groups practicals), the experimental groups experienced the TOPs method with hands-and-minds participation as much as possible.

After this period of teaching, post-tests (Appendices 6.6a+b+c) were applied for both groups at each age level.

Spring term

Another trial was conducted in the same academic year (1998/1999) for other groups of pupils. This time the researcher chose year 10(16) and year 11(17) and excluded year 9(15) as most of its topics, in this term, were theory-based science focusing predominantly on biology and geology.

The same procedure was applied: pre-testing (Appendices 6.7a+b), teaching, and post-testing (Appendices 6.8a+b). The data was then analysed and interpreted as shown in the next section (6.3).

B. Pupils' questionnaire:

A questionnaire of 14 statements was designed, asking the experimental groups about their attitudes to conventional and TOPs teaching. These statements attempted to cover aspects of enjoyment, discussion, visibility, participation and some relevant issues. It was translated to Arabic, since its original version was in English as shown in Appendix (6.9).

6.2.3. TOPs in action

The data was analysed and it was found that the results were in favour of the TOPs method. To compensate for the effect of the researcher's keenness for the project, other teachers were asked to use this new method of teaching and examine its effectiveness in both economical and academic terms.

For this purpose, 29 teachers were trained and given the opportunity to try this method in front of their pupils. They were then asked to fill in another questionnaire (Appendix 6.10) to indicate their response towards the bench demonstrations or TOPs. There were 14 statements covering almost the same aspects as those in the pupils' questionnaire mentioned above in addition to timing and costing terms.

Besides teachers who were already in the field of teaching, 73 student-teachers in the final year of their training were given the opportunity to experience this method. They were then asked to give their response to the same questionnaire, as the one used for teachers in-service.

6.3. Analysing, Interpreting and Discussing the data

6.3.1. TOPs in trial:

Three different pre-tests were applied to all groups in the schools in the autumn term. Results were analysed and compared in order to select two matched groups, which have similar science (chemistry) achievement. The results of these two groups (the control and experimental groups) were treated using the t-test (two-tailed) and can be presented as follows:

Pre-test (1)- Year 9	n	Mean	Standard Deviation	t-test
Control (1)	28	62.6	12.9	Df=55, not significant at 95%
Experimental (1)	30	62.1	12.9	

Pre-test (2)- Year10	N	Mean	Standard Deviation	t-test
Control (2)	34	61.7	13.2	Df=64, not significant at 95%
Experimental (2)	33	62.1	12.5	

Pre-test (3)- Year 11	n	Mean	Standard Deviation	t-test
Control (3)	30	62.6	11.3	Df=58, not significant at 95%
Experimental (3)	31	62.5	11.5	

Therefore, the Null hypothesis "*There is (are) no significant difference(s) in the academic achievement between the control and the experimental group(s)*", is accepted at the 95% level.

The same Null hypothesis was assumed for these groups after been taught for seven continuous weeks BUT by two different teaching methods. While the experimental groups had been taught using TOPs, the control groups encountered the same teaching experience as normal pupils in the schools but by the same teacher of the experimental groups.

Post-tests were performed for both groups and the results were again analysed using mean, standard deviation and the 2-tailed t-test:

Post-test (1)- Year 9	N	Mean	Standard Deviation	t-test
Control (1)	28	63.4	10.7	df=55, significant at better than 0.01% (p=0.0001)
Experimental (1)	30	75.8	11.2	

Post-test (2)- Year 10	N	Mean	Standard Deviation	t-test
Control (2)	34	64.3	10.8	Df=64, significant at better than 0.01% (p=0.0001)
Experimental (2)	33	75.5	11.5	

Post-test (3)- Year 11	N	Mean	Standard Deviation	t-test
Control (3)	30	62.8	10.6	Df=57, significant at better than 0.01% (p=0.0017)
Experimental (3)	31	72.6	12.7	

Quite obviously, all are significant at better than 0.01% and they reject the *Null hypothesis* with more than 99% confidence.

Moreover, another TOPs trial had been conducted in the **spring** term (1999) and lasted for 6 weeks, with different classes, but only with years 10 and 11, ignoring year 9.

Pre-test (1)- Year10	N	Mean	Standard Deviation	t-test
Control (1)	32	64.2	15.0	Df=59, not significant at 95%
Experimental (1)	30	63.2	14.7	

Pre-test (2)- Year11	N	Mean	Standard Deviation	t-test
Control (2)	33	63.5	13.1	Df=64, not significant at 95%
Experimental (2)	34	63.7	13.4	

Post-test (1)- Year 10	N	Mean	Standard Deviation	t-test
Control (1)	31	70.8	10.9	Df=60, significant at better than 0.02% (p=0.016)
Experimental (1)	32	78.0	12.1	

Post-test (2)- Year 11	N	Mean	Standard Deviation	t-test
Control (2)	33	71.8	9.75	Df=64, significant at better than 0.02% (p=0.0044)
Experimental (2)	34	79.4	11.3	

The same procedure was followed and the results obtained also came in favour of this method and hence the Null hypothesis could be rejected again at better than 0.02%.

Besides, the 14-statement pupils' questionnaire was administered for the experimental groups as they experienced this method. Pupils were given the questionnaire just after the completion of each teaching period of each term. Experimental group pupils in the autumn term were 94, whereas the spring term there were 65 pupils.

No	Statement	Demos rather than TOPs	TOPs rather than Demos	No difference
1	I found chemistry experiments are more fun when doing them on the			
2	I found experiments are easier and simpler on the			
3	The spillage of chemicals and breakage of apparatus in the experiments were less in case of the			
4	I feel more interested in chemistry when doing experiments on the			
5	It took less time to complete the experiments in case of the			
6	when doing chemistry experiments, I can understand chemistry more easily when working on			
7	I felt more relaxed and safe when doing experiments on the			
8	experiments have enabled me to concentrate on the chemistry more in case of			
9	Work on the bench was more tidy and less cluttered when doing experiments on the			
10	I feel that I have gained more from experiments when doing them on the			
11	I feel experiments are more visible (observable) when doing them on the			
12	In case of large-size classes, the best idea is doing experiments on the			
13	There is more room for discussion on experiments when doing them on			
14	If I am given a choice between Demos and TOPs, I would prefer			

The results of the first term can be represented by the following table:

Statement	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Demos %	33	34	2	25	12	24	20	33	11	9	3	7	16	26
TOPs %	58	57	98	69	85	66	72	54	87	85	97	89	67	74
No Difference %	9	9	0	6	3	10	8	13	2	6	0	4	17	0

Table (6.2): Pupils' responses (Autumn term)

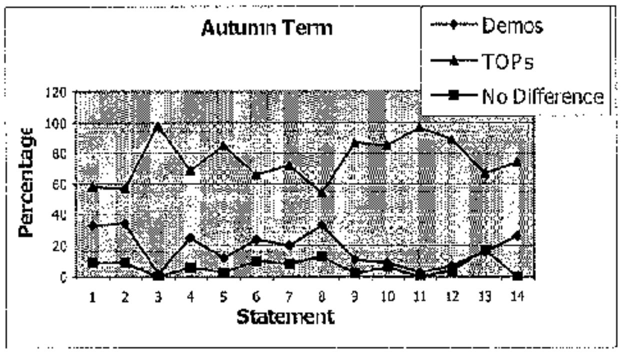


Figure (6.6): Pupils' responses (Autumn term)

Similarly, the experimental sample in the Spring term gave responses for this questionnaire, which were also in favour of the TOPs method. The results are shown in the following Table (6.3) to give a brief overview of this sample's responses:

Statement	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Demos %	20	35	3	20	11	22	23	32	9	13	1	5	13	15
TOPs %	76	60	97	73	87	69	69	62	87	82	99	88	74	85
No Difference %	4	5	0	7	2	9	8	6	4	5	0	7	13	0

Table (6.3): Pupils' responses (Spring term)

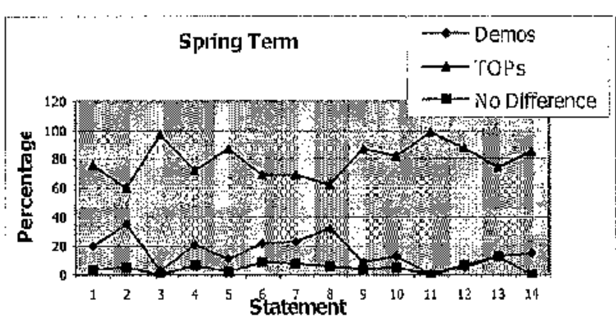


Figure (6.7): Pupils' responses (Spring term)

Again for the purposes of an aggregate statistical treatment, the results of both the Autumn and Spring terms of this questionnaire were gathered into one table taking the weighted mean percentage. Since the group size varies in the two cases, to get the composite mean, each of the two results are multiplied by the group size, summed and then the result will be divided upon the total number of pupils in the whole group. This might be presented as follows:

Composite mean % = [(statement % x 94)+(correspond statement % x 65)] / (94+65)

Statement	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Demos %	28	34	2	23	11	23	21	33	10	11	2	6	15	22
TOPs %	65	59	98	71	86	67	71	57	87	84	98	89	70	78
No Difference %	7	7	0	6	3	10	8	10	3	5	0	5	15	0

Table (6.4): Composite mean percentages of pupils' responses

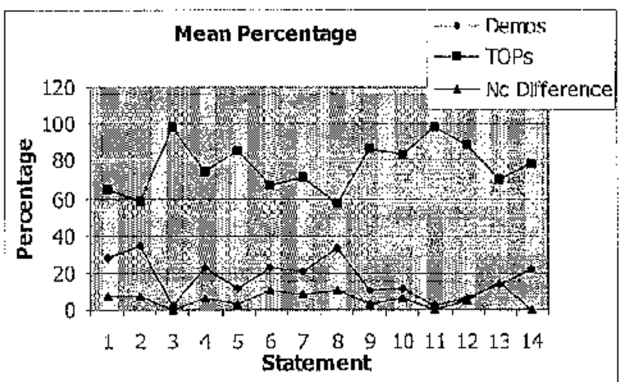


Figure (6.8): Composite mean percentages of pupils' responses

In summary, we can list sentences with the highest responses of agreement (84% or over) as follows: (*the bold words are key words for the sentence*)

1- Pupils feel experiments are more **visible** (observable) when doing them on the TOPs (98%)
2- The **spillage** of chemicals and **breakage** of apparatus in the experiments were **less** in case of TOPs (98%)
3- When classes are **large**, pupils stated that the **best** idea is doing experiments on the TOPs (89%)
4- Work on the bench was more **tidy** and **less cluttered** when doing experiments on the TOPs (87%)
5- It took **less time** to complete the experiments in case of the TOPs (86%)
6- Pupils feel that they have **gained more** from experiments when doing them on the TOPs (84%)

In general, results are in favour of TOPs, but there are a few significant responses for some statements in favour of bench demonstrations as in statements 1,2,4,6 and 8.

Statement 1: chemistry experiments are more fun.

Although 65% of the respondents chose TOPs experiments as more enjoyable than normal demonstration, 26% of them stated that they enjoyed experiments presented by the normal bench demonstration. This group might be the group that is not interested in participating preferring to be merely spectators of the experiments. They may be using the demonstration time to talk to each other instead of paying attention the whole lesson.

Statement (2): Experiments are easier and simpler

Again 34% asserted that experiments are easier and simpler when doing them on the bench. They perhaps did not grasp the reason for projecting experiments. These pupils also could be those who usually sit in the front rows and so have an adequate view of conventional demonstrations in any case.

Statement 4: pupils are more interested in chemistry.

One quarter of the tested sample declared that they have more interest in bench demonstration rather using TOPs. The reason could be the same as given for statement (1) as there is a possibility to be inattentive when not being asked to share in the activity.

Statement 6: when doing chemistry experiments, pupils can understand chemistry more easily.

Two things were changed in these experiments: **visibility** and **participation**, which are new tactics for pupils. So, it is again unsurprising to find about a quarter of the sample said that it is better and easier to understand chemistry during bench demonstrations. Since as there is an appetite or a desire towards the new thing, in contrast, there is also some opposition against it. So, we can expect this ratio of disagreement, or uncertainty (10%), as they do not get used to it. Moreover, the term "*understand*" may stand for some learners as how much information they get in a lesson, and the amount of their abilities to recall as much theory as they can. Therefore, they may choose not to go for TOPs, where fewer facts and less theory were offered as it focused on the processes of science rather merely science itself.

Statement 8: the experiments have enabled pupils to concentrate on chemistry more.

Here about one third of the whole sample found themselves concentrating more on the chemistry when doing bench demonstrations. This can be explained, as the previous statement, as opposition to unfamiliar things or ambiguousness of the word "*concentrate*" which could be taken to mean "*understand*". Hence, about 10% of respondents gave "uncertain" response for this statement.

6.3.2. TOPs in action:

In order to offset the possible bias introduced by the researcher and his enthusiasm for the project, other teachers were asked to attempt teaching using this new method and then examine its effectiveness in both economical and academic terms. 29 teachers (who were already involved in teaching) and 73 student-teachers who are about to enter the teaching profession was the sample asked to judge the effectiveness of this way of teaching. They were then asked to give their responses for 14-statement-questionnaire (below).

No	Statement	Demos rather than TOPs	TOPs rather than Demos	No difference
1	I found that it is easier to conduct experiments on the			
2	I get more responses from pupils at the back rows in case of the			
3	The spillage of chemicals and breakage of apparatus in the experiments were less in case of the			
4	It required less care in handling chemicals and apparatus in case of the			
5	It took me less time to complete the experiments in case of the			
6	There is more chance for pupils to participate in some manual skills in case of the			
7	I felt more relaxed and safe when doing experiments on the			
8	The effort undertaken to prepare, conduct and clean up experiments is less in case of the			

9	My work on the bench are more tidy and less cluttered when doing experiments on the			
10	In case of large-size classes, experiments are more visible (observable) when doing them on the			
11	There is more time for discussion on experiments when doing them on the			
12	Pupils' responses indicate that they learn better in case of experimenting using the			
13	There is more room for discussion on experiments when doing them on			
14	In future and as possible, I prefer to carry out experiments using the			

Frequencies of given responses were calculated, converted into percentages and then briefly displayed as follows in table (6.5) for school teachers and table (6.6) for student teachers:

Statement	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Demos %	14	21	21	34	31	38	31	28	17	7	34	24	0	14
TOPs %	82	67	79	57	55	51	53	70	83	93	54	68	100	86
No Difference %	4	12	0	9	14	11	16	2	0	0	12	8	0	0

Table (6.5): Teachers' Responses (Demonstrations & TOPs)

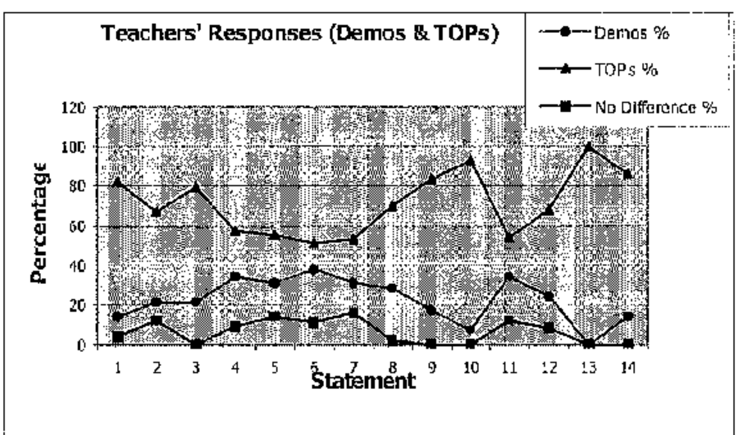


Figure (6.9): Teachers' Responses (Demonstrations & TOPs)

Statement	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Demos %	10	16	12	27	29	40	27	23	8	4	32	16	3	8
TOPs %	85	77	85	59	63	46	59	74	89	93	60	76	97	89
No Difference %	5	7	3	14	8	14	14	3	3	3	8	8	0	3

Table (6.6): Student Teachers' Responses (Demonstration & TOPs)

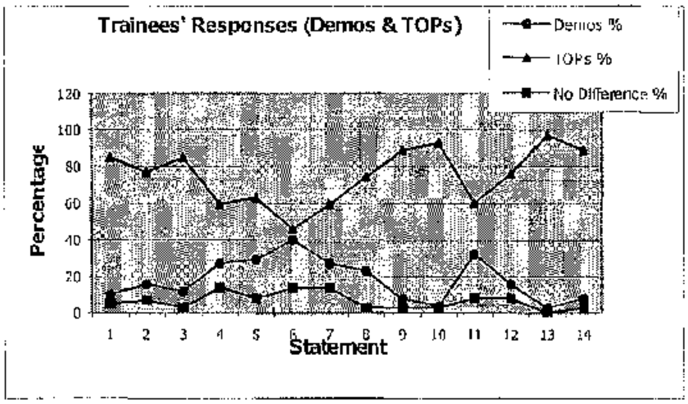


Figure (6.10): Student Teachers' Responses (Demonstrations & TOPs)

From the two previous set of results, we can pinpoint statements which highly (≥80 %) favour TOPs in both samples: (*the number in brackets is the weighted mean percentage*)

1- **less** apparatus and chemicals are needed (~99%)
2- in case of large-size classes, experiments are more **visible** (93%)
3- in the future and where possible, respondents **prefer** to carry out experiments using TOPs (~88%)
4- work is more **tidy** and less cluttered (86%)
5- experiments are **easier** to conduct (~84%)
6- less **spillage** of chemicals and **breakage** of apparatus (82%)

Although the remainder of the results are all in favour of TOPs, there are a few responses in favour of bench demonstrations, which should be discussed:

Statement 4: less care was required in handling chemicals and apparatus.

The word "Less care" does not refer to uncontrolled careless while dealing with chemicals or apparatus as might be interpreted by some teachers. It implies that small-scale hardly does require much care as large-scale chemicals. So, this group (34% teachers and 27% trainees) might have misinterpreted the question.

Statement 5: it took less time to complete the experiment.

Without doubt, unless it had been prepared in advance, setting up the device in the projector, fitting some experimental aspects, taking small amounts, etc… will consume time and the teacher would find himself running out of time and this could explain why 14% of teachers stated that there is no difference. Yet, dealing with small amounts may require some getting used to, and most teachers lack this competence to begin with. This also would explain the results for statement 11, as 33% said that with normal demonstrations, there more room for discussion rather in case of using TOPs.

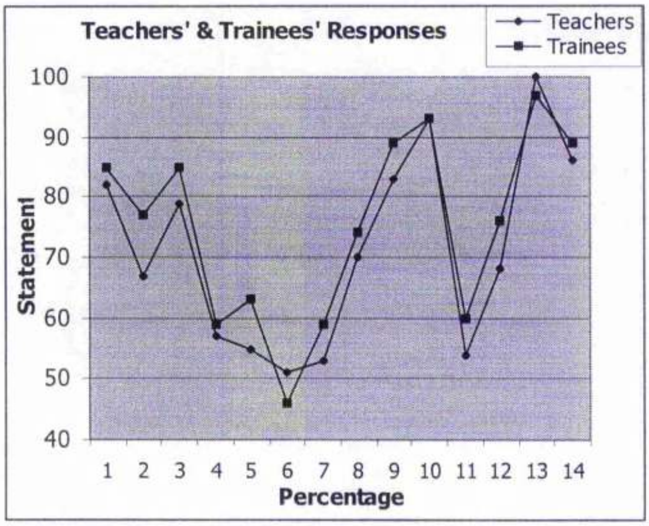
Statement 6: there is more chance for pupils to participate in some manual skills

This statement shows the most scattered responses (in mean percentage 39% chose normal demonstrations, ~49% TOPs, and ~12% stated no difference). This can be explained for two reasons. Firstly, for the reason stated above in statement 5 as there will not be any form of participation since there is no time and teachers need to do it all themselves. Secondly, participation is not, as some conceive, only manual or physical. There is also mental participation as well as hand participation. So, it is not enough to confine participation effectiveness to one side of the coin.

Statement 7:respondents felt more relaxed and safe.

It is not an unexpected result to find out that about one third of the sample felt relaxed and safe whilst doing bench demonstrations, as they are used to it and have become proficients in it.

Though this sample consists of two completely different groups with different teaching experience and different background (and maybe different age), and because we have treated them as an integrated group, we need to examine if their responses are significantly different. In many cases, the frequency is too small for χ^2 or goodness of fit analysis. The following figure may show that there is no significant difference between the openness of the two groups.



With the exception of statements 2, 3, and 5, both groups showed a strong agreement on all statements and all in favour of TOPs. A closer look at statements two "*I got more responses from pupils at the back rows*" and statement three "*the spillage of chemicals and breakage of apparatus in the experiment*" and five "*it took me less time to complete the experiment*" revealed that these groups as novices to the method and not familiar with dealing with small-scale apparatus. It is unsurprising to find some responses not in favour of an unfamiliar technique.

6.3.3. Conclusion

The TOPs (**T**ested **O**verhead **P**rojection**s**) method can be an alternative and one of the best options for teachers who are about to deal with practical work in certain conditions, such as those existing in Oman and many other countries in that region. It is distinct from the conventional demonstration by both visibility and participation of the learner.

Both parties in the educational process (pupils and teachers) gave their responses in favour of it, as it attempts to overcome the weakness of the bench demonstrations and offset the limitations existing in most schools.

However, the reader may attribute these positive results towards TOPs to the "**halo-effect**". i.e. the enthusiasm of practitioner. This may be so for the time being and further research after a while will give evidence whether to accept this argument or deny it.

CHAPTER SEVEN

CHAPTER SEVEN

Conclusions, Suggestions and Recommendations

7.1. Conclusions:

The primary purpose of this research study was to establish a base line of the nature and forms of the present practical activities in Oman, then devise a new teaching technique accordingly. This technique has been designed in the light of the resources and conditions available and taking cognisance of the limitations and constraints existing due to the situation in Oman and other countries in that region. There are a number of key factors which would seem likely to influence the choice of the techniques (or strategies). These factors include:

- ❖ The numbers of pupils currently enrolled at different educational levels.
- ❖ Evidence of shortages and insufficiency of well-qualified science teachers to respond to the new trends in chemistry teaching.
- ❖ The regional patterns of provision (curriculum, teacher's tasks, resource allocation for science).

The aspects, which have emerged in this research study, could be summarised in the following conclusions:

1- **findings in terms of the literature review:**

- ❖ Experiments done by individual pupils can suffer a gross information load. This load would include what has to be processed from the instructions, recalled, digested and interrelated within the space of a single lab class, broken down into theory, experimental and report demands.
- ❖ Unless the theory is in place to begin with, practical work may not be a good tool for teaching theory. The learner will not develop an understanding through observations since the theoretical aspects of science are not there to guide and inform the observations.
- ❖ Pupils' interests and satisfaction do not always increase when the amount of practical work is increased.
- ❖ There is a little evidence that manual skills learnt in science are indeed generalisable and transferable or that they are of vocational value.

- ❖ Laboratories should show what chemist do with their brains and not, only, what they do with their fingers

2- findings in terms of the pupils' views towards practical work:

- ❖ The laboratory is a vital part in learning chemistry and it is the means of verifying the theory.
- ❖ Teachers alone control laboratory sessions leaving no room for pupils to participate. Teachers also disregard any lab experiments (marks) as examinations do not include any practical assessment.
- ❖ Few pupils ever participate in a practical activity or might never have been to any laboratory as there is no room allocated as a lab in the school.

3- findings in terms of the teachers' survey on doing practical work:

- ❖ There are serious limitations and constraints on doing individual (or small groups) practical work in most schools at all educational levels in Oman.
- ❖ Many teachers carry out practical work in the form of normal bench demonstrations but a few do not even perform demonstrations or practicals.
- ❖ Teachers are wilting under the many non-educational tasks, and are therefore dissuaded from doing any form of practical activities.

4- findings in terms of the survey on aims of doing practical work:

- ❖ The teachers' group subscribes to the importance and "idealism" of doing practical work as they reported that they achieved the aims of practical work to a large extent. This is wishful thinking and contains an element of exaggeration.
- ❖ Inspectors have a significant influence on teachers, so it is not surprising that theire responses are the same as those of the teachers, to a considerable extent.
- ❖ Teacher trainers have some objections and are sceptical of the idea that practical work always stimulates interests in science. Instead they emphasise the importance of learning how to use experimental data to solve specific problems.
- ❖ Four aims of practical work given the same response from the members of the three respondent groups (teachers, inspectors and trainers) are:

- To illustrate materials taught in lectures
- To train in observation
- To train in making deductions from measurements and interpretations of experimental data
- To help bridge the gap between theory and reality.

- In spite the fact that respondents fully agreed with the importance of doing investigations, several responses stated some difficulties concerning them:
  - Heavy academic load on teachers
  - Too much syllabus work to cover
  - Other administrative tasks' demands on teachers
  - Lack of materials necessary for investigation
  - Lack of pre- and in-service training for teachers
  - Weakness of pupils' theoretical background
  - Lack of teaching and learning resource centres at schools
  - Current textbooks and lab manuals dissuade teachers from addressing this type of activity.

7.2. some conclusions from the present research's findings:

A number of conclusions based on this study are possible as follows:

- Carrying out laboratory sessions depend on the situations and conditions of teachers but not to the need of the taught topic.
- The situation in the lab is that a minority may participate while the majority is not aware of what is happening.
- Several experiments have never been carried out either because they involve unavailable chemicals or they require a long time to complete.
- There is no practical assessment and no credit is given for practicals. It is possible to complete the course without any practical activity.
- Practical activities are not conducted as investigations or problem-solving strategies. Learners have little opportunity to identify their own problems, play a role in the development of appropriate experiments and collect and interpret data themselves. Their learning may be "minds off" rather than "minds on" in the sense that the cognitive skills associated with problem solving take second place to the following of instructions, which are often poorly understood.

- Generally, laboratories for science are widely under-utilised or wrongly used, i.e. they are used for traditional class teaching. Maintenance of equipment and refurbishing of consumables is a major problem.
- Much of traditional practical work should be replaced by theoretically more sound and pedagogically more useful learning methods.
- There is neither co-ordination nor integration between the pre-service lecturers and in-service inspectors.
- Pre-service training is insufficient qualitatively while in-service training is seldom applied to the concept of investigation.
- Teachers generally believe that all is well in science teaching in Oman but this view might be challenged by an objective observer.
- Teachers are dominated by inspectors and have to "follow the party line".
- A major aim of practical work should be the engagement of learners in holistic investigations in which they use the processes of science both to explore and develop their conceptual understanding.

7.3. The Remedy for this Paradox

What we have seen so far is that learning in the laboratory situation may result in a state of working memory overload because of the large amount of information given at once. The overload also occurs when the learner is incapable of discriminating between the "noise" and "signal" in the laboratory instruction. Also overload arises due to the incidental information given by the teachers and demonstrators which contributes to an increase in "noise" and it becomes difficult for the learner to recognise the "signal". Further some laboratory manuals introduce unnecessary amount of information for the learner to cope with, thus adding to "noise".

Our conception of practical work should therefore be expanded to include other active-learning methods. After being tested and tried by the researcher and many teachers, the **TOPs** method could become popular and be **an** (if it is not **the**) alternative to the normal bench demonstration if its ideas are clearly demonstrated and if it satisfies and convinces both teachers and inspectors. The key of this new technique is that the teacher could control the learning situation but still put the pupils in a position to decide (a) what is important and what is trivial, (b) which measurement should be done accurately and which roughly, (c) which observations are essential and which could be ignored and (d) what is vital relevant information and what is merely "noise".

In addition, as proved statistically from the questionnaires, the noise of frustration is reduced, since phenomena here are more visible than in bench demonstration. Besides, in our experiments, learners responded stating that they participated (manually) and discussed (mental participation) more in the case of TOPs than in their normal demonstration lessons. Since the teacher can have control in both TOPs and conventional demonstrations, the last two advantages certainly suggest that TOPs is preferable.

Moreover, as a bonus, TOPs brings additional benefits of safety, cost, speed, durability, visibility, student-friendliness and easy disposal of smaller quantities of chemicals.

Subsequently, it is my hope and wish for this project to be put into effect by those incharge of education in Oman and for this simple technique to see the light of day and eventually to justify the 3-years of gestation which has gone into it.

There are some recommendations and endorsements which I would like to present and send to people involved in education in Oman (teachers, trainers and inspectors).

7.3.1. The research's message for teachers:

If the extraneous material which causes so much of the overload is regarded as "noise" and the important material as "signal", then the ratio of former to the later is high in the existing methods of conducting practical work. Likewise, bearing in mind class size, demonstration is inevitable and the only way to carry out practical activities at present. There are many instances in which this new method (**TOPs**) would become the essential technique which could reduce the "noise" and enhance the "signals" since the teacher could control things that matter and reduce, or eliminate peripherals. Moreover, it could ease some of the load on teachers as well as greatly enhancing the learning process.

If experiments are shown to the pupils during the explanation, pupils will be able to relate back and remember what they have been doing in the laboratory and connect the two together. This will make their practical work more meaningful. However, there is a danger when teachers start to misuse the demonstrations in such a way that pupils become just observers.

In the situations where individual practical work is done, the "noise" to "signal" ratio is so high that the "signal" is often not apparent to the learner. But, whilst demonstrating, using the TOPs method, teachers have the control and can suppress the "noise" and enhance the "signal" by focussing pupil attention.

In TOPs, a teacher has more control in the laboratory and saves time so that the syllabus can be finished in time. It will also save effort in organising the practical lesson since there is no need to go round the laboratory to deal with the pupils' needs and pupils can be saved from frustration because of restricted vision. This technique doubtlessly is safer than large scale and saves time, effort and resources. It is surprising how, with a little ingenuity, it is possible to devise experiments from everyday inexpensive items using tiny amounts of chemicals. Perhaps more surprising is how these experiments are clearly visible even from the back of a room and are able to provide the means for developing many of the skills that would be developed conventionally by a full scale laboratory experience. In most cases, experiments by this method do not necessarily have to be carried out in the confines of the laboratory and so the integration of practical and theory can become the norm rather the exception in a normal classroom.

7.3.2. The research's message for the trainers and inspectors:

- It is strongly recommended that science teachers at all school levels should be encouraged to use a problem-solving strategy and investigative methods in their practical sessions since they are such important ways of teaching to enhance the scientific method of thinking. To do so, pupils' text-books should include such activities.
- Both pre- and in-service training should include programmes and courses on how to go about solving problems in the laboratory and what are the relevant competences.
- **"What do we learn"** is the major issue of science. It might be true that to have fun and to entertain is one aim of science, to show that science is neither dull nor boring, BUT the major aspect is to focus on learning. By using TOPs, demonstrations can be born again. This new baby is not the same old demonstration method in another jacket, but one which engages learners' hands and minds instead of engaging them only in manipulating apparatus or chemicals (individual experimenting) or leaving them watching in a big theatre passively (normal bench demonstration).

- ❖ Science rooms, and multipurpose specialised rooms with science kits, are an acceptable alternative to laboratories at primary and even preparatory levels. Even at secondary level, most learning objectives can be achieved through TOPs work, which does not require laboratories. Multipurpose rooms are a reasonable solution in resource-poor systems.
- ❖ The quantity of laboratory-based work should be considered in the light of the learning gains associated with it. It may be that shorter and simpler experiments, along with simple practical demonstrations (which might be unsuitable as individual practicals) are a preferable and more cost-effective option compared to curricula that assume individual experimenting should take place virtually every period.
- ❖ Wherever possible, practical work should be designed with costs in mind to make appropriate experiments available to relatively poorly endowed schools which have large classes.
- ❖ Expensive and rarely used equipment should be eliminated from the science curriculum wherever possible and high-cost individual items should be avoided, especially if infrequently used.
- ❖ Imported equipment should always be assessed to determine whether local alternatives of adequate quality could be produced.
- ❖ Appropriately designed science tool kits should be considered as an alternative and or as a supplement to the existing equipment base where costs precludes comprehensively equipping all schools.
- ❖ If TOPs is deployed, advice on kits, materials and methodology should be part of an implementation package.

7.4. Suggestions for further study:

As in any other research study, a researcher may find, at the end of the day, questions have arisen unexpectedly from the research. Each question can be a point of departure for further studies and researches. Some suggestions are offered below:

- ❖ To confirm this study's data and to eliminate the halo-effect for TOPs as a new teaching method, further research could take place to re-examine and double-check the findings and trends. This may be held in the same area in which this research took place or at any other location in that area. It could also be worth conducting similar research in another country of similar resources and background.

- Since scientific investigations have been relatively neglected or very recent in Omani teaching, a few questions may arise:
    - Why is investigation rare in school laboratories? Or in what way is it conducted (if it exists) and has it a positive effect on measured achievement?
    - To what extent do learners use investigative methods to solve scientific problems?
    - What is the effect of investigation on promoting thinking and developing science processes in pupils?
    - What is the relationship between the way teachers understand investigation and the way their pupils use it?

Research along these avenues should be encouraged.

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and

Additional Readings

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Appendices

APPENDIX 2.1

120 Objectives for Practical work

120 different objectives for practical work

(Source: Kirschner,PA and Meester,MAM, 1988)

I- To obtain good (scientific) attitudes

- To formulate a problem

- To identify the nature of a problem

- To survey the literature

- To choose and evaluate useful literature

- To make decisions

- To make personal investigative decisions

- To show self-confidence using these decisions

- to demonstrate a critical attitudes

- To demonstrate the critical and questioning approach which must be adopted by any scientist doing original research work.

- To apply a logical reasoning method of though

- To exhibit self-confidence and independence.

- To exhibit confidence in the subject

- To exhibit confidence in one's own skills

- To take initiative
- To tackle a problem alone
- To plan ahead

- To use time efficiently

-To organise work and work space

- To be orderly

- To interpret the reliability and meaning of results in the widest sense
- To elucidate theoretical work as n aid to comprehension
- To apply principles and attitudes of experimental science (physics, biology and chemistry)
- To apply one's own insights, discoveries and conclusions.
- To formulate generalisation and models
- To define limitations
- To display an open mind
- To works in group when necessary
- To work independently when necessary
- To fulfil an active role in the scientific process
- To exhibit skills inherent to professionals in a chosen field.

II- To understand the scientific method

- to deduce the relation between science and nature

- to show an intuitive understanding of the nature of a variety of phenomena
- to show an analytical understanding of the nature of a variety of phenomena
- to relate theory and experiment
- to test simple theories to their limits of applicability
- to make phenomena more real through experimentation using models
- to explain the facts, theories and principles discussed in the lectures
- to verify facts and laws
- to build a framework for facts and principles occurred in the theory (lectures)
- to use the laboratory work as a process of discovery
- To stimulate the conditions in research and developments laboratories.
- To operate from a scientific point of view
- To experience the intellectual challenge of the experimental method
- To experience the joys and sorrows of experimenting
- To experience a kinship with the scientist
- To have a laboratory experience like that enjoyed by scientists in the past and in the present
- To experience deeper understanding of the discipline studied
- To show the spirit of scientific inquiry and the essence of scientific thinking
- To show interest in the subject area or in science

General and specific objectives

(1) To formulate hypotheses

- To formulate hypothesis using theories
- To translate a conceptual definition of a quantity into a set of measurement procedures

(2) To solve problems

- To solve problems by identifying and defining the nature of smaller problems contained in a larger problem
- To solve problems in a multi-solution situation
- To derive and evaluate relationships
- To use experimental data to solve specific problems
- To solve difficult problems involving the use of scientific facts in laboratory situations
- To understand what an experiment is, what is to be measured and how
- To approach a (physical, biological and chemical) system by identifying variables and using experimental methods to determine empirical relationships
- To solve problems by critical evaluation of the results of the different steps

(3) To use knowledge and skills in unfamiliar

- To apply knowledge in solving new problems
- To apply existing principles in new situations

- To recognise and define problems
- To construct and test complex models based on experimental findings in simple models of phenomena
- To construct new models which fit the evidence instead of confirming more complex theories
- To work oneself out of tight places
- To apply the common place as well as the fundamental

(4) To design (simple) experiments to test hypotheses

- To design an experiment to test or verify the theory
- To properly plan an experiment
- To design observation techniques
- To design new or subsequent experiments involving the phenomena
- To recognise hazards and appropriate safety precautions.

(5) To use laboratory skills in performing (simple) experiments

- To understand and follow instructions
- To exhibit manipulative skills
- To set up laboratory equipment quickly and correctly
- To manipulate apparati
- To conduct experiments making use of the phenomena without endangering the apparatus
- To know and apply some generally useful measuring techniques for improving reliability and precision
- To exhibit basic laboratory techniques
- To handle modern equipment
- To calibrate instruments
- To carry out accurate measurements
- To observe phenomena both qualitatively and quantitatively
- To observe substances both qualitatively and quantitatively
- To be flexible in modifying experiments
- To handle waste in relation with safety and environmental aspects in a proper way

(6) To interpret experimental data

- To collect and process experimental data
- To apply operational definitions to relate symbolic concepts to observed quantities
- To analyse experimental data
- To apply broadly based principles rather than computation of formula in the theoretical analysis of the lab experiment
- To apply elementary notions of statistics(e.g. random errors, systematic errors, mean values, uncertainty and confidence limits)

- To decide how errors in direct measurements may contribute to errors in a derived measurement
- To deduce answers from experimental data in a logical way
- To reliably estimate the outcome of the experimental measurements within a given precision
- To evaluate the outcome with regard to the hypothesis
- To make estimates and order-of-magnitude calculations
- To incorporate unexpected results in the new theory
- To generalise from data

(7) To clearly describe the experiment

- To summarise the important aspects of an experiment based on observations and collected data
- To articulate the central goal of an experiment, its underlying theory and its basic methods
- To define the scope and limiting conditions of the experimental techniques used
- To communicate in written form
- To communicate in oral form
- To keep a day-to-day laboratory diary in such a way that a third person can repeat the experiments
- To discuss results and suggest follow-up work

(8) To remember the central idea of an experiment over a significantly long period of time

- To present the essentials of an experiment in a written form, without using the lab notes
- To used the gained knowledge and skills in interpreting more recent literature data
- To design future experiments in the same field of research

APPENDIX 3.1

Common Structure of Laboratory Manuals in Oman

(Recipe Task)

The original recipe presentation (The common structure)

The relationship between reactant concentration and reaction rate

Equipment

Stirring rod, funnel, 5x 100mL beakers, 4x 100mL standard flasks, labels, timer. Scissors, concentrated hydrochloric acid (6M), distilled water, magnesium ribbon, graph paper, pen, ruler.

Method

1- Check with the teacher regarding the safety instructions for handling and using concentrated acid.

2- Working with a partner, carefully pour 50mL of 6M hydrochloric acid solution (A) into a 100mL standard flask and make this solution up to the mark and mix it well. Label this solution B, 3M.

3- Pipette 50mL of solution B into another 100mL standard flask and make this solution up to the mark and mix it well. Label this solution C, 1.5M. Pour the remaining solution into a 100mL beaker.

4- Pipette 50mL of solution C into another 100mL standard flask and make this solution up to the mark and mix it well. Label this solution D, 0.75M. Pour the remaining solution into a 100mLbeaker, pipette 50mL of solution D into a 100mL beaker.

5- Take a strip of magnesium ribbon and cut off four 0.5-cm pieces.

6- Place one strip into solution A and start timing the reaction until all of the magnesium is dissolved. Record the time in the table copied into your notes.

7- Repeat the previous step with a new magnesium strip for each of solutions B, C and D.

8- Repeat steps 1-7 twice to obtain a second and third set of results which you should average with the first.

9- Draw up a graph of your results with time as the vertical axis and concentration as the horizontal axis. Plot your results on the graph and make a comment about whether a linear relationship exists between acid concentration and the rate at which magnesium dissolves.

APPENDIX 3.2

Reworking Structure Task

The restructured presentation.

The relationship between reactant concentration and reaction rate

Information

You are provided with a supply of magnesium strip and with 6M hydrochloric acid. This acid is fairly concentrated and you should observe the usual precautions when handling it. You also have distilled water, which you can use to dilute the acid solution. As the metal dissolves, hydrogen gas evolves.

Your task

Your task is to investigate the relationship between the concentration of hydrochloric acid and the rate at which magnesium will dissolve. With your partner, you should design an experimental method, and, when your design has been approved by the teacher, perform experiments relevant to exploring this relationship.

Initial risk assessment

1. Considering the equipment available, what safety considerations may need to be considered in this experiment?
2. Perform a trial reaction to gain a feel for the reaction and potential risks.
3. Amend or improve your ideas for a) as necessary.

Overall design

- What will be your overall experimental design? Discuss it with your partner and jot down notes.
- How will you measure rate?
- What will be different in each trail (what is the variable being investigated)?
- What will need to be the same in each trial (what variables will you control)?
- How many trials should you perform to be confident for your results?
- How many trials will you have time to do?

The manipulated variable

- What is the manipulated variable?
- **What volume will you use in each trial?**
- What concentrations will you test? How will you measure and represent your dilutions?
- What volume of acid and water will you use to make your solutions? Draw a table to show the volumes of water and acid required to make each dilution.

The magnesium

- How much magnesium ribbon will you in each trial?
- Will you measure it as a length, area or mass? Will it have to be the same quantity for each trial? Why/ why not? Does the quantity of magnesium have to be measured quantitatively? Why / why not?
- What quantity will be best to use so as to not waste time?

Managing you equipment

- Plan how you will carry out each trial
- What glassware will you use and why will you choose it rather than other equipment?
- **How will you keep track of the different solutions you will make up?**
- What apparatus will hold the magnesium and acid?
- What apparatus will you use to measure time?

- You may find it helps to draw a plan view of your bench to show how you will set out your equipment on the bench.

Working cooperatively

- How will you share the work with your partner?
- Can each of you do a different part of the investigation or is it best to do some or all of it together?
- How will you make sure that you both know and understand what is being done?

Final risk assessment

- After you have worked out your plan, check through it carefully and make a note of any possible dangers and what safety precautions will be needed.

Recording and communicating

- How you will organize and present your data and report on the investigation?
- What information will you include about what was done?
- How do you think the results could be recorded and effectively presented?

Feedback and approval

- When you have finished and recorded your planning, talk it through with another group and discuss any differences between your plans and theirs.
- Present your proposal to your teacher for feedback and approval.
- Do not begin till you have your teacher's approval of your plan.

APPENDIX 4.1

Topics of Omani Science (Chemistry) Syllabuses

First preparatory (year 7)

Term 1

Unit 1: Living things and their adaptation

Chapter 1- Adaptation of living things
Chapter 2- Body structure of living things
Chapter 3- Senses of the living things
Chapter 4- Excretion in the living things

Unit 2: The matter and its changes

Chapter 1- The matter and its states
Chapter 2- Changes of matter

Unit 3: Force, Movement and Pressure

Chapter 1- Movement
Chapter 2- Force
Chapter 3- Pressure

Term 2

Unit 4: Sound

Chapter 1- How sound arises
Chapter 2- Sound movement
Chapter 3- Types of sounds
Chapter 4- Sound and telecommunications

Unit 5: Temperature

Chapter 1- Measurement of temperature
Chapter 2- Temperature effects on the matter
Chapter 3- Thermal expansion

Unit 6: The magnet and electricity

Chapter 1- The properties of a magnet
Chapter 2- The magnetic field
Chapter 3- Electromagnetism

Unit 7: Health

Chapter 1- Diseases
Chapter 2- GP visit

Second preparatory (year 8)

Term 1

Unit 1: Reproduction of the living things

Chapter 1- The animal and plant reproduction
Chapter 2- Reproduction of human beings

Unit 2: The matter and its structure

Chapter 1- The structure of matter
Chapter 2- The chemical reactions
Chapter 3- The atomic structure of elements and compounds

Unit 3: Light

Chapter 1: Mirrors and reflection
Chapter 2: Light refraction
Chapter 3: Vision- prism- colours

Term 2

Unit 4: Power and tools

Chapter 1- Work and power
Chapter 2- Tools

Unit 5: Electricity

Chapter 1- Static electricity
Chapter 2- Current electricity

Unit 6: The Earth, universe and time

Chapter 1- The universe
Chapter 2- The Earth, space and time

Third preparatory (year 9)

Term 1

Unit 1: The Earth (a living planet)

Chapter 1- The Earth is the human medium
Chapter 2- The Earth various resources
Chapter 3- Rocks

Unit 2: Electromagnetism

Chapter 1- Current electricity
Chapter 2- Influences of electrical current
Chapter 3- Electricity and Magnetism

Unit 3: Water and air

Chapter 1- Water
Chapter 2- Air

Term 2

Unit 4: Genetics

Chapter 1- Mendel's Experiments
Chapter2- Human genetics

Unit 5: Solar energy and electromagnetic waves

Chapter 1- Solar and electromagnetic waves
Chapter 2- Solar energy in the Earth

Unit 6: Mining and chemical industries

Chapter 1- Metals
Chapter 2- Metal extraction
Chapter 3- Oil

First Secondary (year 10)

Term 1

Unit 1: Introduction to chemistry

Unit 2: Atoms and molecules

Chapter 1: Valency
Chapter 2: Atomic & molecular mass
Chapter 3: The mole

Unit 3: Chemical reactions

Chapter 1: Chemical equations
Chapter 2: Chemical reactions

Unit 4: Atomic particles

Chapter 1: Atoms' Particles
Chapter 2: Isotopes

Unit 5: Atomic structure

Chapter 1: Dalton's, Rutherford's and Bohr's models
Chapter 2: Quantum numbers
Chapter 3: Electrons arrangement

Term 2

Unit 6: The periodic table and periodicity

Chapter 1: Mendeleev's table
Chapter 2: The modern periodic table
Chapter 3: Periodicity in the periodic table

Unit 7: The chemical bonds

Chapter 1: Ionic bond
Chapter 2: Covalent bond
Chapter 3: Bonds between molecules

Unit 8: Ionic and covalent compounds

Chapter 1: Melting & boiling points
Chapter 2: Electrical conductivity
Chapter 3: Solubility

Unit 9: Groups IV and V

Chapter 1: Group IV
Chapter 2: Carbon
Chapter 3: Group V
Chapter 4: Phosphorus

Unit 10: Groups VI, VII

Chapter 1: Group VI
Chapter 2: Oxygen
Chapter 3: Group VII
Chapter 4: Chlorine

Second Secondary (year 11)

Term 1

Unit 1: Liquids and solutions

Chapter 1: Liquids' properties
Chapter 2: Solutions
Chapter 3: Solubility
Chapter 4: Concentration
Chapter 5: Solutions' properties

Unit 2: Thermochemistry and thermodynamics

Chapter 1:Thermochemistry
Chapter 2: Thermodynamics

Unit 3: Chemical equilibrium

Chapter 1: Reversible and irreversible reactions
Chapter 2: Chemical equilibrium

Term 2

Unit 4: Acids, bases and salts

Chapter 1: Theories of acids and bases
Chapter 2: Acids & bases and Ionisation
Chapter 3: Salts

Unit 5: Organic chemistry (I)

Chapter 1: Organic compounds
Chapter 2: Aliphatic hydrocarbons
Chapter 3: Aromatic hydrocarbons

Third Secondary (year 12)

Term 1

Unit 1: Electrochemistry

Chapter 1: Oxidation & reduction
Chapter 2: Electrochemical cells

Unit 2: Metals and extraction processes

Chapter 1: Metals extraction
Chapter 2: Transition metals

Unit 3: Analytical chemistry

Chapter 1: Chemical analysis
Chapter 2: Dilution
Chapter 3: Titration
Chapter 4: Analysis for cations

Term 2

Unit 4: Organic chemistry (II)

Chapter 1: Functional groups
Chapter 2: Alcohols
Chapter 3: Ethers
Chapter 4: Aldehydes and ketones
Chapter 5: Carboxylic acids and esters
Chapter 6: Amines and amides
Chapter 7: Isomers

Unit 5: Biochemistry

Chapter 1: Carbohydrates
Chapter 2: Lipids
Chapter 3: Proteins
Chapter 4: Hormones
Chapter 5: Vitamins

Unit 6: Industry

Chapter 1: Petrochemicals
Chapter 2: Polymers
Chapter 3: Seawater industry

APPENDIX 5.1

Teachers' and Pupils' Questionnaires for Practical Work

Dear Teacher:

This questionnaire intends to survey the nature of practical work and demonstration and how they have been carried out in schools in the Sultanate of Oman. Please note:
1) If you are involved in practical work, please fill Part **A** only (ignore part **B**)
2) If you are **not** involved in practical work, please fill Part **B** only (ignore part **A**)

School: .... **Taught Classes:**........................

Part A

To make your demonstration effective, there are some things you may do before, during and after.
A few are listed below. Please give your response.
We are interested in statistical aggregate, all information will be confidential and for research purposes only.

I- <u>Before Demonstration</u>, it is important to:

	Agree	Disagree
1. Give pupils the purpose of experiments and how they relate to the topics	☐	☐
2. Highlight the concepts pupils should pay attention to in experiments	☐	☐
3. Prepare in advance all required chemicals and apparatus to be used in experiments	☐	☐
4. Pre-test the experiments before starting laboratory sessions	☐	☐
5. Ensure that laboratory arrangements will allow pupils in the class to observe what is going on in experiments	☐	☐
	☐	☐

Any additional comments
....

II- <u>During Demonstration</u>, to make it effective, it is necessary to:

1. Ensure that all pupils can follow and understand the experiments' procedure	☐	☐
2. Re-demonstrate when necessary and when pupils need further help or feel confused	☐	☐
3. Ask pupils to write their observations about the experiments	☐	☐
4. Allow pupils to participate in the experiment when possible	☐	☐

Any additional comments
....

III- <u>After Demonstration</u>, to make it effective, it is necessary to:

1. Ensure that the experiments have achieved the planned objectives	☐	☐
2. Create questions and discussions to promote understanding	☐	☐
3. Summarise the experimental results to help understanding	☐	☐
4. Encourage pupils to conduct some experiments themselves when possible to explore the real life of chemists	☐	☐

Part B

You have indicated that you do not perform demonstration or practical. This may be because of difficulties in your schools. Give us your views by responding to the questions below.

We are interested in statistical aggregate: all information will be confidential and for research purposes only.

Difficulties:

1. Related to Laboratory

	Agree	Disagree
a) No laboratory is available in our school	☐	☐
b) There are inadequate laboratory materials (apparatus, equipment, chemicals) for experiments	☐	☐
c) Safety precautions are poor (ventilation, fire apparatus, first aid kits)	☐	☐
d) There is inadequate technician support	☐	☐
e) The laboratory does not have adequate supplies of:		
I) Gas	☐	☐
II) Water	☐	☐
III) Electricity	☐	☐

Any additional comments ....

....

2. Related to School

	Agree	Disagree
a) The school does not have funds to finance laboratory requirements	☐	☐
b) There is no encouragement from the administration to make use of the laboratory for teaching	☐	☐
c) There is a deficiency in practical training programs for teachers	☐	☐
d) Classes are too large for laboratory work	☐	☐

Any additional comments ....

....

3- Related to Curriculum

	Agree	Disagree
a) Practical work marks have been disregarded in the final exams	☐	☐
b) Time allocated by school for teaching the subject is limited,	☐	☐
there is no extra time to run laboratories	☐	☐
c) There is no timetable allocated for the laboratory	☐	☐
d) Teachers are too busy teaching to have time to run laboratory sessions	☐	☐
e) Practical experiments are not compatible with what pupils have learnt or what they should comprehend	☐	☐
f) There is no emphasis by the curriculum on doing chemistry at the laboratory	☐	☐
g) Practical works gets in the way of theory and causes confusion	☐	☐

Any additional comments ....

....

4- Related to you as Science Teachers

a) I believe that the laboratory will not help my teaching of chemistry	☐	☐
b) I have not been trained to use apparatus or equipment in the laboratory	☐	☐
c) Since there is little emphasis on practical work, I lack experience in performing chemistry experiments	☐	☐
d) Unlike normal classes, I feel that pupils could get out of control in laboratories leaving little room for learning	☐	☐

Any additional comments ....

....

Thank you for co-operation

Dear pupil :

This questionnaire intends to identify your opinion about practical work and to whatextent it would meet your curiosity. Please answer as many statements as you can.

Your answers will never affect your school work or exams in any way. The questionnaire's results are for research purposes only.

School : .... **Class : ....**

	Agree	Uncertain	Disagree
1- The teacher explains in advance the general purposes of each experiment.			
2- The teacher marks my lab book after lab sessions.			
3- Teachers use a variety of equipment in the laboratory (e.g. OHP, TV, video, etc.) to promote our understanding.			
4- The teacher solely controls laboratory sessions leaving no room for us to participate			
5- Laboratory work never helps my understanding of chemistry topics.			
6- I prefer a revision session for any chemistry topic, than attending a laboratory session about it.			
7- Laboratory sessions assist me to understand complicated topics in chemistry.			
8- I feel that laboratory requirements (e.g. measurements, manipulations, etc.) are difficult to cope with.			
9- Laboratory discussions (pupil-pupil, teacher-pupil) are helpful and could enhance my understanding.			
10- School examinations disregard any laboratory experiments (marks).			
11- I believe that the laboratory is a vital part in learning chemistry.			
12- I feel more interested in chemistry when doing practical experiments in the laboratory.			
13- I feel that i gain little from experiments since they are higher than my school level.			
14- Laboratory sessions are well organised and well prepared.			
15- We made numerous laboratory sessions this year.			
16- I feel that the laboratory is the means for verifying the theory.			
17- The laboratory shows me how chemists deal with real life scientific problems.			
18- The laboratory teaches me how to go about solving problems.			
Comments:			

Thank you for co-operation

APPENDIX 5.2

Teachers' and Pupils' Questionnaires for Practical Work

(Arabic version)

5-29

بسم الله الرحمن الرحيم

عزيزي المعلم / عزيزتي المعلمة :

هذا الاستبيان يهدف إلى مسح طبيعة العمل التجريبي والعرض العملي وكيفية إجرائها في مدارس سلطنة عمان.

الرجاء ملاحظة:

- إذا كنت تقوم بالعمل التجريبي أو العرض العملي دائما يرجى تعبئة القسم (أ) دون القسم (ب).
- إذا كنت لا تقوم بالعمل التجريبي أو العرض العملي دائما يرجى تعبئة القسم (ب) دون القسم (أ).

المدرسة بنات سيناء الثانوية ...... الصفوف التي تدرسها (٣ ث) علوم عامة ٢ث ادبي — ٣ع

القسم (أ)

حتى يكون العمل التجريبي (العرض العملي) فعّالا، هناك بعض الأمور التي تأخذها في اعتبارك قبل وأثناء وبعد إجرائه.

القائمة التالية بها بعض الأمور، لطفاً ضع استجابتك أمام كل عبارة، مع مراعاة أن المعلومات هنا ستعمل بمنتهى السرية وهي لأغراض البحث العلمي فقط.

م	العبارة	موافق	غير موافق
	قبل العرض ، ينبغي على المعلم أن:		
١	يعطي التلاميذ الهدف من التجربة وكيفية ارتباطها بالدرس النظري.	✓	
٢	يبرز المفاهيم والنقاط التي يطلب من التلميذ الانتباه إليها.	✓	
٣	يعد مسبقا جميع الأدوات والمواد المطلوبة والمستخدمة في التجربة.	✓	
٤	يجري التجربة قبل بدء حصة المختبر.	✓	
٥	يتأكد أن ترتيب المختبر يسمح لجميع التلاميذ مشاهدة ما يجري في التجربة.	✓	
	أية إضافات أخرى		
	أثناء العرض ، ينبغي على المعلم أن:		
١	يتأكد أن جميع التلاميذ يستطيعون متابعة واستيعاب (فهم) خطوات التجربة.	✓	
٢	يعيد العرض عندما يلزم أو حينما يحتاج التلاميذ إلى ذلك.	✓	
٣	يطلب من التلاميذ تدوين ملاحظاتهم عن التجربة.	✓	
٤	يسمح للتلاميذ بالمشاركة في التجربة قدر الإمكان.	✓	
	أية إضافات أخرى		
	بعد العرض ، ينبغي على المعلم أن:		
١	يتأكد أن التجربة قد حققت الأهداف المتوخاة منها.	✓	
٢	يخلق (يبتكر) أسئلة مناقشة للارتقاء بفهم التلاميذ.	✓	
٣	يلخص نتائج التجربة للمساعدة على فهمها.	✓	
٤	يشجع التلاميذ لإجراء بعض التجارب بأنفسهم قدر الإمكان.	✓	
	أية إضافات أخرى		

القسم (ب)

عزيزي المعلم:

لقد أشرت إلى أنك **لا** تقم بالعمل التجريبي أو العرض النظري ، وربما ذلك بسبب صعوبات في المدرسة التي أنت فيها.

أفصح عن رأيك بإعطاء استجابة للعبارات التالية ، مع ملاحظة أن المعلومات المعطاة ستعامل بمنتهى السرية وهي لأغراض البحث العلمي فقط.

م	الصعوبة	موافق	غير موافق
	صعوبات تتعلق بالمختبر		
١	عدم وجود قاعة أو غرفة خاصة بالمختبر.		
٢	قلة الأدوات والأجهزة المعملية في المختبر.		
٣	عدم توفر وسائل الأمن والسلامة في المختبر.		
٤	عدم تعاون مشرف (فني) المختبر في إعداد وتحضير مستلزمات التجارب		
٥	عدم توافر الإمدادات الضرورية من : أ- الماء		
	ب- الكهرباء		
	ج- الغاز		
	أية إضافات أخرى:...		
	صعوبات تتعلق بالمدرسة		
١	عدم تعاون المدرسة والإدارة التربوية في تمويل المستلزمات المختبرية		
٢	عدم تشجيع الإدارة المدرسية والتربوية المعلمين استخدام المختبر في التدريس		
٣	النقص في برامج التدريب العملي للمعلمين		
٤	الصفوف كثيرة العدد لاستخدام المختبر وبالتالي صعوبة ضبط التلاميذ		
	أية إضافات أخرى:		
	صعوبات تتعلق بالمنهج		
١	عدم شمول الامتحانات العامة الجانب العملي في تدريس العلوم		
٢	وقت الحصة المدرسية غير كاف لإجراء التجارب المختبرية		
٣	عدم وجود حصة (حصص) خاصة بالمختبر في البرنامج المدرسي		
٤	كثرة عدد الحصص التي يدرسها معلم العلوم أسبوعيا (العبء الدراسي)		
٥	عدم توافق الجانب العملي مع الجانب النظري أو مع ما درسه التلاميذ		
٦	عدم تأكيد المناهج الدراسية على الجانب العملي		
٧	الجانب العملي قد يؤدي إلى الازدواجية مع الجانب النظري		
	أية إضافات أخرى		
	صعوبات تتعلق بك كمعلم علوم / كيمياء		
١	أعتقد أن المختبر غير مجد في تدريسي العلوم / الكيمياء		
٢	لم يتم تدريبي وإعدادي إعدادا مناسبا لإجراء التجارب المختبرية		
٣	النقص في التأكيد إلى الجانب العملي قللت من اكتسابي المهارة المختبرية		
٤	صعوبة ضبط التلاميذ في المختبر ، وبالتالي قلة ناتج التعلم مقارنة مع غرفة الصف		
	أية إضافات أخرى:		

بسم الله الرحمن الرحيم

عزيزي التلميذ:

هذا الاستبيان يهدف إلى التعرف إلى آرائك ووجهة نظرك تجاه العمل التجريبي (المختبر) و إلى أي مدى يشبع فضوليتك العلمية من تساؤلات واستفسارات. يرجى الإجابة على أكبر قدر من العبارات التالية بإعطاء استجابتك المناسبة لها.

إن أجابتك لن تؤثر أبدا وبأي حال من الأحوال في درجة النشاط المدرسي أو نتيجة الامتحانات. هذه المعلومات ستعامل بمنتهى السرية وهي لأغراض البحث العلمي فقط.

المدرسة:...................... **الصف:**......................

م	العبـــــــــــــــــــــــارة	موافق	غير متأكد	غير موافق
١	يوضح المعلم الأهداف والفكرة العامة من التجربة قبل البدء فيها			
٢	يحثنا المعلم على تدوين ملاحظتنا وتسجيل النتائج التي توصلنا إليها			
٣	معلم العلوم يستخدم الكثير من الأجهزة التعليمية المتنوعة (الفيديو مثلا وغيره)			
٤	المعلم هو المسيطر والمالك للعمل التجريبي دون مشاركة للتلاميذ			
٥	العمل التجريبي لن يساعدني في فهم موضوعات العلوم / الكيمياء			
٦	أفضّل حصة مراجعة لموضوع ما بدلا من حصة المختبر لذلك الموضوع			
٧	ساعدني المختبر في فهم الكثير من الموضوعات الصعبة في العلوم / الكيمياء			
٨	أشعر أنه من الصعوبة الإلمام بـمتطلبات المختبر (القياس – التعامل مع الأدوات وغيرها)			
٩	مناقشات المختبر (بين الطلاب أنفسهم وبينهم والمعلمين) مفيدة و تؤكد الفهم وتوثقه			
١٠	الامتحانات المدرسية في العلوم لا تشمل تجارب العلوم / الكيمياء			
١١	أرى أن المختبر جزء هام وحيوي في تعلم العلوم / الكيمياء			
١٢	أشعر أن العلوم / الكيمياء مادة محببة لي عند إجراء التجارب في المختبر			
١٣	أشعر أن استفادتي قليلة من التجارب حيث أنها أعلى من مستواي التعليمي			
١٤	حصة المختبر منظمة ومرتبة جيدا			
١٥	لقد قمنا بإجراء عدد كبير من التجارب هذا العام (أكثرنا من ارتياد المختبر)			
١٦	أرى أن المختبر هو الوسيلة للتحقق والتثبت من النظرية			
١٧	يصف المختبر كيفية تعامل العالم والكيميائي مع المشكلات العلمية في الحياة اليومية			
١٨	علمني المختبر كيفية الوصول إلى حل للمشكلات			

أية إضافات أخرى:

شكرا لتعاونك معنـــا

علي بن هويشل الشعيلي

APPENDIX 5.3

Aims of Practical Work Questionnaires

Dear teacher,

These are a series of statements about practical work gathered from a large sample of teachers and we would be interested about your views on them. In the first column, would you please indicate whither you agree or not with each statement. In the second column, would you indicate if they are achieved in practice in your classes? If they are not please explain why not in the spaces provided.

School:................. Gender: M/F years of experience:.......

Practical work is done :

No	Statement	Agreement		Achievement	
		Agree	Disagree	yes	No* (explain below)
1	To instill confidence in science				
2	To learn basic practical skills				
3	To familiarize with important standard apparatus and measuring techniques				
4	To illustrate materials taught in lectures				
5	To train in observations				
6	To train in making deductions from measurements and interpretations of experimental data				
7	To use experimental data to solve specific problems				
8	To learn some theoretical materials not taught in lectures				
9	To foster a critical awareness (e.g. extraction of all information from the data; the avoidance of systematic errors)				
10	To help bridge the gap between theory and practical				
11	To stimulate and maintain interests in science.				

* Give reasons why not achieved:

Although not on the list above some writers suggest that the essential ingredient of practical work is to allow pupils to learn how to conduct an investigation.
Do you allow (encourage) your pupils to carry out investigations?
If so, give a short description of how you organize this. If not, would you please give reasons for this?
It may be that you agree with the idea of investigations, but can not do so for some reasons. We would like to have these reasons. On the other hand, you may disagree with the whole idea of investigations and again we would value your reasons. Please respond in the spaces below. If they are insufficient, continue your response on the back of the sheet.

....

....

....Thanks for cooperation.

Dear inspector,

These are a series of statements about practical work gathered from a large sample of teachers and we would be interested about your views on them. In the first column, would you please indicate whither you agree or not with each statement. In the second column, would you indicate if you, as a science inspector, assess teachers on that or not? If not please explain why not in the spaces provided.

Directorate :.................. Gender: M/F years of experience:........

Practical work is done :

No	Statement	Agreement		Assessment	
		Agree	Disagree	yes	No* (explain below)
1	To instill confidence in science				
2	To learn basic practical skills				
3	To familiarize with important standard apparatus and measuring techniques				
4	To illustrate materials taught in lectures				
5	To train in observations				
6	To train in making deductions from measurements and interpretations of experimental data				
7	To use experimental data to solve specific problems				
8	To learn some theoretical materials not taught in lectures				
9	To foster a critical awareness (e.g. extraction of all information from the data; the avoidance of systematic errors)				
10	To help bridge the gap between theory and practical				
11	To stimulate and maintain interests in science.				

* Give reasons why not achieved:

Although not on the list above some writers suggest that the essential ingredient of practical work is to allow pupils to learn how to conduct an investigation.
Do you encourage teachers to let pupils carry out investigations and evaluate them on it?
Is it included in your teacher-assessing sheet?
If you do not prescribe this, would you please give reasons?
It may be that you agree with the idea of investigations, but can not do so for some reasons. We would like to have these reasons. On the other hand, you may disagree with the whole idea of investigations and again we would value your reasons. Please respond in the spaces below. If they are insufficient, continue your response on the back of the sheet.

....
....
....

Thanks for cooperation.

23

Dear teacher trainer,

These are a series of statements about practical work gathered from a large sample of teachers and we would be interested about your views on them. In the first column, would you please indicate whither you agree or not with each statement. In the second column, would you indicate if you, as a science educationalist, train and practice student teachers on that or not? If not please explain why not in the spaces provided.

Directorate :................. Gender: M/F years of experience:.......

Practical work is done :

No	Statement	Agreement		Training	
		Agree	Disagree	yes	No* (explain below)
1	**To instill confidence in science**	18 78	5 23	74	
2	**To learn basic practical skills**	22 96	1 4	96	
3	**To familiarize with important standard apparatus and measuring techniques**	20 87	3 13	83	
4	**To illustrate materials taught in lectures**	23 100	– zero	100	
5	**To train in observations**	23 100	– zero	100	
6	**To train in making deductions from measurements and interpretations of experimental data**	23 100	– zero	100	
7	**To use experimental data to solve specific problems**	22 96	1 4	96	
8	**To learn some theoretical materials not taught in lectures**	16 70	7 30	65	
9	**To foster a critical awareness (** e.g. extraction of all information from the data; the avoidance of systematic errors**)**	19 83	4 17	83	
10	**To help bridge the gap between theory and practical**	23 100	– zero	100	
11	**To stimulate and maintain interests in science.**	21 91	2 9	91	

* Give reasons why not achieved:

Although not on the list above some writers suggest that the essential ingredient of practical work is to allow pupils to learn how to conduct an investigation

Do you practice student teachers to investigate let pupils carry out investigations?

What types of courses and programs do you use concerning this?

If you do not prescribe this, would you please give reasons?

It may be that you agree with the idea of investigations, but can not do so for some reasons. We would like to have these reasons. On the other hand, you may disagree with the whole idea of investigations and again we would value your reasons. Please respond in the spaces below. If they are insufficient, continue your response on the back of the sheet.

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Thanks for cooperation.

بسم الله الرحمن الرحيم

عزيزي المعلم/عزيزتي المعلمة:

تم تجميع العبارات أو الأهداف التالية من خلال تجربة عينة كبيرة من المعلمين فيما يتعلق بالعمل التجريبي، ونحن بصدد معرفة رأيك ووجهة نظرك فيها. لذا نرجو منك التكرم بأن تدلي بوجهة نظرك، وذلك بانتقاء المربع المناسب لموقفك من كل هدف على حدة من حيث الموافقة أو الرفض كخطوة أولى. أما الخطوة الثانية فتتعلق بالمجال التطبيقي، فإذا كنت -كمعلم علوم- تنجز وتقوم بذلك فيكتفى بوضع علامة (?) أما إذا لم تكن تقوم بأحد الأهداف فيرجى تبرير ذلك في الخانة السفلية المرفقة.

المدرسة:......................   الجنس: ذكر/ أنثى   عدد سنوات الخبرة:........................

من أهداف العمل التجريبي أن:

م	العبـــــــارة	موافق	غير موافق	هل تـقوم بـذلك؟ نـعـم	لا(أعط السبب) *
١	يغرس ثقة الطالب بالعلوم.				
٢	يعلم ويكسب مهارات عملية أساسية.				
٣	يعوّد على استخدام الأدوات الهامة وتقنيات القياس العلمي.				
٤	يثبت عمليا ما تم تدريسه نظريا.				
٥	يدرب الطالب على الملاحظة العلمية.				
٦	يدرب على عمل استنتاجات من القياسات والتفسيرات لبيانات التجربة.				
٧	يعزز التفكير العلمي لحل المشكلات المستقبلية.				
٨	يعلم بعض الأمور النظرية غير المتعلمة في الحصة الدراسية.				
٩	ينمي وعي انتقادي، مثل استخلاص معلومات من البيانات المعطاة مع تجنب الأخطاء.				
١٠	يعمل كقنطرة لسد الثغرة (الفجوة) بين العملي والنظري.				
١١	يثير الميول العلمية لدى الطالب.				

*ما هو السبب في عدم القيام بذلك؟

ولعل من أهم المقترحات التي يركز عليها الباحثون التربويون أن يعطى المتعلم الفرصة ليقوم بمهارة الاكتشاف والاستقصاء بنفسه. وحيث أنها لم تذكر في الجدول السابق، لذا رأينا أن نفرد لها حيزا خاصا.

فهل تمنح تلاميذك الفرصة (أو تشجعهم) على عمل ذلك ؟

إن كانت إجابتك بنعم، يرجى التفضل بإعطاء وصف مبسط لكيفية تنظيم وإجراء ذلك، أما إذا كانت الإجابة بلا فيرجى التعليل.

قد تتفق مع الرأي في أهمية التعلم بالاكتشاف والاستقصاء، ولكنك لا تستطيع تحقيقه لأسباب ما، نرجو الإفادة بذلك. ومن جهة أخرى، قد تكون مخالفا للفكرة مطلقا فبالمثل سنقدر وجهة نظرك ونحترم السبب من الرفض. لذا يرجى التفضل بإعطاء استجابتك ووجهة نظرك أدناه.

(أكمل على الظهر عند الضرورة)

....

....

....   شكرا لحسن تعاونك   علي بن هويشل الشعيلي

بسم الله الرحمن الرحيم

عزيزي الموجّه::

تم تجميع العبارات أو الأهداف التالية من خلال تجربة عينة كبيرة من المعلمين فيما يتعلق بالعمل التجريبي، ونحن بصدد معرفة رأيك ووجهة نظرك فيها . لذا نرجو منك التكرم بأن تدلي بوجهة نظرك، وذلك بانتقاء المربع المناسب لموقفك من كل هدف على حدة من حيث الموافقة أو الرفض كخطوة أولى. أما الخطوة الثانية فتتعلق بالمجال التطبيقي، فإذا كنت -كموجّه علوم- تقوم المعلمين على ذلك فيكتفي بوضع علامة ( ) أما إذا لم تكن تقوم بذلك فيرجى تبرير ذلك في الخانة السفلية المرفقة.

المديرية:........................ الجنس: ذكر/ أنثى عدد سنوات الخبرة:........................

من أهداف العمل التجريبي أن:

م	العبارة	موافق	غير موافق	هل تقوّم ذلك؟	
				نعم	لا (أعط السبب) *
١	يغرس ثقة الطالب بالعلوم.				
٢	يعلم ويكسب مهارات عملية أساسية.				
٣	يعوّد على استخدام الأدوات الهامة وتقنيات القياس العلمي.				
٤	يثبت عمليا ما تم تدريسه نظريا.				
٥	يدرب الطالب على الملاحظة العلمية.				
٦	يدرب على عمل استنتاجات من القياسات والتفسيرات لبيانات التجربة.				
٧	يعزز التفكير العلمي لحل المشكلات المستقبلية.				
٨	يعلم بعض الأمور النظرية غير المتعلمة في الحصة الدراسية.				
٩	ينمي وعي انتقادي، مثل استخلاص معلومات من البيانات المعطاة مع تجنب الأخطاء.				
١٠	يعمل كخطوة لسد الثغرة (الفجوة) بين العملي والنظري.				
١١	يثير الميول العلمية لدى الطالب.				

*ما هو السبب في عدم القيام بذلك؟

ولعل من أهم المقترحات التي يركز عليها الباحثون التربويون أن يعطى المتعلم الفرصة ليقوم بمهارة الاكتشاف والاستقصاء بنفسه. وحيث أنها لم تذكر في الجدول السابق، لذا رأينا أن نفرد لها حيزا خاصا.

فهل تشجع المعلمين وتحاول تدريبهم على ذلك ؟

إن كانت إجابتك بنعم: يرجى التفضل بإعطاء وصف مبسط لكيفية تنظيم وإجراء ذلك، أما إذا كانت الإجابة بلا فيرجى التعليل.

قد تتفق مع الرأي في أهمية التعلم بالاكتشاف والاستقصاء، ولكنك لا تستطيع تحقيقه لأسباب ما، نرجو الإفادة بذلك. ومن جهة أخرى، قد تكون مخالفا للفكرة مطلقا فبالمثل سنقدر وجهة نظرك ونحترم السبب من الرفض. لذا يرجى التفضل بإعطاء استجابتك ووجهة نظرك أدناه.

(أكمل على الظهر عند الضرورة)

....

....

.... شكرا لحسن تعاونك علي بن هويشل الشعيلي

بسم الله الرحمن الرحيم

عزيزي الدكتور:

تم تجميع العبارات أو الأهداف التالية من خلال تجربة عينة كبيرة من المعلمين فيما يتعلق بالعمل التجريبي، ونحن بصدد معرفة رأيك ووجهة نظرك فيها .لذا نرجو منك الكريم بأن تدلي بوجهة نظرك، وذلك بانتقاء المربع المناسب لموقفك من كل هدف على حدة من حيث الموافقة أو الرفض كخطوة أولى. أما الخطوة الثانية فتتعلق بالمجال التطبيقي، فإذا كنت -كأستاذ تدريس علوم - تطالب الطلاب المعلمين التدرب على ذلك فيكفي بوضع علامة ( ) أما إذا لم تكن تقوم بذلك فيرجى تبرير ذلك في الخانة السفلية المرفقة.

من أهداف العمل التجريبي أن:

م	العبارة	موافق	غير موافق	هل تقوم بذلك؟ نعم	هل تقوم بذلك؟ لا (أعط السبب) *
١	يغرس ثقة الطالب بالعلوم.				
٢	يعلم ويكسب مهارات عملية أساسية.				
٣	يعوّد على استخدام الأدوات الهامة وتقنيات القياس العلمي.				
٤	يثبت عمليا ما تم تدريسه نظريا.				
٥	يدرب الطالب على الملاحظة العلمية.				
٦	يدرب على عمل استنتاجات من القياسات والتفسيرات لبيانات التجربة.				
٧	يعزز التفكير العلمي لحل المشكلات المستقبلية.				
٨	يعلم بعض الأمور النظرية غير المتعلمة في الحصة الدراسية.				
٩	ينمي وعي انتقادي، مثل استخلاص معلومات من البيانات المعطاة مع تجنب الأخطاء.				
١٠	يعمل كقنطرة لسد الثغرة (الفجوة) بين العملي والنظري.				
١١	يثير الميول العلمية لدى الطالب.				

*ما هو السبب في عدم القيام بذلك؟

ولعلّ من أهم المقترحات التي يركز عليها الباحثون التربويون أن يعطى المتعلم الفرصة ليقوم بمهارة الاكتشاف والاستقصاء بنفسه. وحيث أنها لم تذكر في الجدول السابق، لذا رأينا أن نفرد لها حيزا خاصا .

فهل تشجع الطلاب المعلمين وتحاول تدريبهم على ذلك ؟

إن كانت إجابتك بنعم؛ يرجى التفضل بإعطاء وصف مبسط لكيفية تنظيم وإجراء ذلك ، أما إذا كانت الإجابة بلا فيرجى التعليل.

قد تتفق مع الرأي في أهمية التعلم بالاكتشاف والاستقصاء ، ولكنك لا تستطيع تحقيقه لأسباب ما ، نرجو الإفادة بذلك. ومن جهة أخرى ، قد تكون مخالفا للفكرة مطلقا فبالمثل سنقدر وجهة نظرك ونحترم السبب من الرفض . لذا يرجى التفضل بإعطاء استجابتك ووجهة نظرك أدناه.

(أكمل على الظهر عند الضرورة)

....

....

.... شكرا لحسن تعاونك علي بن هويشل الشعيلي

APPENDIX 6.1

Different Photos for TOPs Method at Different Distances

Photo 1: Ammonia fountain 3m from front bench

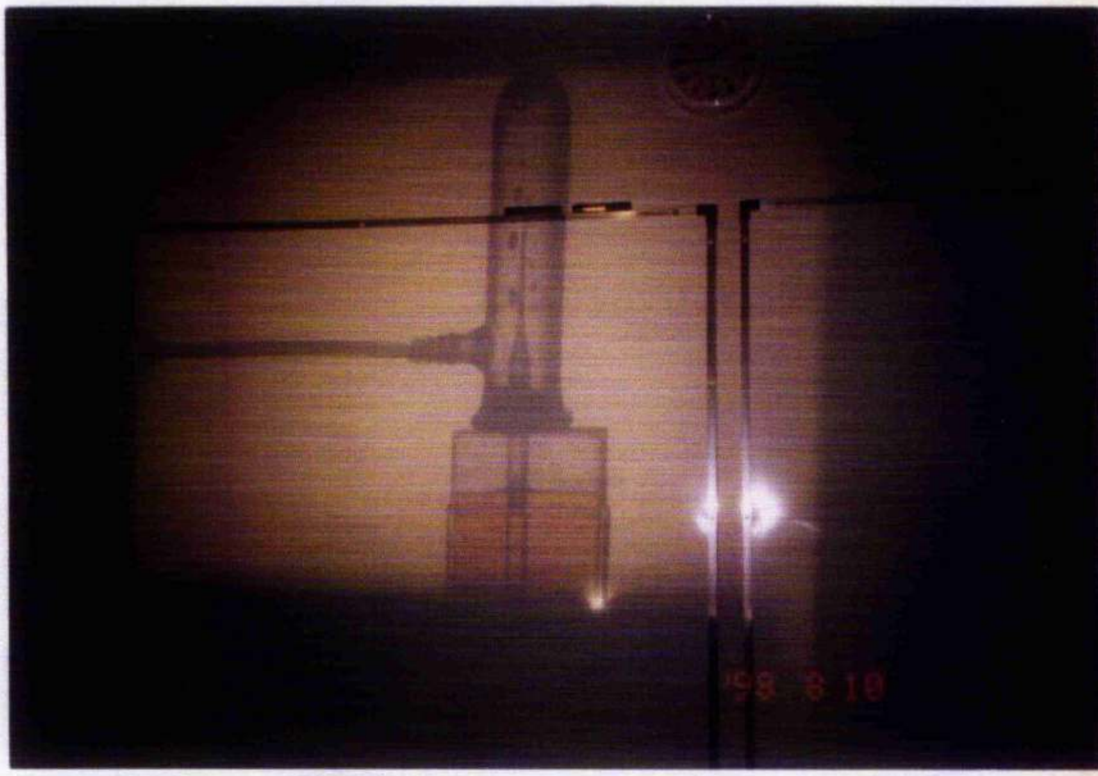


Photo 2: Ammonia fountain 6m from front bench

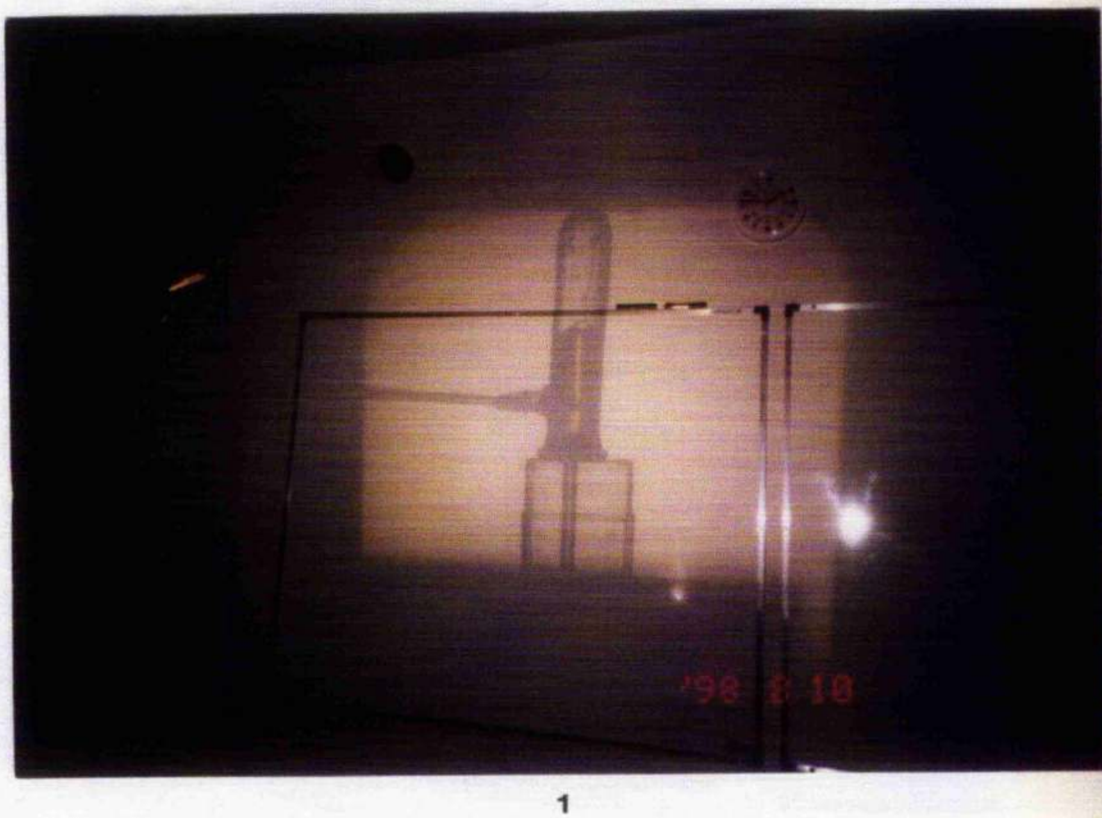


Photo 3: A conductivity experiment 4m from front bench

Photo 4: Aconductivity experiment 12m from front bench

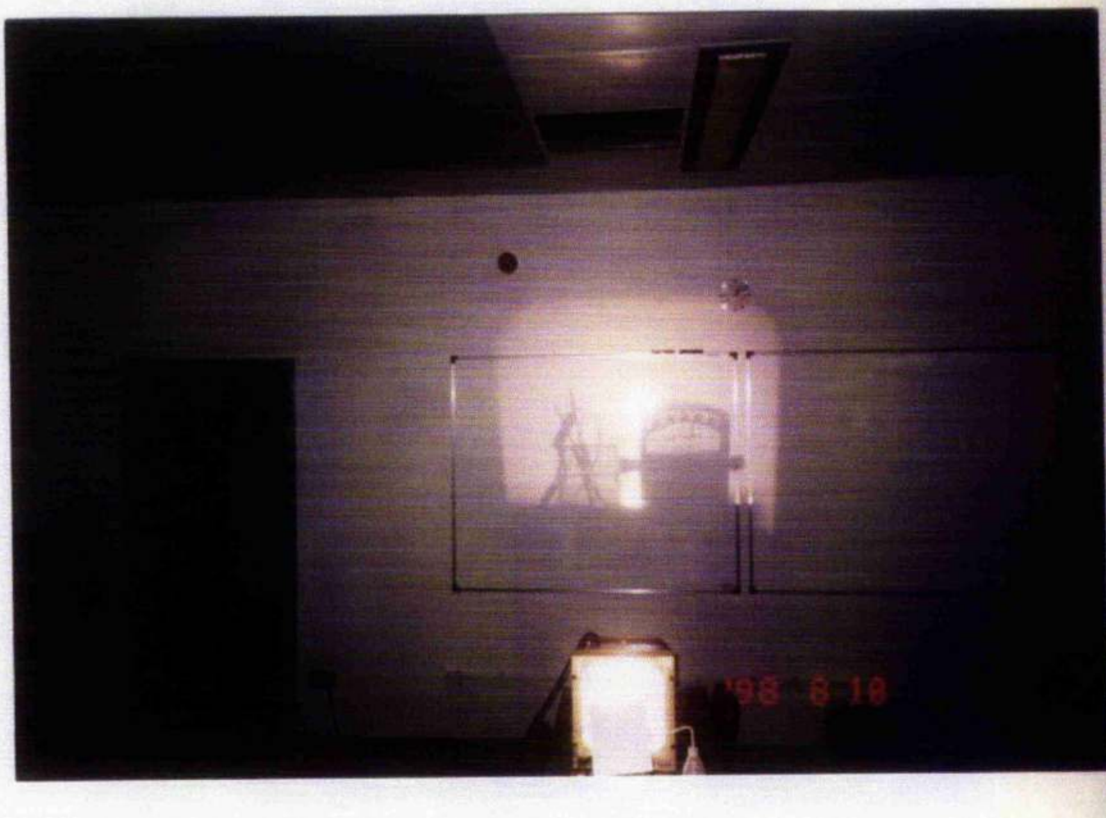


Photo 5: 2m from front bench

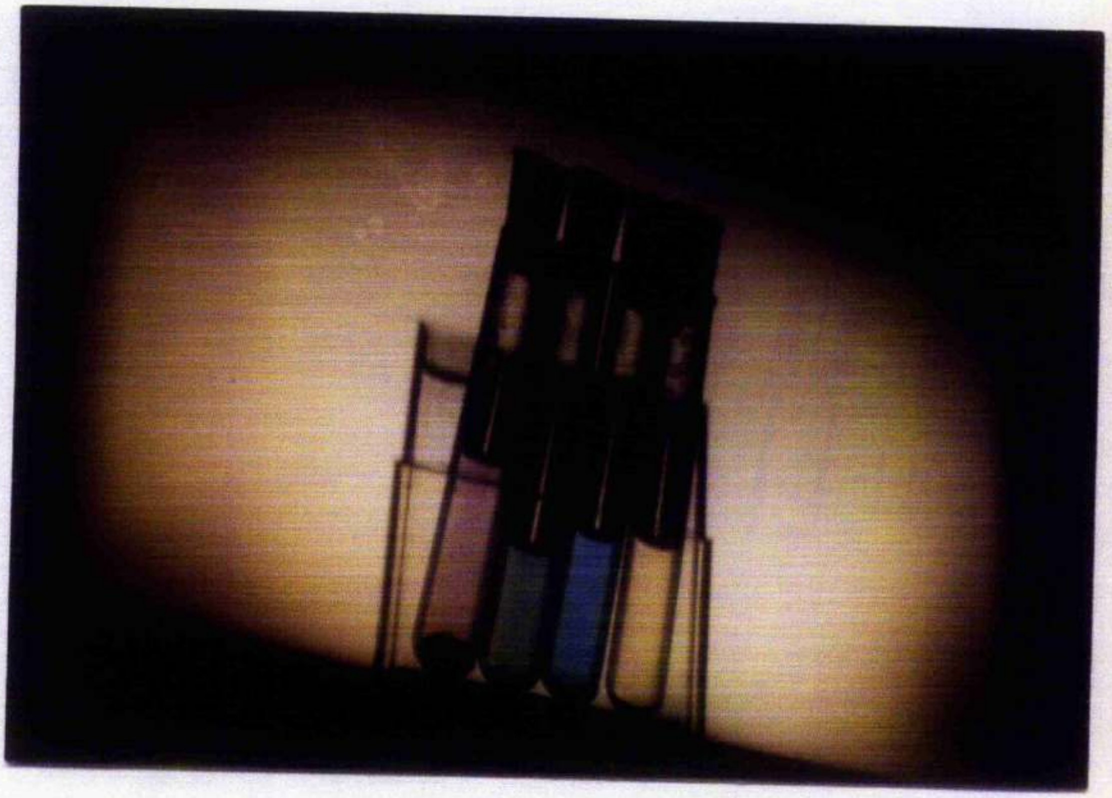


Photo 6: 6m from front bench

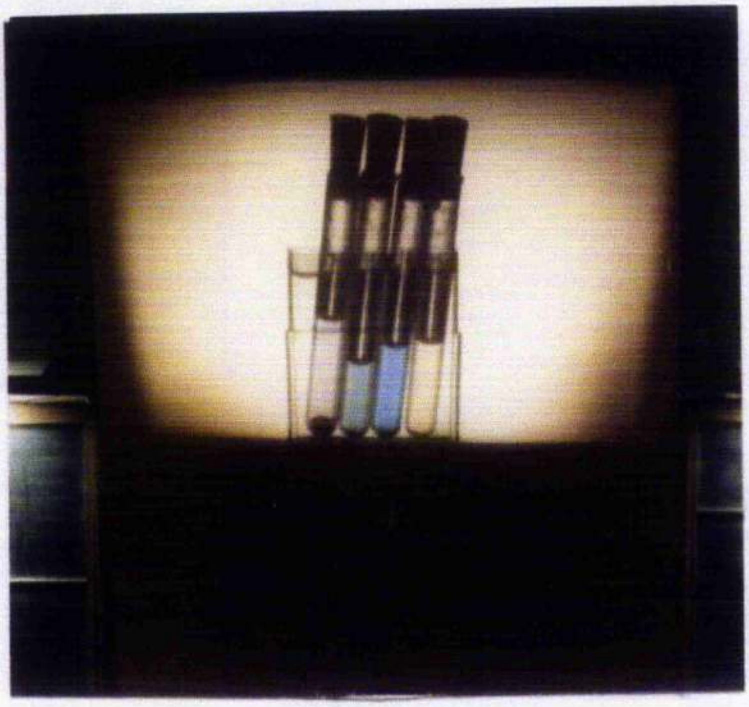


Photo 7: iron nails (rusting) 4m from front bench

Photo 8: A conical flask 2m from front bench

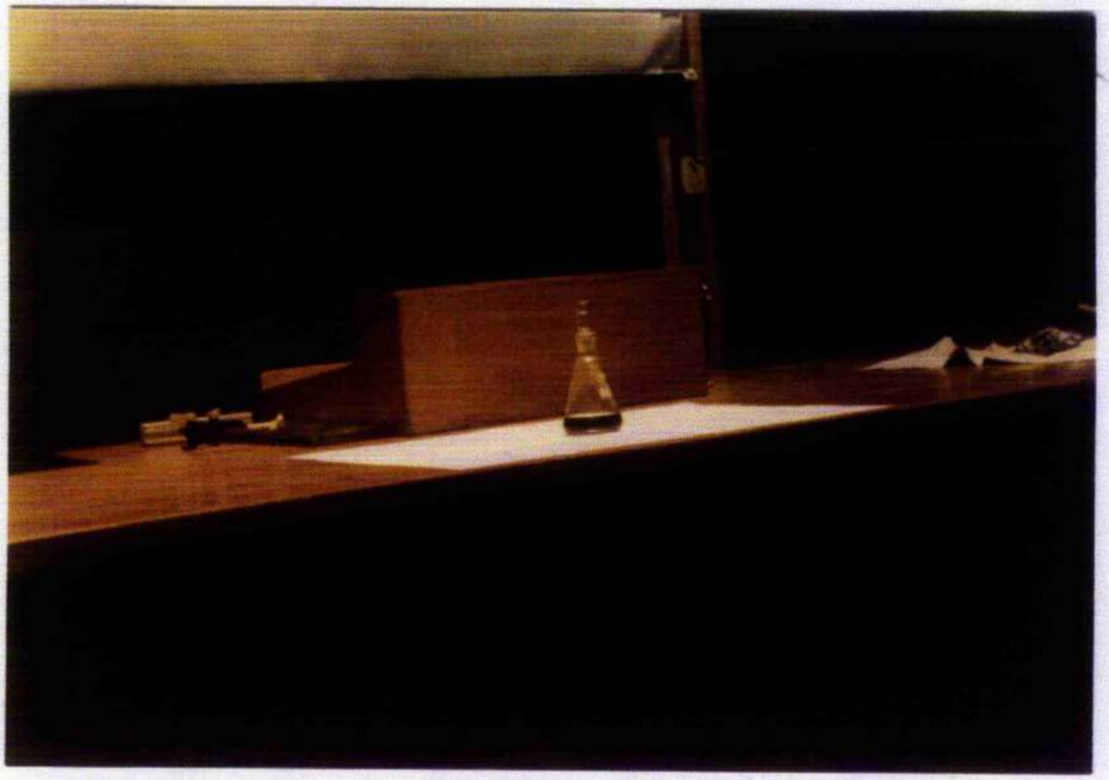


Photo 9: Test tube set iron 4m from front bench

Photo 10: Electrolysis 4m from front bench

Photo 11: Ammonia fountain 12m from front bench

APPENDIX 6.2

TOPs Published Series

Series published under the heading of TOPs in the *Journal of Chemical Education* by Hubert Alyea.

Year	Volume	Number	Pages
1962	39	1	12 - 15
	39	2	A127 – A128
	39	3	A217 – A218
	39	4	A299 - A300
	39	5	A381 – A382
	39	6	A471 – A472
	39	7	A561 - A562
	39	8	A613 - A614
	39	9	A673 – A674
	39	10	A795 – A796
	39	11	A893 – A894
	39	12	A965 - A966
1963	40	1	A29 – A30
	40	2	A131 - A132
	40	3	A213 – A214
	40	4	A303 – A304
	40	5	A383 – A384
	40	6	Nothing in this issue
	40	7	A523 – A524
	40	8	A575 – A576
	40	9	A635 – A636
	40	10	A813 – A814
	40	11	A885 – A886
	40	12	A947 – A948
1964	41	1	A61 – A62
	41	2	A121 – A122
	41	3	A193 – A194
	41	4	A265 – A266
	41	5	A384 – A385
	41	6	A457 – A458
	41	7	A519 – A520
	41	8	A581 – A582
	41	9	A661 – A662
	41	10	A799 – A800
	41	11	A879 – A880
	41	12	A955 – A956

Year	Volume	Number	Pages
1965	42	1	A29 – A30
	42	2	A131 – A132
	42	3	A205 – A206
	42	4	A307 - A308
	42	5	A409 – A410
	42	6	A461 – A462
	42	7	A551 - A552
	42	8	A601 - A602
	42	9	A677 – A678
	42	10	A823 – A824
	42	11	A903 – A904
	42	12	A996 - A997
1966	43	1	A87 - A88
	43	2	A135 - A136
	43	3	A241 - A242
	43	4	A349 - A350
	43	5	A437 - A438
	43	6	A539 - A540
	43	7	A585 - A586
	43	8	A658 - A659
	43	9	A747 - A748
	43	10	A901 - A902
	43	11	A977 - A978
	43	12	A1079-A1080
1967	44	1	A83 – A84
	44	2	A145 - A146
	44	3	A273 – A274
	44	4	A341 – A342
	44	5	A461 – A462
	44	6	A545 – A456
	44	7	A599 – A600
	44	8	A669 – A670
	44	9	A717 – A718
	44	10	A919 – A920
	44	11	A1005-A1006
	44	12	A1053-A1054

1968	45	1	A59 – A60
	45	2	A151 - A152
	45	3	A225 – A226
	45	4	A313 – A314
	45	5	A425 – A426
	45	6	A517 – A518
	45	7	A567 – A568
	45	8	A607 – A608
	45	9	A673 – A674
	45	10	A835 – A836
	45	11	A929 - A930
	45	12	A977 – A978
1969	46	1	A33 – A34
	46	2	A107 - A108
	46	3	A217 – A218
	46	4	A309 – A310
	46	5	A355 – A356
	46	6	A451 – A452
	46	7	A495 – A496
	46	8	A537 – A538
	46	9	A633 – A634
	46	10	A755 – A756
	46	11	A843 - A844
	46	12	A889 – A890
1970	47	1	A51 – A52
	47	2	A117 - A118
	47	3	A237 – A238
	47	4	A333 – A334
	47	5	A387 – A388
	47	6	A437 – A438
	47	7	A484 – A485
	47	8	A534 – A535
	47	9	A601
	47	10	A718 – A719
	47	11	A799 – A800
	47	12	A849 – A850
1971	48	1	A43 – A45

48(1) A SUMMARY OF CHEMICALS, DEVICES AND PROJECTORS (1970 MODELS) IN AN APPROPERIATE ENDING TO THIS TOPs SERIES, BEGUN IN 1962.

APPENDIX 6.3

Video Script

Demos Video Script
NYHOLM LECTURE

Pupils were still on their feet, sorting themselves out, when Mr. Dixon came into the lab. As usual, he wasted no time in getting under way….

"All right, get in your seats. Come on, settle down. Now I promised you last day we are going to carry out a practical today. Unfortunately, the headmaster has decided to call an early stop, so we are down to one period and we have got to get it all done inside this one period, so we can't afford to waste any time".

He cleared his throat.

"As I promised last day we are going to try and follow a reaction using the calanthropic technique. Now, you've heard about this before, but you have never done it. What we are going to do is we are going to study the reaction between solanol ditrate and digitis mitronide. We are going to measure the calanthropy and follow the reaction by the changes in calanthropy that accompany the reaction. Now, obviously we need a wee revise about how we measure calanthropy".

He moved round to the front of the demonstration bench, leaned back against it, and continued in the voice that his pupils recognized as the one he used when he expected them to pay particular attention.

" We are going to take 10 winceyettes of solanol ditrate and put it in a calanthropy tube. Once it is in the calanthropy tube, then you are simply going to measure the calanthropy, drop in the sphere---"

His hand flicked through the air and he made a clicking noise with his tongue---

"That's you got your zero point. Once you know the calanthropy of the solanol ditrate, then any changes in that figure from then on are going to reflect changes in the chemical reaction. Now we'd better check that you know what's happened".

He moved himself off the bench, reached sideways, without looking, and picked up a piece of chalk. He was at the board and writing as he spoke again…

"We are starting off with a solution, solanol ditrate. We're adding digitis mitronide. Now it is very clear, eh… George, you know what we get."

George had been paying attention:

"Solulation!" he said.

"Right" said Dixon; "You get a solulate of solanol mitronide. That doesn't have any effect on the calanthropy, but you're left with a solution of digitis mitron. ... Wait! I've got mixed up. George, what is it? - That's right, digitis ditrate. Now you are quite clear that the digitis ditrate has a lower calanthropy than the solanol ditrate?"

One or two nodded.

"Now we are not interested in finding that out. We know that if you carry on measuring the calanthropy. It is going to get faster, or if it stops and reaches a constant calanthropic value or if it increases again, in other words gets slower. Now when you've carried out the reaction you're going to have a series of ordered pairs."

He constructed two columns on the black board and quickly inserted dashes as entries.

"You're going to have figures for the number of winsters of the digitis mitronide you've added, and you're going to have a series of your measured values of calnthropy. Now we're sure about that? You're going to take the solution of solanol ditrate; you're going to measure its calanthropy, and you're going to take the berridenes, and you're going to add digitis mitronide, one winster at a time. Give it a good stir after each addition and measure the calanthropy."

He stirred something in the air in front of him.

"There is only one problem you're going to have, and that is that the berridenes you're using with the digitis mitronide are going to react with the solanol ditrate. You've had that problem before, so you mustn't let them come into contact with the solanol ditrate, or you'll get a reaction that isn't this one. And obviously any change in the calanthropy if your berrridenes are reaction with solanol ditrate won't reflect the changes caused by this reaction.

Now, I think I've covered the whole thing."

He paused to glance round the class. He could usually tell when IIIC had understood his instructions. Reassured, he wound it up quickly...

"What I want you to do now, before you start the practical, is write down exactly what I have told you to do, in sequence, every step you are going to carry out, written down, so that I know what you're going to do. All right? Get on with it."

APPENDIX 6.4

Official Letters from Relevant Authorities in Oman

بسم الله الرحمن الرحيم

tan Qaboos University

COLLEGE OF EDUCATION

جامعة السلطان قابوس

كليـــة التربيـــة

الرقم : ك . ت / ٩٩ / ٢٥٠٢

التاريخ : ٢٧ جمادى الأولى ١٤٢٠هـ

الموافق : ٨ / ٩ / ١٩٩٩م

te : / / 14 Hijra

/ / 19

الفاضل / مدير عام التخطيط التربوي *المحترم*

وزارة التربية والتعليم

السلام عليكم ورحمة الله وبركاته .. وبعد ...

يقوم الطالب / علي بن هويشل بن علي الشعيلي برسالة الدكتوراة في التربية تخصص مناهج وطرق تدريس العلوم (كيمياء) . كما يقوم المذكور حاليا لإعداد بحث في مجال تخصصه .

برجاء التكرم على تسهيل مهمته حتى يتمكن من إنجاز البحث .

شاكرين لكم دعم البحث العلمي والباحث .

المدير الإداري

حمد بن هلال الشقصي

جامعة السلطان قابوس كلية التربية

COLLEGE OF EDUCATION SULTAN QABOOS UNIVERSITY

المرفقات :

بيان الاستبيان .

صندوق البريد : ٣٢ الخوض

الرمز البريدي ١٢٣

مسقط ـ سلطنة عمان

تلكس : ٥٦٠٢ إس كيو يو أون ـ برقيا : جامعة

فاكس : ٥١٣٨١٧ ، هاتف : ٥١٥٦٨٠

Box : 32 Al-Khod

l Code : 123

- Sultanate of Oman

: 5602 SQU ON Cable: Jami'ah

3817, Telephone: 515680

بسم الله الرحمن الرحيم

سلطنة عُمان
وزارة التعليم العالي

الرقم : د.د.ع / ١٢٥٠٠ / ٩٩١
التاريخ : .... هـ الموافق ٦/٩/١٩٩٩م

شهادة لمن يهمه الأمر

تشهد دائرة الدراسات العليا بوزارة التعليم العالي بأن الفاضل/ علي بن هويشل بن علي الشعيلي يدرس في جامعة جلاسجو بالمملكة المتحدة لنيل درجة الدكتوراه في مجال مناهج وطرق تدريس الكيمياء على نفقة جامعة السلطان قابوس.

ويقوم المذكور حالياً بإعداد بحث في مجال تخصصه ، للتكرم بتسهيل مهمة المذكور في الحصول على البيانات والمعلومات التي ستساعده في إعداد البحث.

وتفضلوا بقبول فائق احترام ،،،

سعيده بنت عبدالله الصبحي
٩٩/٩/٦
مدير الدراسات العليا

لعناية / الفاضل / علي هويشل علي الشبلي

ج ٧٨ / ٥٥٢
٩٩/١٣/١٢

الفاضل / مديري دوائر الإشراف التربوي المحترم
بالمناطق التعليمية

السلام عليكم ورحمة الله وبركاته .. وبعد ...

الموضوع : تسهيل مهمة الباحث / علي بن هويشل الشبيلي .

يقوم المذكور أعلاه بالاعداد لنيل درجة الدكتوراة في التربية تخصص مناهج وطريقة تدريس العلوم (الكيمياء) ويرغب الباحث في تطبيق اداة بحثه المكون من فقرات مغلقة وفقرة واحدة مفتوحة على بعض معلمي وموجهي مادة العلوم بمنطقتكم .

يرجى التكرم بمساعدة الباحث وتسهيل مهمته

وتفضلوا بقبول فائق الإحترام ...

محمد بن شهاب بن حبيب اللواتي
مديرعدائرة البحوث والاحصاء
الأصل بتوقيع
مدير دائرة البحوث والإحصاء

نسخة الى :
- نائب مدير العام للتخطيط والمعلومات التربوية ,
- ملف .

بسم الله الرحمن الرحيم

سلطنة عُمان
وزارة التربية والتعليم
المديرية العامة للتربية والتعليم
للمنطقة الداخلية
دائرة الاشراف التربوي
قسم العلوم والرياضيات

الرقم: م:ع:ت:د / ٥ / ٥ / ٥٤-٦
التاريخ: ١٢/٦/١٤٢٠هـ الموافق: ٢٢/٩/١٩٩٩م

الأفاضل / موجهو مادة العلوم المحترمون
الأفاضل / مديرو ومديرات المدارس الثانوية والاعدادية المحترمون
السلام عليكم ورحمة الله وبركاته ... وبعد :-

يقوم الفاضل / على بن هويشل الشعيلى بالإعداد لنيل الدكتوراه فى التربية - تخصص مناهج وطرق تدريس العلوم (الكيمياء) ويرغب الباحث فى تطبيق أداة بحثه المكون من فقرات مغلقة وفقرة واحدة مفتوحة على بعض موجهى ومعلمى مادة العلوم .

عليه يرجى التكرم بمساعدة الباحث وتسهيل مهمته .

وتفضلوا بقبول فائق الاحترام،،،،

عيسى بن خلف بن سالم التوبى
نائب مدير دائرة الاشراف التربوى

سلطنة عمان
المديرية العامة للتربية والتعليم
للمنطقة الداخلية
وزارة التربية والتعليم

APPENDIX 6.5

Pre Tests for Autumn Term

PRE-TEST 1

1- Write the molecular formula for the following compounds:

Sodium Oxide   Magnesium Hydroxide

Sulfur Dioxide   Silver Nitrate

2- When magnesium burns in air, which substance does it form:

- Magnesium Nitrate
- Magnesium Carbonate
- Magnesium Oxide
- Magnesium Hydride

3- You have been given samples of the following:

Lemon juice, orange juice, vinegar, yogurt, dil. sulfuric acid, dil. hydrochloric acid

Using litmus paper, design an experiment to classify these samples into acidic or basic solutions.

4- From the following symbols, fill gaps in the table:

$^{56}\mathbf{Fe}_{16}$ $^{32}\mathbf{S}_{26}$

Element	Atomic number	Mass number	No. of Protons	No. of Electrons	No. of Neutrons
Iron					
Sulfur					

PRE-TEST 2

1- Write the balanced equations for the reactions which occurs when Magnesium is place into:

- Hydrochloric acid.
- An aqueous solution of zinc chloride.

  (Show the aqueous ions)

2- Draw an electrical circuit, which consists of 1 battery, 1 bulb, 1 switch, 1 ammeter and a voltmeter.

3- An electrical bulb is connected to a battery of voltage 6 volts, a current of 0.5 ampere flows in the circuit. What is the resistance of the bulb?

4- Complete the following table:

Appliance	Power (W)	Voltage (V)	Current (I)
Car flood light	48	12	?
Television	200	240	?
Vacuum cleaner	500	240	?
Ironing machine	920	240	?
Electric kettle	?	240	10

PRE- TEST 3

1- Translate the following statements into the equivalent balanced chemical equations (Show the physical states of reactants and products)

- ➢ *Sulfuric acid solution reacts with solid zinc sulfide and gives hydrogen sulfide gas and zinc sulfate solution.*
- ➢ *Barium chloride solution reacts with ammonium sulfate solution to give ammonium chloride solution and precipitate barium sulfate.*

2- Circle the number of the correct answer for the following:

- ➢ the bonds in the molecule NH_3 are:

  i- Covalent *ii- Coordinate*
  iii- Ionic *iv- Metallic*

- ➢ most ionic compounds are:

  i- Solid and have low melting point *ii- Aqueous*
  iii- Solid and have high melting point *iv- Gaseous*

- ➢ Number of moles of Oxygen molecules (O_2) in 16g is:

  i- 1mole *ii- 0.5 mole* *iii- 2moles* *iv- 0.2 mole*

- ➢ Lime water turns milky in:

  i- Oxygen *ii- Nitrogen* *iii- Air* *iv- Carbon dioxide*

APPENDIX 6.6

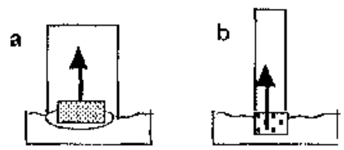
Post Tests for Autumn Term

POST-TEST 1

1- Circle the number of the correct answer for the following:

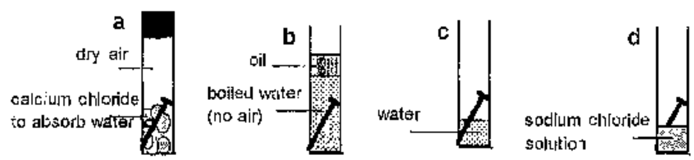
- ➢ Magnesium covered with fine, dry sand does not burn. Which is the best explanation for this:
  - *i-* *the sand keeps the air from the magnesium*
  - *ii-* *the sand keeps the heat from the magnesium*
  - *iii-* *the sand produces carbon dioxide, which prevents burning*
  - *iv-* *the flame from Bunsen burner can not get at the magnesium to light it*

- ➢ The diagram in the figure below shows a candle burning in different jars, inverted over water. which of the following statements is correct:



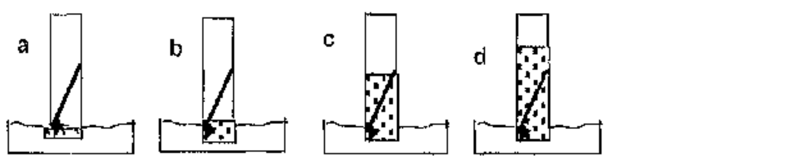
i- Candle a will go out first *ii- candle b will go out first*
iii- Both candles will go out together *iv- Both Candles will keep on burning*

- ➢ four experiments were carried out to investigate the rusting of iron nails:



i- *identify the experiment in which the nail rusted*

- ➢ when iron rusts inside a damp test tube that has been turned upside down over water, the water rises inside the tube. Which one of the following diagrams best represents the height to which you would expect the water to rise



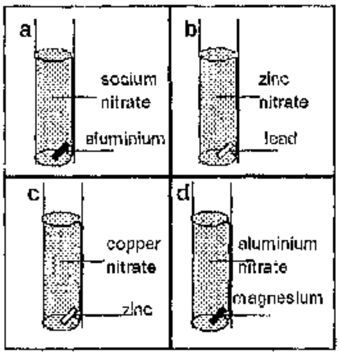
2- If you wish to electroplate a metal onto an object, describe (and sketch) an experiment for that determining at which electrode must the object be connected?

♦ Topics taught relevant to: corrosion and electroplating.

POST-TEST 2

1- Why does copper not replace zinc in its compounds?

2- Each box in the grid below shows a test tube containing a solution and a piece of metal, which box (or boxes) shows a test tube in which a reaction occurs?



3- A metal Q will displace a metal R from a solution containing ions of metal R if Q is above R in the electrochemical series.

Some results of displacement experiments using metals A, B and C are given in the table below:

Reactants	Result
C + ions of B	No reaction
B + ions of A	A displaced
A + ions of C	C displaced
A + ions of B	No reaction

i- What conclusions can be drawn from each of these four experiments?

ii- What is the order of these metals in the electrochemical series?

4- calculate the mass of each of the following:

i- 4 moles of ethane, C_2H_6

ii- 2.5 moles of ammonium carbonate, $(NH_4)_2CO_3$

♦ Topics taught relevant to: displacement reactions and ionic migration

POST-TEST 3

1- Imagine you have four different liquids and one solid substance. You want to find out which liquid dissolves the solid fastest. In setting up an experiment to do this you should do three of the following things. Which is the one you would not do:

- use the same volume of each liquid each time
- take the same weight of the solid each time
- stir the liquids that seem to be dissolving slowly
- keep all the liquids at the same temperature

2- Which of the following are likely to conduct electricity to approximately the same extent? Explain your answer.

A 0.1 mol/L HCl	**B** 0.1 mol/L HNO3	**C** 0.1 mol/L MgCl2
D 0.1 mol/L $C_{12}H_{22}O_{11}$	**E** 1.0 mol/L HCl	**F** 0.1 mol/L acetic acid

3- The table below gives the solubilities of sodium chloride and potassium nitrate at various temperatures. Each solubility is the mass in grams of solute that will dissolve in 100mL of water at the specified temperature.

	10	**20**	**40**	**60**
Potassium nitrate	21.0	32.0	64.0	110.0
Sodium chloride	35.8	36.0	36.6	37.3

- plot solubility curves for the two solutes using the same set of axes
- use the curves to estimate the temperature at which the two salts are equally soluble
- Use the curves to estimate the temperature at which the solubility of potassium nitrate is 70g per 100ml of water.

♦ Topics taught relevant to: solubility and conductivity

APPENDIX 6.7

Pre Tests for Spring Term

PRE-TEST 2

1. How many moles of zinc are there in 0.311g of zinc? (Z=65) {4.76x 10^{3-}}

2. How many moles of acid are there in 75mL of 0.2 mol/L HCl? {1.5x 102-}

3. If 10 mL of 0.30 mol/L HCl is added to 40mL of water to give 50mL solution, what is the new concentration of HCl? {6 x 10-2 mol/L}

4. Rewrite the following equation in ionic form,

$$Cl_2 + 2NaBr(aq) \rightarrow 2NaCl\ (aq) + Br_2$$

PRE-TEST 3

1- Circle the number of the correct answer for the following:

1- When sugar put into water and stirred, it disappears after a while. What has the water done to the sugar:

i- Filtered it *ii- Distilled it* *iii- Condensed it* *iv- Dissolved it.*

2- Which one of the following statements is true:

i- All liquids can dissolve all solids *ii- Water can dissolve any substance*

iii- Only water can dissolve substances *iv- Iodine will not dissolve in water*

3- which of the following statements is NOT true:

i- The same weigh of any substance will dissolve in the same volume of a liquid

ii- Different substances have different solubilities

iii- Dissolving a substance in hot water is usually easier than in cold

iv- Not all substances will dissolve in water

4- Which one of the following is the best definition of a saturated solution:

i- A very strong solution containing only one dissolved substance

ii- A solution in which no more solid can be dissolved at a given temperature

iii- A solution made up at the boiling point of the liquid doing the dissolving

iv- A solution made up with a lot of distilled water

2- Write the equation for the ionization of acetic acid CH_3COOH in water then write the expression for the equilibrium constant.

APPENDIX 6.8

Post Tests for Spring Term

POST-TEST 2

1- Each box in the following table refers to an element:

A *The element with electron arrangement 2,8,3*	**B** *The element of atomic number 19*	**C** Ar
D *Sodium*	**E** *the element which is a brown liquid at room temperature*	**F** *the element which has 6 electrons in each atom*

Which box (es) refer(s) to:

- *a metal which does not react violently with water*
- *a very unreactive element*
- *elements in the same group of the periodic table*
- *an element which is a gas at room temperature*

2- A main group element Z is known to bond covalently with chlorine to form a compound with the formula ZCl3. In this compound, both element Z and chlorine have the stable electron arrangements of noble gases by sharing outer electrons.

- To which main group of the periodic table is Z likely to belong?
- Show, in a diagram of outer electrons, how covalent bonds form in a molecule of their compound.
- Using lines to represent covalent bonds, show in a diagram the expected shape of a molecule of this compound.

3. From the periodic table below, answer the following questions. Write down the letters for:

   i. Two elements in the same group.
   ii. An alkali metal
   iii. A noble gas
   iv. A transition metal
   v. What type of bonding would you expect in a compound of A and D.

	I	ii			iii	iv	v	vi	vii	0
1										C
2									D	
3										
4	A			B					E	

- Topics taught relevant to: periodic table and chemical families

POST-TEST 3

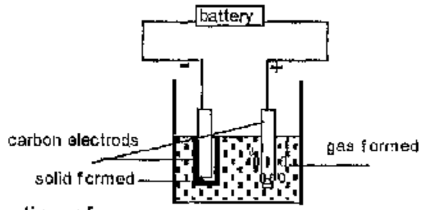
1- Which box(es) from the following table shows a statement that applies to 100 cm^3 of:
  - Calcium hydroxide solution (lime-water)?
  - Dilute sulfuric acid?

A	More $H^+(aq)$ ions than $100cm^3$ of pure water
B	The same number of $H^+(aq)$ ions as $100cm^3$ of pure water
C	More $OH^-(aq)$ ions than $100cm^3$ of pure water
D	The same number of $OH^-(aq)$ ions as $100cm^3$ of pure water
E	Equal numbers of $H^+(aq)$ and $OH^-(aq)$ ions
F	More $OH^-(aq)$ ions than $H^+(aq)$ ions
G	More $H^+(aq)$ ions than $OH^-(aq)$ ions

2- A 50-mL sample of unknown concentration of sodium hydroxide solution requires 25mL of 0.02mol/L hydrochloric acid to neutralise it. What is the concentration of the sodium hydroxide solution?

3- How many hydroxide ions are there in 30mL of 0.12mol/L sodium hydroxide solution?

4- Copper (II) chloride was electrolyzed in the apparatus shown below:



- Write ion-electron equations for the formation of:

  i- The solid ii- The gas

- During electrolysis what chemical change is taking place at the cathode? At the anode?

5- 4- For a general aqueous salt, MA, in solution write the cathode half reaction and the anode half reaction.

6- Dilute acids have four general reactions. They are:

i. Dilute acid + fairly reactive metal $\longrightarrow$ .....+......

ii. Dilute acid + a metal oxide $\longrightarrow$ .....+......

iii. Dilute acid + a metal carbonate $\longrightarrow$ .....+......+ ....

iv. Dilute acid + an alkali $\longrightarrow$ .....+......

- Topics taught relevant to: Acids & bases, redox reactions and electrolysis

APPENDIX 6.9

TOPs Pupils' Questionnaire

Dear Pupil:

During this semester, we have done some experiments using tilted overhead projector. Comparing this technique with the normal laboratory demonstration, we would value your response to the following statements about Tested Overhead Projections (TOPs) and the normal Demonstrations (Demos). Your views will help us in our future planning. Please indicate your views about each statement by ticking <u>ONE</u> box for each.

	Demos rather than on TOPs	TOPs rather than on Demos	No difference
1) I found chemistry experiments are more fun when doing them on the			
2) I found experiments are easier and simpler on the			
3) The spillage of chemicals and breakage of apparatus in the experiments were less in case of the			
4) I feel more interested in chemistry when doing experiments on the			
5) It took less time to complete the experiments in case of the			
6) When doing chemistry experiments, I can understand chemistry more easily when working on			
7) I felt more relaxed and safe when doing experiments on the			
8) Experiments have enabled me to concentrate on the chemistry more in case of			
9) Work on the bench was more tidy and less cluttered when doing experiments on			
10) I feel that I have gained more from experiments when doing them on			
11) I feel experiments are more visible (observable) when doing them on			
12) In case of large-size classes, the best idea is doing experiments on			
13) There is more room for discussion on experiments when doing them on			
14) If I am given a choice between Demos and TOPs, I would prefer			

Any additional comments

Than you for your help

APPENDIX 6.10

TOPs Teacher' Questionnaire

Dear Teacher:

You have been trained to do, and then you performed, some experiments using tilted overhead projector. Comparing this technique with the normal laboratory demonstration, we would value your response to the following statements about Tested Overhead Projections (TOPs) and the normal Demonstrations (Demos). Your views will help us in our future planning. Please indicate your views about each statement by ticking ONE box for each.

....

....

	Demos rather than on TOPs	TOPs rather than on Demos	No difference
1) I found that it is easier to conduct experiments on the	☐	☐	☐
2) I get more responses from pupils at the back rows in case of the	☐	☐	☐
3) The spillage of chemicals and breakage of apparatus in the experiments were less in case of the	☐	☐	☐
4) It required less care in handling chemicals and apparatus in case of the	☐	☐	☐
5) It took me less time to complete the experiments in case of the	☐	☐	☐
6) There is more chance for pupils to participate in some manual skills in case of the	☐	☐	☐
7) I felt more relaxed and safe when doing experiments on the	☐	☐	☐
8) The effort undertaken to prepare, conduct and clean up experiments is less in case of the	☐	☐	☐
9) My work on the bench are more tidy and less cluttered when doing experiments on the	☐	☐	☐
10) In case of large-size classes, experiments are more visible (observable) when doing them on the	☐	☐	☐
11) There is more time for discussion on experiments when doing them on the	☐	☐	☐
12) Pupils' responses indicate that they learn better in case of experimenting using th	☐	☐	☐
13) Less apparatus and chemicals are needed when doing experiments on the	☐	☐	☐
14) In future and as possible, I prefer to carry out experiments using the	☐	☐	☐

....

Any additional comments

Than you for your help

UNIVERSITY
of
GLASGOW

TEACHERS' MANUAL

for

INTERACTIVE PROJECTED DEMONSTRATION TECHNIQUES

By

ALI HUWAISHEL ALI AL-SHUAILI

A Message for Teachers

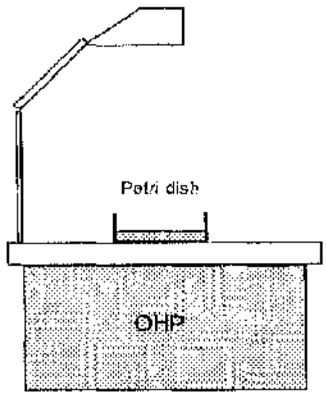
Because the classes in educational institutions are becoming much larger and the cost of practical courses is escalating, space becomes at a premium and the learning effectiveness of the available courses is being questioned. Demonstration experiments could be seen as a feasible and efficient alternative to other practical activities. An education in science, rather than training in science, would see practical work and the "doing" of science as only **one** element of the process of learning science and a minor element at that.

A teacher can expect to have to teach to as many as 40-50 pupils. There are also several cumulative constraints on doing individual practice. If the lesson (or the topic) demands carrying out such a practical activity, the teacher has no choice **but** to turn to demonstration. This presents three options.

Firstly, experiments can be carried out on a normal scale and hope that the pupils at the back rows of the classroom (or the laboratory theatre) have 20:20 vision or have the use of telescopes. Secondly, the experiment can be scaled up. This can become hazardous and it also would be impossible, as it is prohibitively costly. Or thirdly, the teacher can forget about it. The first one is the usual option chosen.

There is, however, a fourth option; that is for the experiment (less than the standard scale or possibly even smaller) to be projected on to a screen, therefore increasing the size many times without increasing the amount of chemicals used. This improves visibility and minimises costs.

The overhead projector (OHP) can be used in the normal fashion (Figure 1 below) by using a transparent flat sheet (overlays) with drawing of lines and formulae on it or sometimes by using petri dishes or similar small transparent containers. This method is good for 'flat' projection to see colour changes or ionic migration or bubble rafts or ball bearings or mini-modules which do not have shadow problems. However, it is still a limited number of experiments which can be done in this way. Things involving layers, gas production, electrolyses, etc... cannot be done, and so this led to the design of another technique.



Flat projection

TOPs Mode:

A mirror method can allow for images to be projected the right way up and hugely magnified. We have designed a very simple, cheap, easily constructed, fitted and maintained gadget by which a practical demonstration can be done on a normal or even smaller scale and be greatly magnified. We called it "Tested **O**verhead Projections" or TOPs. This can be easily done by clipping a mirror on to the head after tilting the projector through 90^{0} in order to allow the beam to go through the working area and then be deflected by the mirror on a screen which is in front of the projector as shown in the following diagram and photos (4) and (5):

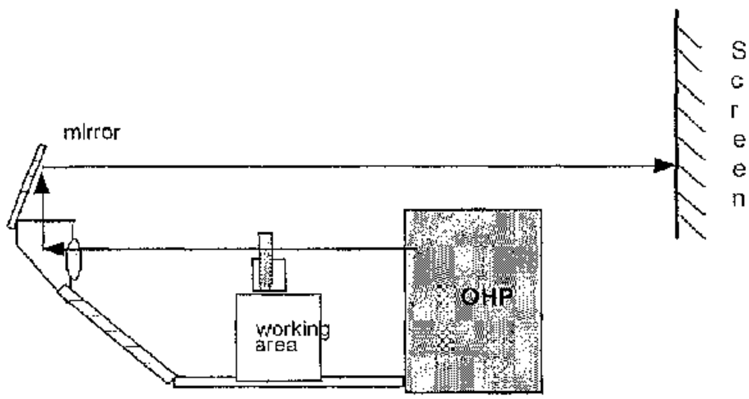


Figure 2: The TOPs' Mode Set Up

This new gadget has the following advantages: (Photos (1) and (2))

1. It is simple to build and design as it is just a normal plain mirror (tile-size, 15x15cm) stuck in a wooden frame and fixed on to the front head of the projector.
2. It is easy to carry this attachment between classes, easy to store in a drawer, easy to fix to the projector and the projector can be used normally as long as this attachment is folded out of the way with no need to take it off.
3. It is safe for the Fresnel lenses in that no solvent spillage can damage it.
4. It is visible to a large number of people at once.

5. It can provide a wide working area, so it gives room to carry out different experiments, even those, which require more than one piece of apparatus at the same time such as titration, ammonia fountain, etc…
6. It is possible to project nearly all experiments with almost no exception; i.e. experiments involving a Bunsen burner, water tap and things such as these.
7. It is capable of being used on nearly all OHP's, and almost all OHP's in Omani schools are suitable for this gadget. Besides, the OHP can be used without making any further adjustment for normal projection so that the lesson can carry on without any interruptions (Photo (3)).
8. There is enough room for making concrete a theoretical point when teaching a topic in a normal classroom. It provides concrete evidence to pupils along side the theoretical.
9. The teacher, either in the classroom or in the lab, can establish a theoretical base before consolidating it practically, i.e. he can reshape the activity in the way of interactive demonstration following the scientific method in learning and to suit the time and resources available.
10. There is room for allowing pupils to engage both hands and minds. They are no longer in a big theatre watching passively.
11. The teachers has the key to control the input from the experiment to pupils minds and then enhance the "signal" and reduce the "noise" and so avoid the unstable overload state.
12. The teacher would also be able to link "signals" to pupils' previous knowledge as Johnstone stated (1997) "*what we have already known and understood controls what we learn*".

However, two main issues can be regarded as faults for this attachment. **Firstly**, a tilted projector might obstruct the ventilation path of some few projectors such as "3M-five sixty six" projector in which its ventilation fan would be below- the base (but not the ones in Oman). This can be easily overcame by raising the projector up on a two parallel sticks to allow ventilation to take place. **Secondly,** as these attachments are based on using test tubes as reaction vessels, this gadget, and the previous one, have a problem of "convergent" test tubes.

Solving the problem of "convergent" test tubes:

If an empty test tube is placed within the beam of the projector, a clear, sharp focused image is obtained (the glass being so thin means that there is little refraction of the light). However, if a solution is poured into the test tube, it will act like a cylindrical lens (Figure 3) and produce an image with only a line showing the colour of the solution surrounded by dark bands on either side.

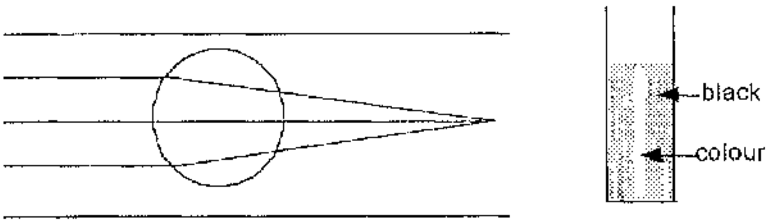


Figure (3): Convergent test tube (cylindrical lens) effect

The cylindrical lens properties of the full test tube can be overcame by placing the test tube into a flat walled transparent container containing a clear substance with refractive index almost identical to that of the test tube; i.e. water (Figure 4).

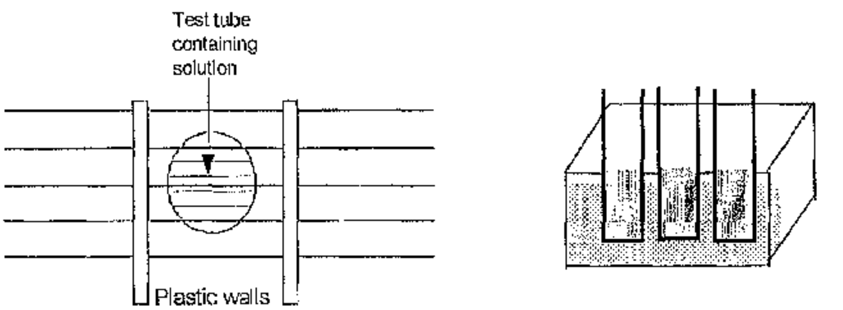


Figure (4): Solving the problem of cylindrical lens

A convenient plastic container turned out to be a plastic box in which litmus (or pH) papers are supplied. These are cheap, easily available and produce excellent results.

The attachment when used for demonstration can give every pupil in the class (or the laboratory theatre) a front seat view.

Developing TOPs experiments

Plenty of projectable experiments could be designed and outlined in the light of the following issues:

- Availability of apparatus, chemical and equipment.
- Matching experiments to Omani syllabuses using textbooks as the set course.

- Length of each experiment to ensure that we can offer room for discussion before, during and after the demonstration takes place. (Allocated time for the whole laboratory session is 40-45 minutes).
- Pupils' theoretical background since what we already know determines what we learn.

Thus for this purpose, experiments were designed and adapted for this gadget.

Experiments found to be projectable and suitable for the resources available in Oman have been collected into this manual.

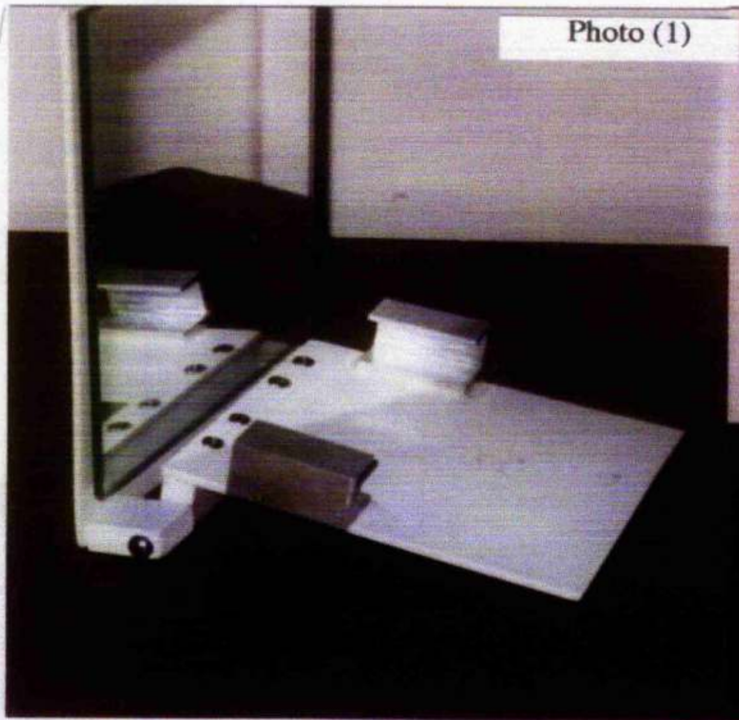


Photo (1)

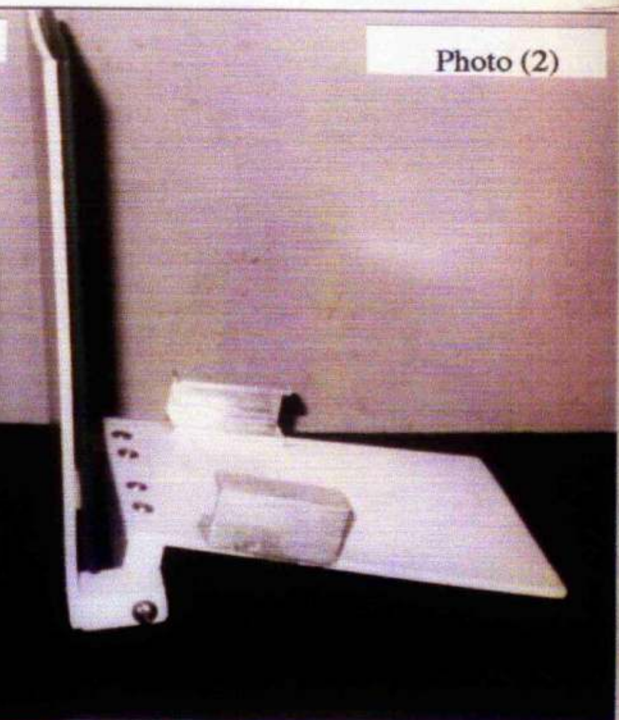


Photo (2)

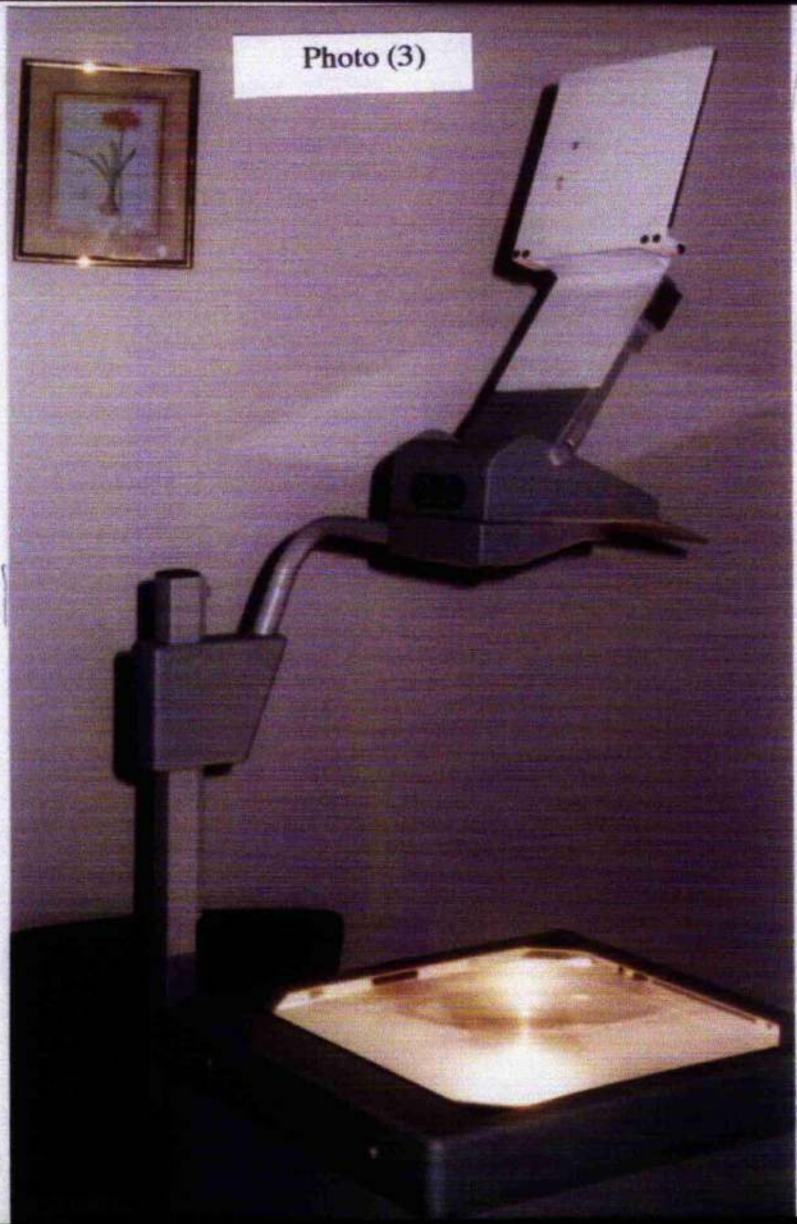


Photo (3)

Photo (4)

Photo (5)

This side up

Introduction

This manual is presented in an attempt to give chemistry (or even science) teachers a package to use as a mini-scale set of useful items in their teaching. It consists of six main parts starting from general instructions for anyone who may address practical work.

The second part contains some experiments that can be projected using the ordinary overhead projector.

Part three divides experiments into five main categories and gives briefly the main apparatus, materials and chemicals necessary for each category of experiments.

The fourth part gives some experiments that are tested and extracted from the current Omani textbooks in years (9,10 and 11) and those which have already been tried in schools. These experiments are designed to help you understand and practise TOPs. Each experiment begins with a theoretical background related to the idea of the experiment. A list of materials and chemicals that may be needed is included in each one. For each experiment, there is also a procedure telling you clearly what to do, step by step.

Part five also contains experiments that can be implicit to some topics, which exist in the current curriculum or the future curriculum. The same layout is used for these experiments.

For these experiments (part 4 and 5), you should have a basic kit of equipment. This kit should be related to those techniques listed in part 3 of this manual. A few extra things might be required but most of these are easily found in a school laboratory or can be obtained locally.

The sixth part gives some biological experiments that can be done using the TOPs method and those others which contain some chemistry.

PART 1:

General instructions and precautions.

The use of a laboratory and chemicals requires serious consideration of safety. Make sure to manipulate things carefully and correctly especially in front of pupils. Besides things already taught in your teacher training courses, the following points may be useful. It is also recommended that your pupils should be aware of them:

1. Make sure that room is organised in a method where projecting experiments are visible to all.
2. Prepare in advance all materials and chemicals involved in the experiment.
3. Do not touch, smell or taste any chemical.
4. When using a Bunsen burner, make sure that there are no flammable items nearby such as ether, alcohol, etc…. Ignite the match first then open the gas tap. Make sure that the match is extinguished properly.
5. When heating a test tube use the appropriate holder pointing the test tube mouth away from you and your pupils.
6. To dilute, add acid slowly to water not the reverse and stir gently.
7. Replace the stopper in any bottle immediately after use. Also do not open more than one bottle of chemicals at the same time.
8. After finishing, wash chemicals down the drain with plenty of water.
9. Wash your hands after each lab visit.
10. Ask pupils to write their notes and observations and make sure to allow them to participate as much as you can both mentally and physically.

Part 2:

Experiments using ordinary overhead projector

1. Metathesis reactions:

Theory:

These reactions happen between two compounds XM and YN where ions X and Y are exchanged.

$$XM + YN \longrightarrow XN + YM$$

Materials and chemicals:

Transparent sheet (overlay sheet) with lines and formulae drawn on it as shown in the diagram below, 5mL of each of the solutions: copper (II) sulphate, barium chloride, silver nitrate, sodium carbonate and 2M hydrochloric acid.

Procedure:

"Now before we begin, can we predict what is likely to happen in each box". Similar grid in blackboard with pupils predictions, e.g. P = precipitate, B = bubbles etc…"Let us now do the experiments to find out how good are predictions were. I shall need the help of 5 pupils".

"Pupil A place a drop of copper sulphate solution in all the boxes in the first row and the first column. Pupil B now come and do this for $BaCl_2$ (second row and second column) [and so on till all the reactions are complete]. How have our predictions done?"

where predictions and experiments agree, give compliment to class. Write equations to confirm.

Where predictions and experiments do not agree ⟶ discuss, correct and confirm with equations.

Chemicals	**$CuSO_4$**	**$BaCl_2$**	**$AgNO_3$**	**Na_2CO_3**	**HCl**
$CuSO_4$					
$BaCl_2$					
$AgNO_3$					
Na_2CO_3					
HCl					

Diagram of formulae written on an overly.

2. Oxidation reduction reactions

Theory:

When an element or a compound takes in oxygen during a chemical reaction, we say that it has been oxidised. On the other hand, oxidation is the loss of electrons whereas the gains of electrons is the reduction.

In brief [OIL RIG , Oxidation Is Loss, Reduction Is Gain]

Note: useful revision experiments. Not necessarily done at the same time. Get pupils to predict what will happen before doing the experiments.

Because no gases escape, this can be safely done in a normal classroom.

Materials and chemicals:

Transparent sheet, plastic petri dish with hole in the middle, sodium carbonate solid, sodium sulphite solid, 2M hydrochloric acid, solutions of potassium dichromate, potassium permanganate, barium chloride, lime water, bromine water, and a universal indicator.

Procedure:

a- Burning Magnesium

A teacher can start this experiment by burning a piece of magnesium ribbon in the class and then ask the pupils what happened to the ribbon. The teacher will get "it is burnt", "turned to ash", "react with oxygen", or a few similar responses. To the third boy "Could you tell more about what you said?", "Magnesium reacted with oxygen and gave magnesium oxide". The teacher to the class "Who can write the chemical equation for this reaction?". A pupil writes:

$$2Mg + O_2 \longrightarrow 2MgO \ \{\text{in ionic forms } Mg \longrightarrow Mg^{2+} \text{ and } O_2 \longrightarrow 2O^{2-}\}$$

"Magnesium gains oxygen and therefore oxidised, or in other words, Mg has lost electrons to become Mg^{2+} and so it has been oxidised".

b- Carbonate and sulphite

"Lots of oxidations and reductions need not involve oxygen, let us compare CO_2 and SO_2 to see if they can oxidise or reduce". On a transparent sheet with circle drawn and labelled as shown below, ask a pupil to put a few drops of each of chemicals shown below. Let him cover the sheet with a plastic petri dish with a hole in the middle of it. Another learner would add a few drops of hydrochloric acid in the sodium carbonate (any carbonate) and in a later experiment sodium sulphite.

"what might happen?" the teacher can ask those pupils before they add HCl. "Carbonate and acid gives carbon dioxide whereas the sulphite will give sulphur dioxide" the two pupils may reply. Now the teacher says: "how will these gases affect chemicals inside the petri dish?, predict and then check experimentally".

Carbon dioxide generated is neither oxidising nor reducing. It will affect the indicator, since it gives an acid with H_2O, and give a precipitate with $BaCl_2$ to give $BaCO_3$. In the other case, the sulphur dioxide liberated is a reducing agent as well as acid. It will turn the:

- orange dichromate ($Cr_2O_7^{2-}$) to green (Cr^{3+})

$$6e^- + Cr_2O_7^{2-} + 14H^+ \longrightarrow 2Cr^{3+} + 7H_2O$$

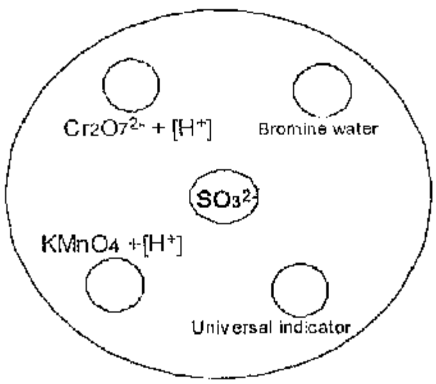
- MnO_4^- (purple) to Mn^{2+} (colourless)

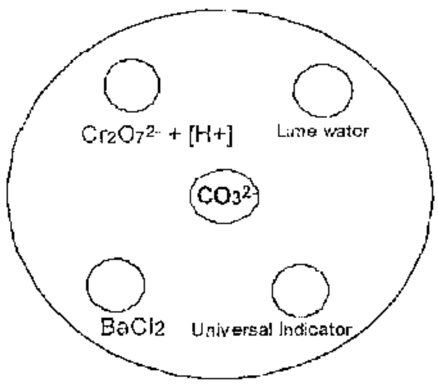
$$5e^- + MnO_4^- + 8H^+ \longrightarrow Mn^{2+} + 4H_2O$$

- Br_2 (brown) to $2Br^-$ (colourless)

$$2e^- + Br_2 \longrightarrow 2Br^-$$

- In all cases electrons are taken in by the reactants to give the products. Therefore they are REDUCED.
- Indicator will change





3. Halogens

Theory:

EXPT (1) A solution of chlorine in water may be used in many experiments instead of chlorine gas, which is very poisonous and dangerous to use. For example, chlorine water can easily displace bromine (and iodine) from solutions of their ions.

EXPT (2) Silver nitrate solution can be used to identify solutions of chlorides, bromides and iodides. If you then add a drop of concentrated ammonia to these precipitates, you will see silver chloride is soluble while silver bromide is slightly soluble but silver iodide is not soluble at all.

Note: It is important to use very dilute solutions so that the colour can be seen. Conc. solutions will just give black on the projector.

Materials and chemicals:

Transparent sheet, single drops of dilute halide solutions, single drops of chlorine water, dilute silver nitrate and ammonia solution.

Procedure:

1- displacement of halogens from halides

Place single drops of NaF, NaCl, NaBr and NaI on the strip. Before adding chlorine water, get the class to "suggest what might happen". "Can Cl_2 displace F_2 from a fluoride? Let us find out". Now let a pupil to add drops of Cl_2 to NaF, the rest would see that nothing happens?

"What about Cl_2 on chloride, bromide, iodide?"

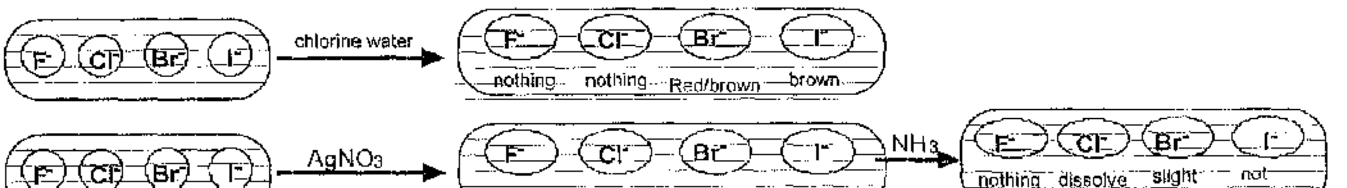
2- reaction of silver nitrate on halides:

Similarly, a pupil will place single drops of NaF, NaCl, NaBr and NaI on the strip. But before adding silver nitrate solution, get the class to "suggest what might happen". "Does it react with fluoride? Let us find out". "How to detect that?". "your friend will add drops of $AgNO_3$ to NaF", the class will see that nothing happens?

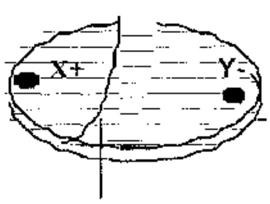
"What about $AgNO_3$ solution on chloride, bromide, iodide?"

"Now what about solubility of silver halide in ammonium hydroxide? What might happen if we add drops of ammonium hydroxide solution to each precipitate we got from the previous experiment? Let us check". The pupil is adding drops of ammonium hydroxide solution to each set. The class will again see what happens and then write their observations.

To gather trends and patterns, the following diagram may illustrate this:



4. Diffusion of solutions ***(Colour changes)*** (it can be projected on an OHP in normal position using a petri dish)



red line

Theory:

Molecules or ions can migrate in water solution, and when they meet, they can react to give observable compounds. They diffuse at different rates and the "line" of the product is nearer the slower ion source.

The example above indicates that Y^- has moved faster than X^+ because the precipitate is nearer X^+ than Y^-.

Materials and chemicals:

Petri dish, distilled water, solid iron (III) chloride and solid potassium thiocyanate.

Procedure:

Half fill the petri dish with distilled water and then put 0.5g of solid $FeCl_3$ in one side and on the other side put about the same amount of solid KSCN. Wait for a minute and see the formation of a red line at the position where diffusing ions of Fe^{3+} meet SCN^- ions.

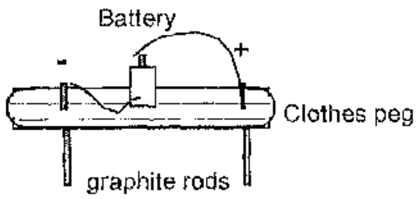
Techniques Required For Teacher Package Of Experiments Using TOPs.

1. General Chemicals and Apparatus.

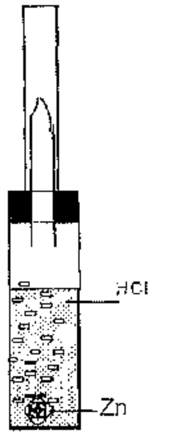
1. 1-2 small transparent flat-sided boxes {of pH (or litmus) papers} used to put test tubes (or the U-tube) in, in order to eliminate shaded views of projected tubes and to hold tubes vertically.
2. 1-2 transparent flat-sided boxes to use as beakers.
3. A set of small-scale test tubes-4mL.
4. Distilled (or deionised) water for dilution and dissolving where required.
5. Bunsen burner for purpose of heating or getting warm (or hot) water bath.
6. A splint or a match to test oxygen or hydrogen gases or in using Bunsen burner.
7. A laboratory coat, gloves and safety glasses to be used in some experiments involving safety precautions.
8. Teat droppers for adding and mixing (bubbling).

2. Electrolysis:

1. 4-5 cm Transparent flexible tubing of a diameter of 1.0 cm or less can be used as a U–tube for electrolyte solutions, but a piece of glass tubing bent into a U shape is even better.
2. A universal indicator for colouring solutions to be visible and detectable in changing of pH values.
3. Chemical solutions intended for electrolysis.
4. A mini-set of 6-volt battery connected to two graphite rods (pencil leads) fixed in a small wooden strip such as one half of a clothes peg or a short piece of wooden ruler as shown in the diagram:



3. Gas Collection.



1. A 4-6 mL test tube to put reactants in.
2. A 2-3 mL small test tube to collect gas in.
3. About 7 cm dropper without its bulb to be inverted upon the reaction.
4. Small amounts of reactants according to gas wanted.
5. A glass tube pulled into a "jet"

E.g.

- For oxygen:
  - 3 ml H_2O_2 (1M) with 0.1 g catalyst (MnO_2 or yeast)
- For hydrogen:
  - 3ml 2M acid (HCl) with 1-0.5g of a metal (Mg, Zn)
- For carbon dioxide:
  - Heating 1.0-g carbonate (or bicarbonate).
  - Add dil. HCl to a carbonate or bicarbonate.

4. Colour Changes:

1. A set of test tubes to compare colours between them before and after addition of a particular chemical.
2. Few droppers to add chemicals into solutions.
3. Small amounts of different chemicals used in the experiment.
4. Dropper to act as a bubble-mixer.

N.B:

Since stirring in such small tubes is impossible, mixing can be easily done by inserting a dropper and passing a stream of bubbles through the solution.

Most experiments involving halogens or acids and bases can be demonstrated using this technique.

5. Precipitation

1- A set of test tubes to see how to get precipitate and (in some cases) to form a complex in adding particular chemical. This is just a variation in the method suggested in page 8

E.g.: Adding ammonia solution after having precipitated AgCl by mixing $AgNO_3$ and NaCl

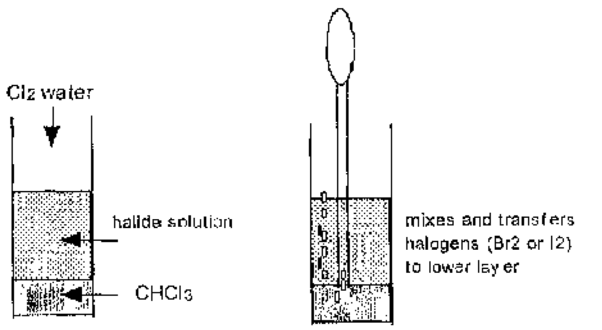
2- Small amounts of chemicals stated in the experiments.

N.B: All precipitates look black in TOPs

6. Layer Experiments.

1. A set of test tubes to compare layers before and after injecting a particular solution into another one.
2. A small-size pipette or a dropper or a syringe.
3. Small amounts of appropriate chemicals.

E.g.



Part 4:

Experiments using tilted overhead projector or (TOPs)

Third Preparatory

1. Batteries and cells *(Electrolysis and colour changes)*

Theory:

Cells can be set up by connecting two half-cells together. A half-cell consists of a metal in contact with a solution of its ions, such as a strip of copper metal in a small container of copper (II) sulfate solution.

Materials and chemicals:

2 small transparent containers (flat-sided boxes), transparent voltmeter, 3 cm-long piece of zinc, 3 cm-long piece of copper, filter paper, wires, sodium chloride solution, zinc sulphate solution (~2M) and copper sulphate solution (~2M).

Procedure:

"Have you ever opened a car battery or get to know what does it consist of". "How is the electricity generated in such batteries or cells?" The teacher can open a discussion with these queries. A pupil would say: "These cells are changing chemical energy to electrical", The teacher says: "But, how?"

In a transparent box let a pupil dip a piece of zinc into a solution of zinc ions (zinc sulphate solution). The pupil will then Place a piece of copper into another box of copper ions (copper sulphate solution). Another boy will join the two pieces of metal to a voltmeter and, to complete the circuit, he will also dip a roll of filter paper (wet with sodium chloride solution) into each box (Ion Bridge). The class would note the electron flow.

Now you can answer the question why do cells produce electricity.

Zinc is more easily oxidised than Cu. That is, $Zn \rightarrow Zn^{2+} + 2e^-$

is more likely than $Cu \rightarrow Cu^{2+} + 2e^-$

In the Zn/Zn^{2+} half of the cell we have $Zn \rightarrow Zn^{2+} + 2e^-$ (Oxidation)

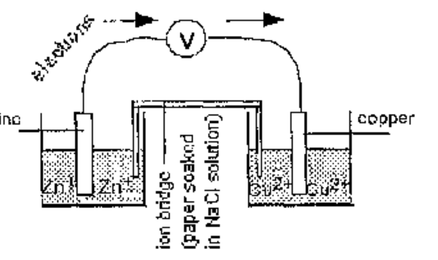
In the Cu/Cu^{2+} half of the cell we have $\underset{\text{blue}}{Cu^{2+}} + 2e^- \rightarrow Cu$ (Reduction)

The source of the current is this redox reaction which together becomes:

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

As Cu^{2+} (blue) is used up, the colour fades.

Now get pupils to predict the relative size of voltage, direction of electrons. Also, keeping the Cu/Cu^{2+} cell as a reference, what if the Zn/Zn^{2+} cell is replaced by others such as Mg/Mg^{2+}.



Copper and zinc half-cells

Conclusion:

Electricity is produced when two half-cells containing different metals are connected together. The metals are joined by wires and the two solutions are connected using an ion (salt) bridge. A length of filter paper soaked in sodium chloride is often used for the ion bridge. The figure above shows how to build a cell in this way. The ion bridge completes the circuit by connecting the two half-cells together.

(See the change in colour in Cu^{2+} (blue) cell).

2. Other redox cells *(Electrolysis and colour changes)*

Theory:

A carbon rod is used to make electrical contact with a solution, which can undergo redox.

For example, $I^- \rightarrow \frac{1}{2} I_2$ $\qquad$ Fe^{3+} (yellow) $\longrightarrow$ Fe^{2+}(green)

Materials and chemicals:

2 small transparent flat-sided boxes, transparent voltmeter, 2 small carbon rods, filter paper, wires, sodium chloride solution, iron (III) chloride solution and potassium iodide solution.

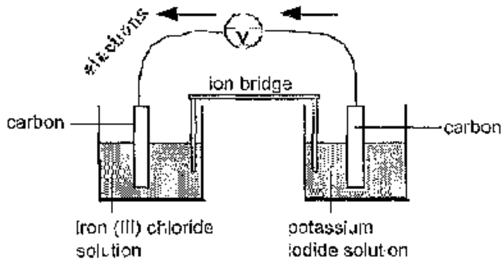
Procedure:

"The dry cell (torch battery) has a non-metallic carbon rod, how to interpret that?", In a transparent box, get a pupil to put 10mL of a solution of iron (III) chloride solution and about the same volume of potassium iodide solution in another box. Let him also to dip a carbon rod into each and link them to a meter. Complete the circuit with a wet filter paper as before. Ask the class to note the electron flow. Again get pupils to predict the relative size of voltage, direction of electrons.

$2I^- \rightarrow I_2 + 2e^-$ (Oxidation)

$2e^-$ collected by C rod and sent (via the meter) to the other C rod. These electrons are then delivered to the other half-cell to give the reaction

$2Fe^{3+} + 2e^- \longrightarrow 2Fe^{2+}$ (Reduction)



Iodide / Iron(III) cell

3. Corrosion *(Electrolysis and colour changes)*

Theory:

Rust is the name of the compound, which is formed when iron corrodes (oxidises). To investigate what causes rusting, the experiment illustrated in the following figure gives some clues to this.

Materials and chemicals:

4 small test tubes, 4 small iron nails and another painted one, iron wool, stopper, 1 mL oil, 3 mL boiled water, 3 mL tap water, few crystals of calcium chloride, 3 mL sodium chloride solution, ferroxyl indicator.

Procedure:

Start to discuss pupils' knowledge about the meaning of rust and reasons for its cause. They might say: "water", "air", "material the nail made of", "temperature", etc… Write all of these probabilities in the board. "Now how can we investigate this problem?". Ask for suggestions.

Now you can start the experiment by putting a nail in each test tube, but before that ask a pupil to clean the nails with the iron wool explaining why to do that. Then label them A-E.

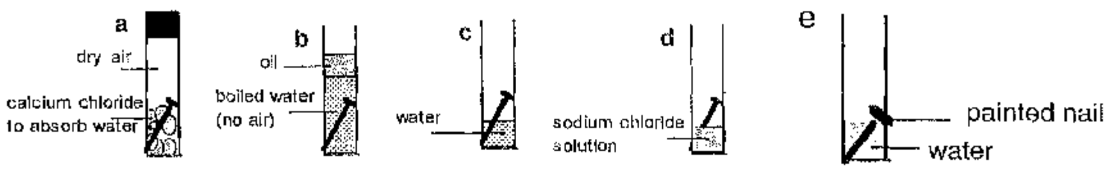
Let a pupil to put few lumps of anhydrous calcium chloride in test tube A. this tube should be stoppered after putting a nail in it (Discuss why to stopper the second tube whilst leaving the first one open).

Another pupil will be going to heat 3mL of water in tube C, then drop a nail and pour in 1mL cooking oil. (Discuss the point of boiling and adding a layer of oil).

In tube D, just place a nail whereas in tube E, put the painted nail. Add few drops of indicator to tubes B-E, leave for few minutes and then compare and justify the results. (If there is no ferroxyl indicator, then you need to leave this set for a week)

Now get pupils to predict in which tube the nail will rust giving their reasons.

And then ask a pupil to put the four test tubes in order and put the one with the most rust first. What do they found? What does the anhydrous calcium chloride do in tube B, and why was oil put on top of the water in tube C. Now which factors are needed to make iron rust? What can pupils suggest to protect ion from rusting? Why do we paint our metallic belongings such as cars, bikes, etc…



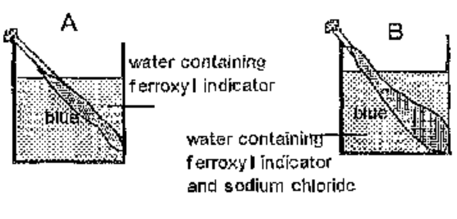
	Test tube	Results after a week
A	Air / no water	No rusting
B	Water / no air	No rusting
C	Air + water	Rusting
D	Air + water + salt	A lot of rusting

NOTE:

(If available, ferroxyl indicator is a pale yellow solution which turns blue when it reacts with Fe^{2+} ions (the ions which are formed when iron metal starts to rust) so the more blue colour there is, the more rusting has taken place).

$[Fe_{(III)}(CN)_6]^{3-} + Fe_{(II)} \longrightarrow$ Prussian blue

Ferroxyl



4. Mechanism of corrosion ***(Electrolysis, precipitation and colour changes)***

Theory:

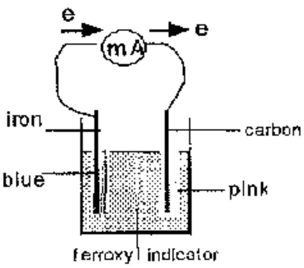
Rust occurs when there is a loss of electrons and the formation of $Fe^{2+}(aq)$ ions. This can be speeded up or slowed down depending upon what is attached to the Fe.

Materials and chemicals:

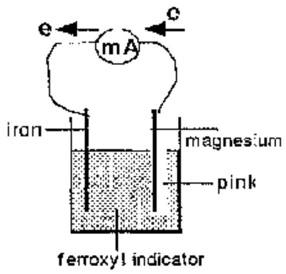
3 small boxes, transparent meter, 3 cm-long rods of iron, carbon, magnesium, and tin, ferroxyl indicator, distilled water and wires.

Procedure:

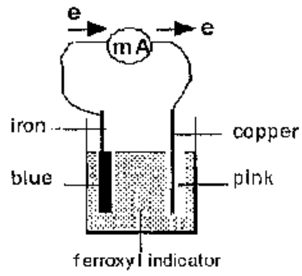
Let a pupil set three different cells as shown in figures below. Get pupils to predict what will happen around each electrode, what is the direction of electron flow in each cell as they expect. Knowing what happens in iron/carbon cell, ask them to predict what is going to happen if we replace carbon with magnesium or copper. What is happening to the carbon, magnesium and copper in the cells? Are there any gas bubbles on the Mg or C rods? If so, what are they? Where have they come from?



iron / carbon cell



iron / magnesium cell



iron / copper cell

Conclusion:

In the corrosion process, electrons flow away from iron. As shown in the figure above, in (A) the blue colour around the iron shows that it is rusting because electrons are flowing from the iron towards the carbon, whereas the pink colour around the carbon is due to the formation of OH^- ions. In figure (B) there is no blue colour around the iron. It has not rusted since the electrons flow towards the iron from the magnesium (Mg is higher than the iron in the electrochemical series, as in 1st secondary). The pink colour surrounding the magnesium shows the formation of OH^-.

In figure (C), the rusting of iron is particularly rapid and electrons flow from the iron to the Cu. In such cases, the iron is 'sacrificed' and the Cu is protected.

$$H_2O + e^- \longrightarrow OH^- + \tfrac{1}{2} H_2 \text{ (bubbles on C rod)}$$

NOTE:

Iron can be protected by sacrificial protection. To prevent a steel hull from rusting, blocks of a suitable metal are strapped to the steel hull. The metal used must be more reactive than iron. Zinc or magnesium would be suitable metals to use as they are higher than iron in the reactivity series.
The zinc or magnesium blocks corrode in preference to iron. As long as they remain no rusting will take place. These blocks can be easily replaced when they have corroded away.

5. Electroplating *(Electrolysis)*

Theory:

The object to be plated is used as the negative electrode. To do this you must make sure of three things:

1. The object to be electroplated must be made the cathode in the cell.
2. The anode must be made of a metal the same as the ions in solution.
3. The electrolyte solution should contain ions of the metal to be plated.

Note: Not all metals deposit well on others. If the current is too high, the deposit is soft and woolly and just drops off. Sometimes, there is no need to apply electricity, as the system will plate without it as in the example (dipping Zn in $CuSO_4$)

Materials and chemicals:

1 small transparent flat-sided box, 6-volt battery, 3 cm-long zinc electrode, a copper plate, 3 mL copper sulphate solution and wires.

Procedure:

It is recommended for the teacher to bring a golden electroplated ring or a watch and ask pupils, with discussion, whether they think that it is made of gold or just plated with gold. How expensive it is if it is made of gold. How to plate metals. Is it with paints, or there is a special process for that.

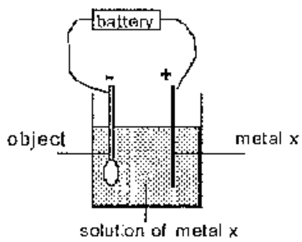
Present a zinc rod and ask how to plate it with copper. To verify, now let a boy to dip a zinc rod in CuSO4 solution and ask pupils to assume what might happen.

They can be then asked to guess what will happen if we do the other way by dipping copper rod in zinc solution? Should we design an experiment in light of the figure below? What would be the cathode and what is the anode? What type of electrolyte do we need? What if one of these three things is missing? What do they expect to happen when electricity is applied? What in the absence of electricity? What type of reaction is likely to occur? What are equations they predict for this reaction?

Copper plating of zinc needs no electricity whereas zinc plating of copper needs electricity to drive the "natural" reaction backwards

$Zn + Cu^{2+} \longrightarrow Zn^{2+} + Cu$ (natural reactivity series direction)

$Cu + Zn^{2+} \longrightarrow Zn + Cu^{2+}$ (needs to be driven "uphill", hence the need for electricity from battery)



Electroplating

First secondary

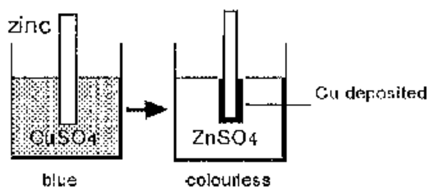
1. Displacement reactions *(Precipitation and colour changes)*

Theory:

A metal will displace a metal lower than itself in the electrochemical series from a solution of its ions.

Materials and chemicals:

Transparent flat-sided box, 3cm-long piece of zinc, a test tube and copper (II) sulphate solution. 2 test tubes, 3 cm-long strips of magnesium and copper and zinc sulphate solution.



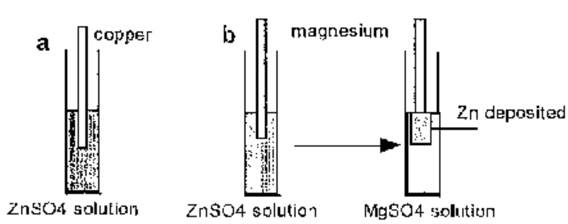
Zn and CuSO4 displacement reaction

Procedure:

Get pupils to predict what may happen if you dip a piece of zinc in a solution of copper (II) sulfate. Ask for suggestions then let a pupil to do it practically while the class is observing. Zinc will be, after some time, covered with a brown solid. Also the blue copper (II) sulfate solution loses its colour (the figure below). Ask the class to explain that? Now how to elucidate the displacement reactions of (a) copper and zinc sulfate solution, (b) magnesium and zinc sulfate solution

Demonstrate one, and then ask pupils to predict what will happen to the others, what reactions are going to occur? How long do these reactions take to come to completion? Such questions can be verified by experiments.

They will also notice gas on the Mg. What is it? Where has it come from? $ZnSO_4$ is an acidic solution. As well as displacing Zn, the Mg will also displace H_2.



N.B.

All of these experiments can be also done on drop scale on transparent sheet as follows:
Have transparent sheet with lines and formulae as shown below, with pupils assistance put a drop of $AgNO_3$ in each box below it. Do the same with $CuSO_4$, $FeSO_4$, etc...

Now put a small piece of Cu in contact with each drop in the first row, some Fe wire in each drop in the second row and so on.

You can see the displacement easily and get the whole series in one:

Mg displaces Zn, Fe, Cu, Ag

Zn displaces Fe, Cu, Ag

Fe displaces Cu, Ag

Cu displaces Ag

Chemicals	**$AgNO_3$**	**$CuSO_4$**	**$FeSO_4$**	**$ZnSO_4$**	**$MgSO_4$**
Cu					
Fe					
Zn					
Mg					

2. More on displacement *(Precipitation, gas collection and colour changes)*

Theory:

Hydrogen can be placed in the electrochemical series by considering the reactions of metals with dilute acids.

Find out where hydrogen is placed in the electrochemical series?

Materials and chemicals:

4 test tubes, few filings of magnesium, zinc, iron and copper, 2M hydrochloric acid.

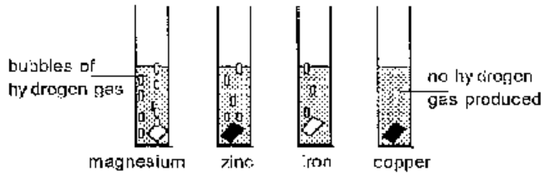
Procedure:

The teacher can start with a revision question "How can a metal be placed in the electrochemical series?" A pupil may answer "From considering its reactions with other metal solutions". The teacher then needs to ask for examples of that. "Now how to determine the place of hydrogen in this series?" A question could be answered by considering the reaction of metals with dilute acids.

The figure below shows that metals in the electrochemical series from magnesium down to copper react with dilute acids to produce hydrogen gas. This means they displace hydrogen ions from acids as the equation:

$$2H^+ + 2e \longrightarrow H_2$$

With many trials, it can be decided that hydrogen can be placed below iron but above copper.



with dilute hydrochloric acid

4. Rusting as a redox reaction ***(Electrolysis, colour changes and precipitation)***

Theory:

Rusting is an oxidation-reduction reaction. The flow of electrons away from iron towards carbon is demonstrated in the figure below.

Materials and chemicals:

A small box, transparent meter, iron nail, carbon rod, wires, sodium chloride solution and ferroxyl indicator. (Magnesium and tin strips)

Procedure:

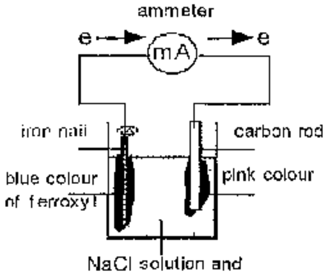
Remind pupils with an example of a redox reaction making clear the reduction reaction and the oxidation one. Ask whether these two processes are in separable or can one happen without the other.

Set out the cell shown below using materials provided. Note that the ferroxyl indicator shows that Fe^{2+} ions are formed at the iron electrode and OH^- ions at the carbon electrode.

Now we can get pupils to investigate what will happen if the carbon rod is replaced by a strip of magnesium or tin.

1- In case of the strip of magnesium, electrons will flow from the strip to iron and iron does not rust.

2- In the tin strip, electrons will flow from tin to iron, iron rusts faster than in the iron-carbon cell.



6. Displacement of a halogen by another theory ***(Colour changes and layers)***

If chlorine is added to halide solutions, it will oxidise the halide ions to halogen solution. For example, chlorine will oxidise bromide ions to a red/brown solution of bromine.

Materials and chemicals:

4 test tubes, dropper, chlorine water, dilute solutions of NaF, NaCl, NaBr and NaI, and chloroform (trichloromethane).

Procedure:

Before adding chlorine water, get the class to "suggest what might happen". "Can Cl_2 displace F_2 from a fluoride? Let us find out". Now in a test tube, let a pupil to add one drop of chlorine water to 3mL of a dilute solution of sodium fluoride. The class would see that nothing happens? Now ask them to predict what will happen with sodium chloride, then sodium bromide and then sodium iodide.

Ask a pupil to add three drops of chloroform (trichloromethane) to each of the solutions. It will form a lower layer, but mix the two layers with a bubble dropper and observe the colour of the chloroform layer. Discuss what happens with pupils? Halogens are more soluble in chloroform than they are in water because it is less polar than water. The class will record their observations in the table below.

Halides + Cl_2	Initial colour produced in water	Colour of chloroform solution	Products
NaF + Cl_2			
NaCl + Cl_2			
NaBr + Cl_2			
NaI + Cl_2			

Note: you must be careful of the amount of chlorine you add or you will continue the oxidation to colourless substances

$Cl_2 + 2I^- \longrightarrow 2Cl^- + I_2$ (brown)

I_2(brown) $+ 6H_2O + 6Cl_2 \longrightarrow 2IO_3^-$(colourless) $+ 12HCl$

Iodine should appear brown in water and pink in $CHCl_3$

In KI solution, the displaced I_2 combines with excess I^- to give I_3^- (brown)

In a non polar solvent there is no I^- and so I_2 (pink/purple) appears.

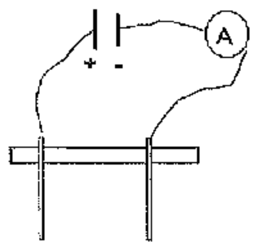
Second Secondary Experiments

1. Electrolytic *(Electrolysis)*

Theory:

Solutions can be divided into two categories:

- Electrolytic solutions such as acids, bases and salts solutions: those which conduct electricity since they dissociate into cations and anions. Some of these solutions are strong electrolytes (exist in the form of ions only) while others are weak electrolytes (exist in form of both ions and molecules).
- Non-electrolytic solutions: do not conduct electricity since they have no ions, such as solutions of sugars, alcohols, etc...



Materials and chemicals:

U-tube, transparent flat-sided box, 2 carbon rods, battery, electric switch, transparent ammeter (or a small torch bulb), wires, 5 mL of few different solutions (0.2M HCl, 0.2M NaOH, NaCl, $CuSO_4$, ethyl alcohol, sugar solution, etc…).

Procedure:

Let pupils suggest what solution will conduct and which won't and justify their choice. Now using materials provided, build up the set shown above and check whether a specific solution conducts electricity or not. They then can categorise solutions into electrolytic and non-electrolytic.

2. Solubility: (Ammonia fountain) *(Colour changes)*

Theory:

Ammonia is soluble in water giving basic solution. The gas being absorbed in the water creates a vacuum.

$$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$$

Materials and chemicals:

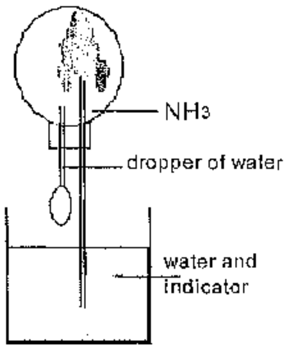
Spherical flask, connecting tube, dropper, small box, 0.88 ammonia, methyl orange indicator and distilled water.

Procedure:

Set up this experiment as shown in the diagram below. In the flask, put 1 mL of NH_3 to fill the flask with NH_3 gas, whereas the box contains 10 mL of water with few drops of methyl orange indicator.

Now ask the class: "What do you expect if we squirt (with the dropper) water in NH_3 (0.88) flask?" A boy would reply: "NH_3 will react with water." "then what will happen?" the teacher asks, the boy: "It is leaving space (vacuum) which pulls (atmosphere pushes) water". Verify by doing the experiment.

After discussing with pupils, the teacher then comments "Vacuum will be making a fountain with coloured water. Indicator will change to show that a base has been formed". "What is the base?"



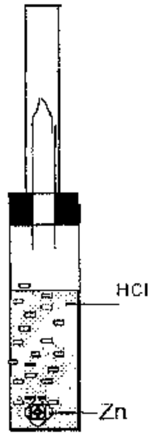
3. Hydrogen *(Gas collection)*

Theory:

Reactive metals give hydrogen with dilute acid.

Materials and chemicals:

A test tube, a smaller test tube, connecting tube drawn into a jet, granulated zinc, 0.2M hydrochloric acid.



Procedure:

Put 3mL of dil. HCl in the tube and then ask pupils to suggest what will happen if we add 1g of granulated zinc. Also discuss the gas bubbles, "what is it?" and "where has it come from?" "Now how can we collect the evolving gas?" Cover and collect the evolving gas by putting a smaller tube upside down in the mouth of the test tube of dil. HCl. Test for the gas.

4. Acids & Bases Properties *(Gas collection and colour changes)*

Theory:

Acids and bases have some specific properties. The following lines may highlight their main properties.

Materials and chemicals:

Test tubes, a magnesium ribbon, red/blue litmus solution (or methyl orange indicator), universal indicator, 2M hydrochloric acid, 2M sodium hydroxide solution, milk, vinegar, orange juice, soft drink, distilled water and detergent.

Procedure:

1. Effect on litmus solution.

- ❖ Put 3.0 mL of dil (HCl) in two test tubes and 3.0 mL of dil (NaOH) in another two test tubes.
- ❖ Add few drops of red/blue litmus solution to one of the acid and one of the base and see what happens.

2. Reactions with metals.

- ❖ Put 3.0 mL of dil (HCl) in a test tube and 3.0 mL of dil (NaOH) in another tube.
- ❖ Cut a small piece of magnesium and drop it in each and see if any gas is evolving. Does H_2 come from both?
- ❖ What about a piece of Al in each? You get H_2 in **BOTH** cases

$$Al + 3HCl \longrightarrow AlCl_3 + 1\frac{1}{2} H_2$$

$$Al + 3NaOH \longrightarrow Na_3AlO_3 + 1\frac{1}{2} H_2$$

(Al is amphotric i.e. is somewhere between a metal and a non-metal)

3. pH Number.

- ❖ In separate test tubes, put 3.0 mL of dil (HCl), vinegar, milk, diluted orange juice, soft drink, detergent solution and dil (NaOH) solutions.
- ❖ Add few drops of universal indicator.
- ❖ Compare the colour codes finding out the pH number.
- ❖ Classify into acidic, neutral, basic solutions.

Part 5:

Some additional experiments

1. Reactivity series *(Gas collection)*

Theory:

Metals vary in their reactivity and can be grouped in a particular series.

Materials and chemicals:

Test tubes, small transparent flat-sided box, measuring cylinder, watch glass, balance, few samples of powdered zinc, magnesium, copper, tin and iron, 2M. HCl, detergent solution.

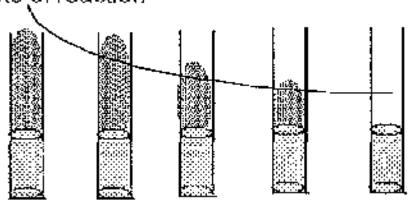
Procedure:

To make a fair comparison between the metals, ask a pupil to measure out about the same bulk (pile on end of spatula) of each of powdered magnesium, copper, tin, iron and zinc and put each into a separate test tube. In a measuring cylinder mix 15mL of 2M hydrochloric acid with 15mL of a detergent. Tip 3mL of this mixture into each of the test tubes containing the powdered metal.

The rate of production of a given volume of foam is related to the rate of production of hydrogen which is, in turn, related to the reactivity of the metal.

Summarising:

<table>
<tr><td>K</td><td>Na</td><td>Li</td><td>Ca</td><td>Mg</td><td>Al</td><td>Zn</td><td>Fe</td><td>Sn</td><td>Pb</td><td>H_2</td><td>Cu</td><td>Hg</td><td>Ag</td><td>Au</td><td>Pt</td></tr>
<tr><td colspan="5">Metals displace H_2 from cold water</td><td colspan="4">Metals displace H_2 from steam</td><td colspan="7">Metals do not displace H_2 from water or steam</td></tr>
<tr><td colspan="3">Metals too reactive to risk in acid</td><td colspan="7">Metals displace hydrogen from acid</td><td colspan="6">Metals do not displace hydrogen from acid</td></tr>
</table>



2. Electrons changing over (displacement) *(Precipitation and colour changes)*

Theory:

Any metal will displace a metal lower in the reactivity series from a solution of one of the lower metal's salts.

Materials and chemicals:

Test tubes, pipette, small pieces of Mg, Cu, Ag, Zn, Pb and Fe, solutions of $AgNO_3$, $CuSO_4$, $Pb(NO_3)_2$, $FeSO_4$ and $MgSO_4$.

Procedure:

Get a pupil to cut each of the following metal foils- magnesium, copper, silver, zinc, lead and iron into thin strips. He will then place one sample of each metal in a test tube.

Using a pipette, ask another one to add few drops of a solution of silver nitrate and get others to say their predictions. Wait about two minutes before the noting which metals have become discoloured. Now ask them what they expect if we repeat the experiment but with a few drops of a solution of lead (II) nitrate. Repeat the experiment, this time with that solution $\{Pb(NO_3)_2\}$. Again let them note which metals have become discoloured.

Once more ask and then repeat using samples of the metals and solutions of copper (II) sulphate, iron (II) sulphate, zinc sulphate and magnesium sulphate. According to their observations, the class would fill in the following table and then list the six metals beginning with the one, which had discoloured the most metals. How does this list compare with the reactivity series?

Note:

- After doing the first tube, get pupils to predict what will happen in other tubes giving their explanations in light of theory they have.
- Cut metals into thin strips and when Ag is displaced it appears as "needles" along the strip, like a tree.

Metal	**$AgNO_3$**	**$CuSO_4$**	**$Pb(NO_3)_2$**	**$FeSO_4$**	**$ZnSO_4$**	**$MgSO_4$**
Mg						
Zn						
Fe						
Pb						
Cu						
Ag						

3. Nitric acid, the electron acceptor *(Gas collection)*

Theory:

Concentrated nitric acid is a powerful oxidising agent and it is reduced by metals to nitrogen (IV) oxide (NO_2). But if it is dilute, it produces nitrogen (II) oxide (NO) and water when added to a metal. Only when very dilute, it will react with reactive metals to give salt and hydrogen.

Materials and chemicals:

3 test tubes, small transparent flat-sided box filled with water, magnesium ribbon, dropper, distilled water, concentrated nitric acid.

Procedure:

First of all, start with a simple example of granulated zinc with HCl, and then draw a question "Do all acids behave in the same way?" i.e. "Do they give hydrogen with reactive metals? What about nitric acid?"

Get a pupil to place 2mL of water in a test tube and drop in a piece of magnesium ribbon. With a dropper, he will then add one drop of dilute (2M) nitric acid. If necessary, ask him to add another drop or two of the acid until the bubbles of gas are streaming from the magnesium. Ask them to identify the gas. What is it? Where has it come from?

Once more let him add a little more of the acid until another change occurs in the reaction. Is the same gas being given off? What is happening near the mouth of the test tube?

Get another pupil to put a fresh piece of magnesium into another test tube and add a few drops of concentrated nitric acid directly to it. What is the result this time?

There have been at least three different gases given off, depending upon this concentration of the acid.

Repeat the experiment with a small piece of copper foil. What are the results this time? Why do they differ from the Mg results?

Very dilute HNO_3

Will give hydrogen with Mg, but no reaction with Cu (electrochemical series)

Dilute HNO3

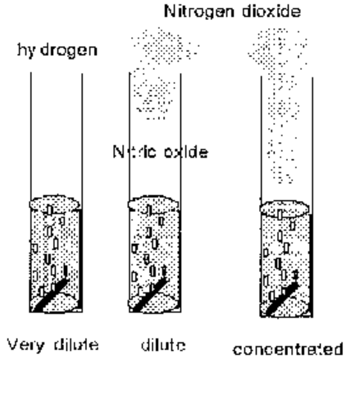
Nitrate ions will give the gas nitric oxide (colourless)

$NO_3^- \longrightarrow NO$ or $NO_3^- + 4H^+ \longrightarrow NO + 2H_2O$

Then $NO + \frac{1}{2} O_2 \longrightarrow NO_2$ (at the mouth of the tube)

Concentrated HNO3

$NO_3^- \longrightarrow NO_2$ or $NO_3^- + 2H^+ \longrightarrow NO_2 + H_2O$



4. Ammonia (A thought problem in practical) *(Gas collection)*

Theory:

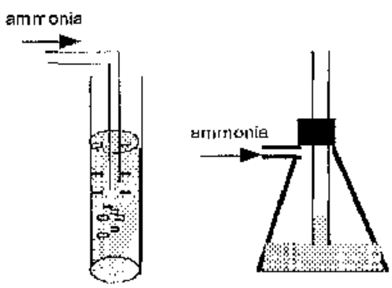
Ammonia is extremely soluble in water and forms a base called ammonium hydroxide.

Materials and chemicals:

1 test tube, inlet side-arm flask, right-angled connecting tube, connecting tube, stopper, distilled water and ammonia.

Procedure:

If a very soluble gas like ammonia is to be dissolved in water, it could be done as shown in diagram 1. However, there is a danger of the water being sucked back up the tube as the NH_3 dissolves rapidly producing a vacuum. Diagram 2 shows an apparatus for dissolving the gas, which is supposed to be an improvement on diagram 1.



Dig 1 Dig 2

Discussion starter:

Think of reasons, which make apparatus 2 a clear improvement over apparatus 1.

Hint. It could be three of the following five statements:

1. A larger water surface is exposed to the gas and so it will dissolve more quickly.
2. The water cannot reach the inlet side-arm tube and so cannot be sucked back.
3. The gas can push the water up and out of the centre tube and so escape harmlessly.
4. The flask being full of air will slow down the absorption of the gas by the water.
5. A sudden increase in gas pressure will force water up the centre tube until the bottom of the tube comes clear of the water in the flask. The water in the tube will then fall back into the flask.

5. Sulphur dioxide ***(Colour changes)*** (this can be also done using plastic sheet)

Theory:

Sulphur dioxide is a dense, colourless gas with a choking smell. It is very soluble in water, which turns blue litmus paper red. It reacts with alkalis. It is also a strong reducing agent when it is wet or in a solution.

Materials and chemicals:

2 test tubes, stopper, dropper, connecting tube, sodium sulphite, blue litmus paper, filter paper, 2M hydrochloric acid, potassium manganate (VII) solution, potassium dichromate (VI) solution.

Procedure:

Invite a pupil to put a few crystals of sodium sulphite into the test tube and then slowly drip small amount of dilute hydrochloric acid. Pupils will notice gas (sulphur dioxide) now ask them what is it? and where has it come from? What should we do if we need more gas? Shall we drip on some more acid? Does the gas have any colour or a distinctive smell?

Ask another pupil to hold two pieces of blue litmus in the gas (one dry and one wet) and tell his classmates what happens to the colour.

($SO_2 + H_2O \longrightarrow H_2SO_3$) water is necessary for it to become an acid.

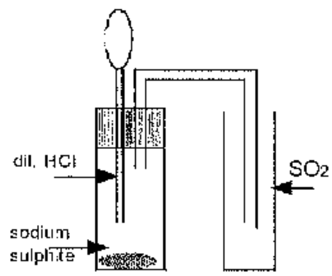
Fold a piece of straw (or paper) over the edge of the test tube in which the sulphur dioxide is being made and tell a boy to hold it in place with a stopper. It will become bleached because of the reaction $SO_3^{2-} + O \longrightarrow SO_4^{2-}$

The bleaching is caused by the reducing properties of the SO_2. The dye is reduced to a colourless form. In the air, this can be reoxidised and the colour slowly returns. Paper is bleached in this way but becomes yellow after a while, for example, newspaper.

Now get the whole class to guess what if sulphur dioxide is bubbled through acidified potassium manganate (VII) solution? The potassium manganate is reduced and changes from a purple colour to colourless. (Or hold a filter paper, dipped in this solution, in the SO_2)

Similarly, could they predict what might happen if sulphur dioxide is bubbled through acidified potassium dichromate (VI) solution? It is reduced from an orange colour to a green one. (Or hold a filter paper, soaked in this solution, in the SO_2)

Either of these colour changes can be used as a test for sulphur dioxide.



6. The properties of ammonia *(Other experiments)*

Theory:

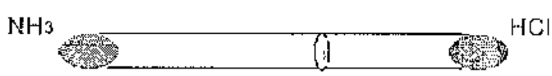
Ammonia is a colourless gas, which dissolves in water, and forms a base called ammonium hydroxide. It also reacts with hydrogen chloride gas and forms a solid called ammonium chloride.

Materials and chemicals:

1 long glass tube, 2 small plugs of glass wool, conc. ammonia, and conc. hydrochloric acid.

Procedure:

Have a long horizontal tube. Get a pupil to put a plug of glass wool at each end. *Ask the class to guess what might happen if their friend drops conc. HCl on one plug and conc. NH_3 on the other.* The diffusion causes a white ring of NH_4Cl to appear not exactly in the middle since rate of diffusion is related to the inverse of the square root of the density of the gas. *Ask for explanation.* NH_3 is less dense than HCl and so diffuses faster. The white ring will then be nearer the HCl end.



7. Preparation of halogens *(Colour changes)*

Theory:

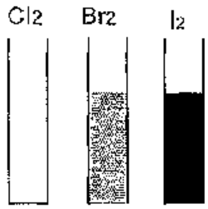
Halogens are very similar in their physical properties and have distinctive colours in that chlorine is green yellow while bromine is deep red in colour and iodine is silver black.

Materials and chemicals:

3 test tubes, solid potassium permanganate, solid potassium chloride, potassium bromide, potassium iodide, conc. hydrochloric acid and distilled water.

Procedure:

Get a pupil to take three different test tubes, and add 1-2 crystals of potassium permanganate and few drops of concentrated hydrochloric acid in each. Put few crystals of potassium bromide in the second and potassium iodide in the third one. Stir solutions and find chlorine yellow, bromine reddish brown and iodine violet.



Looking at the period table:

What is the colour and state of Cl_2?	Green gas
What is the colour and state of Br_2?	Brown liquid
What is the colour and state of I_2?	Black solid

What then would be the colour and state of At_2? (Looking for pattern)

Part 6:

Some Biological Experiments That May Be Projected Using TOPs Method.

1. Liquid Diffusion:

- Put one crystal of potassium permanganate ($KMnO_4$) in a test tube of 3ml water and write down your observation.

2. Gaseous Diffusion:

- Release some perfume in the lab (or classroom) and ask pupils to raise their hands when they smell it. Front row will get it first, followed by next row, the third and so on.

3. Diffusion from cell to the surroundings:

- Cut two small round flat pieces from red beetroot.
- Wash them and put in a test tube of warm (or hot) water.
- Write what you see.

4. Digestion of food – Enzyme properties.

- Put some amylase into a test tube and then put a piece of bread.
- Put the tube in a transparent flat-sided container of warm water.
- Add Benedict's or Fehling's solution

5. Respiration (Breathing)

- Put 3 ml of lime water in a test tube and then breath into it, the water will turn milky (Testing for CO2) ask why?
- Keep on blowing, the water turns clear again, ask for explanation?
- Then if you heat, it will become cloudy once more, ask for explanation?
- Equations: (ask to investigate possible equations)

This is the normal $\underset{\text{Soluble}}{CO_2 + Ca(OH)_2} \longrightarrow \underset{\text{insoluble}}{CaCO_3} + H_2O$

Place for discussion $CaCO_3 + H_2O + CO_2 \longrightarrow \underset{\text{Soluble}}{Ca(HCO_3)_2}$

$Ca(HCO_3)_2 \xrightarrow{\text{Heat}} \underset{\text{insoluble}}{CaCO_3} + H_2O + CO_2$

To turn into an investigative way:

You know that limewater turns milky when you breath into it. Let us do the experiment again, but with a difference. I need a volunteer to blow into the limewater.

Now blow and the class will watch the effect. *{it turns milky as expected}*

Now keep on blowing and blowing and blowing !! *{milkiness disappears}*

Here is a problem. What has happened to the limewater?

What was the milkiness? *{$CaCO_3$}*

Write the equation to refresh your memories. *{$Ca(OH)_2 + CO_2 \rightarrow CaCO_3(milky) + H_2O$}*

Now we have $CaCO_3$ in water and keep on adding CO_2 *{$CaCO_3 + H_2O + CO_2 \longrightarrow$*

What could the product be? (Take suggestions)

{Arrive at $CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$ (dissolves)}

how could be check this and reverse it? *{Remove extra CO_2}*

How *{Heat}*

Try it and see the milkiness returns.

6. Catalysts.

- Put 3ml of hydrogen peroxide in a test tube.
- Drop 1ml of suspension of yeast in the tube. (or piece of dirt; soil)
- Hydrogen peroxide will fizz vigorously and give off oxygen due to breaking down of H_2O_2 showing that yeast is a catalyst.

  (The soil will also cause this)

7. Osmosis *(v. slow, but it can be detected slightly at the end of the lesson)*

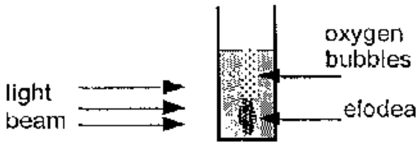
- Cover the base of a small funnel with a permeable membrane(cellophane)
- Put 1ml of concentrated sugar solution in the funnel
- Immerse the funnel in a transparent flat-sided box of distilled water.
- The natural tendency in any system is to have equal concentrations throughout. With no membrane, sugar will move into the water and water into the sugar to get equal concentrations. With a membrane, the sugar cannot move and so water enters to dilute the sugar solution in an attempt to equalise concentration. It "stops" only when the pressure build up balances the tendency for the diffusion.

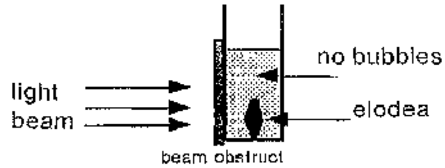
8. Photosynthesis process:

Evolving of oxygen

- Dissolve about 0.5g of $NaHCO_3$ in 10 mL water.
- Fill 2/3 of a small test tube with water.
- Put a small piece of ***elodea canadensis***

- Leave for a while exposed to the light then observe the oxygen bubbles on the plant pieces.
- Obstruct the light beam and see how the bubbles stop
- Admit light (from projector) again and see bubbles again





9. 9. Food Digestion

- **Effect of saliva on starch**
  - put 1.0 cm3 of starch solution in each of four test tubes
  - add to each the following:

First tube: $1.0cm^3$ of water.

Second tube: $1.0cm^3$ of saliva solution*.

Third tube: $1.0cm^3$ of warm water + boiled saliva solution.

*(Prepared by rising out mouth or spitting in water)

Fourth tube: 1.0cm3 of saliva solution + 1 drop of conc. HCl.

  - put the whole set in water bath (37^oc)
  - add few drops of iodine solution till blue colour appears.
  - Shake and leave in the water bath for 15 minutes.
  - See colour changes
  - To test for glucose:

Put 1.0 ml of starch solution into 1.0ml of saliva solution.

Add Benedict solution

Heat for two minutes

Leave to cool

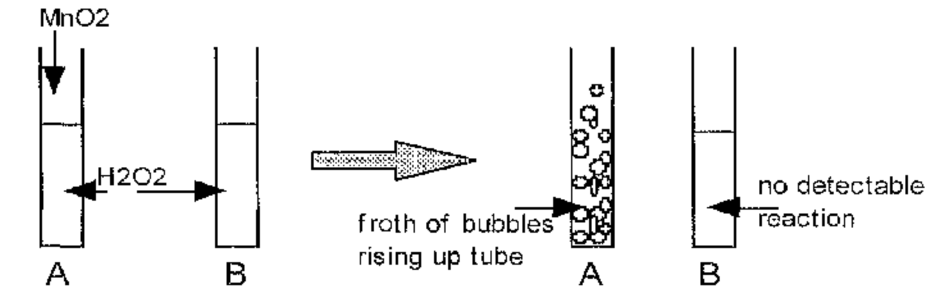
- **Impact of gastric juice on fat**
  - Put 2.0ml of olive oil in two test tubes.
  - Put 0.5 ml of water in the first tube and 0.5 ml of gastric acid in the second
  - Shake well and leave for awhile to see how does gastric acid affect oil.

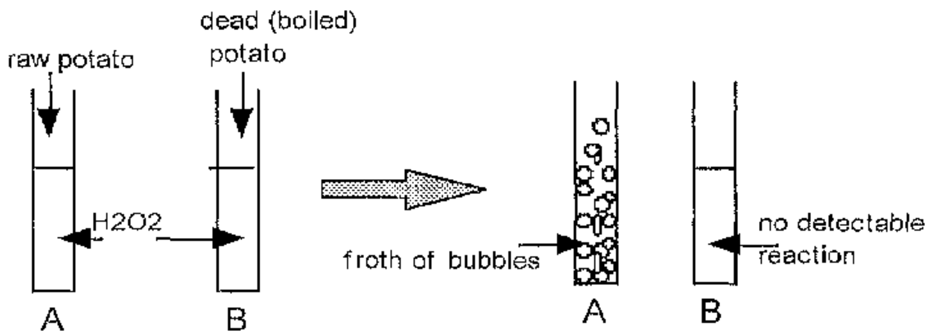
10. Investigating enzymes.

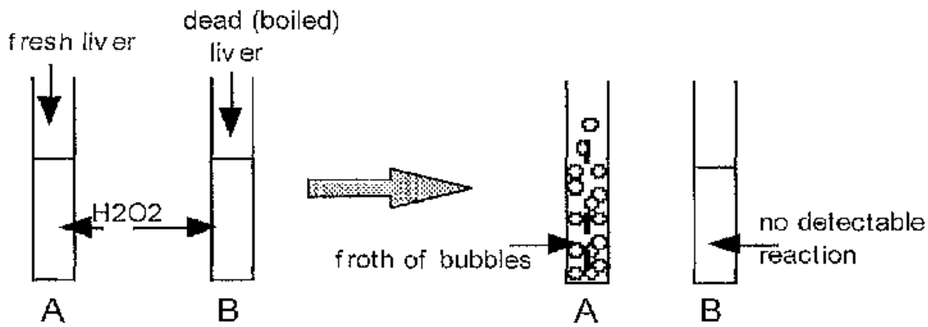
- **Effect of a catalyst** (as an example of enzymes)

The bubbles forming the froth in tube A are found to re-light a glowing splint, showing that oxygen is being released during the breakdown of hydrogen peroxide (into water and oxygen). In tube B, the control, the breakdown process is so slow that no oxygen can be detected.

Therefore, manganese dioxide (which remains chemically unaltered at the end of the reaction) has increased the rate of a chemical reaction which otherwise would only proceed very slowly. Now to discuss, pupils can be asked firstly to suggest effect of catalyst in reactions, and also investigate the effect of boiling in enzymes. They then can widely discuss the effect of boiling on proteins, vitamins, and minerals in food.







◆ Effect of pH on catalase activity.

One factor of the action of catalase on hydrogen peroxide solution is its pH. Each of different pH conditions is maintained by adding a suitable buffer solution (a special chemical which keeps an experiment at a required pH).

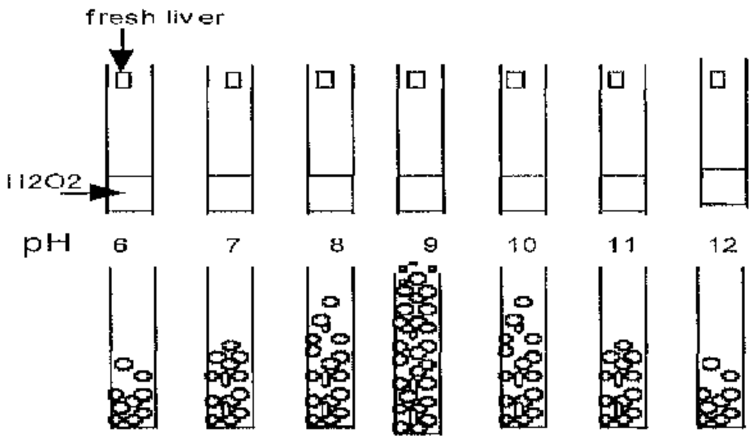
When an equal-sized piece of fresh liver is added to each cylinder, the result shown in the diagram is produced. Since liver contains enzyme catalase, the following reaction would promote:

$$H_2O_2 \longrightarrow H_2O + O_2$$

As O_2 is released, it makes a froth of bubbles. Although bubbles may burst, the amount of froth (height) formed could be noticed which refers to the activity of the enzyme at each pH. Clearly, catalase works well in the range of pH 7 – 11. It has most activity at around pH9.

Discussion:

Discuss about where in the digestive tract the pH will be 9. What about enzymes in the mouth (ptyalin)? What pH do they work at? Try pH papers on saliva.



◆ Effect of plant amylase (diastase) on starch.

In tube A, the enzyme plant amylase (diastase) has promoted the breakdown of starch to simple sugar (maltose).

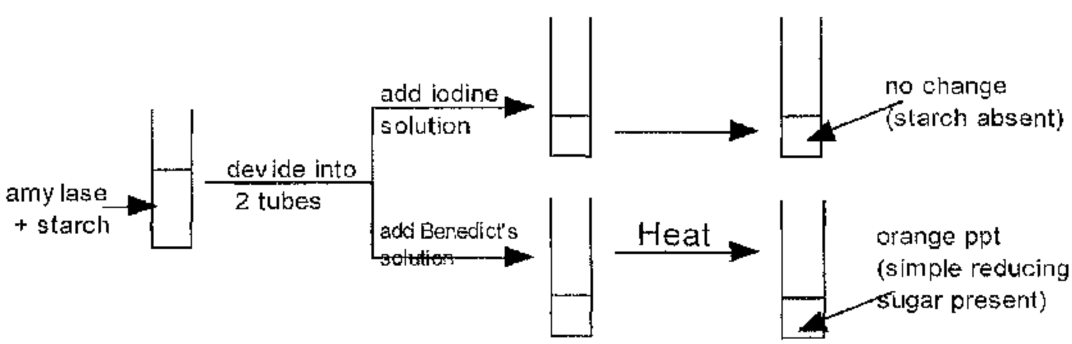
In tube B, the control, which lacks the enzyme no detectable reaction has occurred.

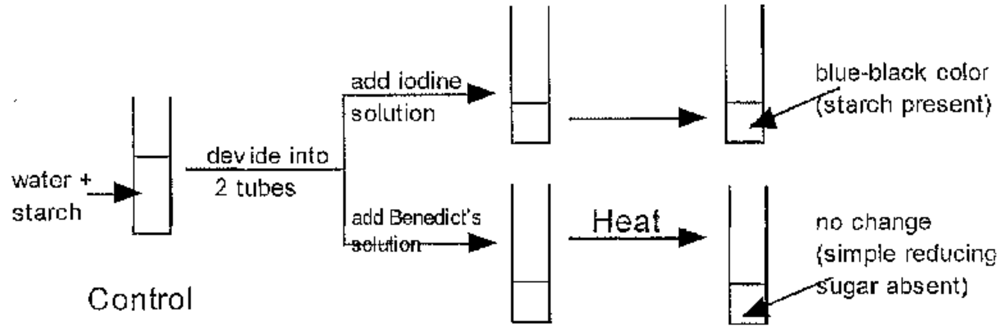
The substance upon which an enzyme acts is called the substrate. The substance produced as a result of the reaction is called end product.

The reaction being promoted is summarised as:

Starch	**amylase (enzyme)** ⟶	**simple sugar (maltose)**
substrate		**end product**

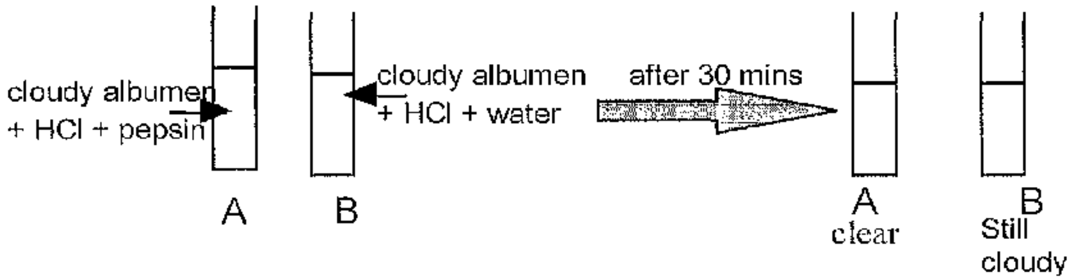
- Amylase is a digestive enzyme present in saliva and pancreatic juice.
- Salivary amylase and pancreatic amylase made in the human body similarly promotes the breakdown of starch into simple sugar.





♦ Action of pepsin on protein

Pepsin is a digestive enzyme, which is active in the human stomach. Glands in the stomach wall make it. It works best in conditions of low pH. In this experiment, we use egg white (albumen) as protein and we add drops of HCl to initiate the stomach conditions.



11. Shadows Experiments

A teacher can project few objects related to some biology topics. This is suitable for those solid objects which their shapes matter (signal) while their colour and dimensions do not matter (noise). For instance, when talking about birds' beak shapes, the teacher can easily project their different shapes and characteristics of each. The same thing can be said for birds' feathers, birds' feet (claws), teeth of animals or even shapes of bones. Sometimes the outlines of plant leaves, flowers, stems or roots may work through projections.