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Attitudes to School Physics Laboratory in Oman

by

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A Thesis Submitted in Fulfillment of the Requirements for the Degree of Master of Science

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Abstract

The major goal of this study is to explore the attitude of students and teachers to physics laboratory work in after-basic education schools in Oman. The world has seen an explosion of scientific knowledge in the past hundred years or so. The outcomes of this have brought immense changes to societies and to lifestyles; the communications revolution, the world of new materials, the development of medical advances, etc. All of these have depended on very highly skilled scientists, given the support and facilities to experiment and explore. The place of the laboratory in this has been critical and this has had an effect on the way the sciences are taught at school and university levels.

The Ministry of Education in Oman incorporated laboratory work as an integral part of school education from the 1970s. Many changes have been implemented in recent years to reform the science school education. Secondary education (Grades 11 and 12) are the last episode of the basic education system. It is composed of both compulsory and elective subjects. Upon completion of this level, students receive General Education Diploma in Post-Basic Education. The curricula have been changed radically to include practical as well as theory components.

The main aim of this study is to gather insights about students' and teachers' attitudes to physics laboratory in Oman, and how the perceptions of students and teachers differ. The attitudes of 881 Omani students and 39 teachers were surveyed using questioners designed in line with the methods of Osgood et. al (1957) and Likert (1932). The sample came from 29 public Omani schools in Al-Dahera Region. The goal was to present a picture of the attitudes based on the patterns of responses of large samples. This allows investigating the trends with students and teachers differences.

Overall, students and their teachers hold positive attitudes towards laboratory work in physics. Both students and teachers argued that laboratory work is the best part of physics; it is enjoyable, important, interesting and promotes critical thinking. However, they pointed out some issues and concerns that should be addressed to fully harness the laboratory work in teaching school physics. Chi-square analyses shows that students and teachers have minor dissimilarities of views towards laboratory work.

With such large sample, the study has offered a general idea about students and teachers perceptions towards physics laboratory work. Interviews with more than forty physics teachers show strong conformity between the teachers' survey results and the results obtained from these interviews. The interviews also gave the teachers a chance to express different concerns related to physics curriculum, technical support, training and attitudes related to the use of laboratory in teaching school physics. Moreover, the study shed some light on issues and concerns that should be addressed. It also offered proposals for possible future research and presents general findings and implications.

Dedication

To the soul of my mother,

To my husband and children,

To my father, brothers and sisters,

For all their endless love, encouragement and support

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First and foremost, I must thank the almighty Allah who has again helped me and provided me with the strength to surmount another challenge in my life.

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My words will fail to express my heartfelt thanks to my husband, *Nasser*, his love, understanding and encouragement have helped me survive through the most difficult times. I would like to thank him for pushing me to the limits on this thesis, for spending hours on my drafts and for ceaselessly providing me with feedback and discussion. He has always made time regardless of his busy workload. I could not have done it without him. He shares my success and I will be forever grateful for his loving support. This thesis is as much his as mine.

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Chapter 1

Introduction

The Sultanate of Oman is the second largest country in terms of area and population in the Arabian Peninsula, with about 309,000 square kilometres (120,000 square miles), which is equal to the size of the United Kingdom and Ireland (Ministry of Education, 2004). Administratively, Oman is divided into four counties (County of Muscat, County of Dhofar, County of Musandam, and County of Buraimi) and five regions (Dhakhilia, Batinah, Dhahira, Sharkiyah, and Wusta). Figure 1.1 shows the map of Oman with the administrative boundaries.

This chapter highlights the development of education in Oman, the development of its education system, basic and general education. Finally, this chapter sheds some light on the physics laboratory in Omani schools.

Figure 1.1: Map of Oman

1.1. Education in Oman

Education in Oman began in memorisation schools where the curriculum was mainly memorising the Quran, along with basics of reading and writing Arabic characters (Al-Shuaili, 2000). The demand for educational development in the Sultanate of Oman has been so urgent that the past 36 years have witnessed many attempts at reform looking at both expanding provision - the quantitative aspects - and improving the provision - the qualitative aspects (Al-Nabhani, 2007).

Before 1970, most children went to Quranic schools. They were taught by teachers of the Quran in various places including under the shade of trees, public boards1 known as Saplah, mosques or in the homes of teachers themselves. Most of the young students were aged between six and fourteen and the students who managed to recite the whole Quran were known as having completed the Seal of the Quran. There were no clear criteria for evaluating the student’s performance, but the quality of reciting the Quran correctly was the sole criterion of excellence (Ministry of Education, 2007a).

Oman's renaissance, led by His Majesty Sultan Qaboos Bin Said, began in 1970. Since then, the Sultanate launched a plan to develop the people's potential, abilities and trends of thinking, in order to prepare future generations. The people are now in the process of becoming more aware of their potential in all areas of life (Al-Shuaili, 2000). This development was achieved by the efforts of the government and the loyal citizens who devoted themselves to build a modern educational system. Developments continue and there are great efforts to bring education in line with modern developments worldwide to achieve the best provision possible. The following subsections summarize these efforts.

1.1.1. The period 1970 - 1975

This period was characterized by rapid spreading of educational services. New schools in the cities and villages were opened at an enormous rate. The following table shows the quantitative development achieved during these five years (Ministry of Education, 2007a).

---

[1] Places where people gather and discuss issues related to their society

Academic year	**70/71**	**75/76**	**Growth % (70/75)**
Schools	16	207	1194
Classes	151	1617	971
Students	6941	55752	703
Teachers	196	1980	910

Table 1.1: Growth of schools, classes and students between 1970 and 1975

1.1.2. The first five-year plan (1976 - 1980)

This plan continued the policy of spreading educational services in addition to diversification of education. Two model vocational schools were opened, one for girls and one for boys, a secondary agricultural institute was opened in Nizwa in addition to a commercial school for boys. The following table illustrates the quantitative development between 76/77 and 80/81 which, inevitably, were not as great in percentage terms as the previous five years period. (Ministry of Education, 2007a)

Academic-year	**76/77**	**80/81**	**Growth %(76/80)**
Schools	261	373	43
Classes	1992	3618	82
Students	64975	106032	63
Teachers	2553	5150	102

Table 1.2: Growth of schools, classes and students between 1976 and 1980

1.1.3. The second, third and fourth five-year plans (1981 - 1995)

The following three five year plans (i.e. 1981-1985, 1986-1990 and 1991-1995) tackled two dimensions: expansion of education services and improvement of quality of education. Thus, more schools covering both elementary and preparatory levels were established. Preparatory schools were provided with laboratories, libraries, and workshops. Table1.3 illustrates the increase in the number of schools, students and teachers (Ministry of Education, 2007a).

Academic year	**81/82**	**95/96**	**Growth % (81/95)**
Schools	408	953	134
Classes	4137	15024	263
Students	120718	488797	305
Teachers	5864	22292	280

Table 1.3: Growth of schools, classes and students between 1981 and 1995

1.1.4. The fifth five-year plan (1996 - 2000)

In this plan, basic education was introduced to develop the quality of education and reduce its cost with some guarantee of better outcomes. Table 1.4 illustrates the quantitative development during the five years of this plan (Ministry of Education, 2007a).

Academic-year	96/97	00/01	Growth % (96/00)
Schools	967	993	3
Classes	15403	17141	11
Students	502674	554845	10
Teachers	22693	26416	16

Table 1.4: Growth of schools, classes and students between 1996 and 2000

1.1.5. The sixth five-year plan (2001 – 2005)

This plan is a continuation of the development policy adopted by the Ministry of Education in the Sultanate especially in expanding the gradual implementation of the basic education. In addition to expanding educational services, the plan tackled the following:

- Minimizing the quality gap between basic education and general education;
- Developing and implementing the developmental evaluation system ;
- Expanding and improving teacher training;
- Abolition of streaming in grades 11 and 12 (ages 16 and 17) and introducing the system of obligatory and optional courses.

The following table illustrates the quantitative development during the sixth five year plan (Ministry of Education, 2007a).

Academic-year	01/02	05/06	Growth % (01/05)
Schools	1010	1046	4
Classes	17902	19664	10
Students	567997	568074	0
Teachers	28385	37500	32

Table 1.5: Growth of schools, classes and students between 2001 and 2005

1.1.6. The seventh five-year plan (2006 - 2010)

This plan is a continuation of the sixth five-year plan. However, it is somewhat different because it is characterized by putting into action the first steps of the development of grades 11 and 12. The system is a two-year of schooling followed by the stage of basic education that lasts for ten years. The main aims of this system are to continue developing basic skills and job skills and providing career planning to students which will help them to be active members of the society and to be able to take advantage of opportunities for education, training and work after school. Table 1.6 shows the numbers of schools, classes, students, teachers and administrative staff for the academic year 2006/2007 (Ministry of Education, 2007a).

Academic year	**06/07**	**70/71**
Schools	1053	16
Classes	19868	151
Students	563602	6941
Teachers	39993	196
Administrators	4521	almost none

Table 1.6: Numbers of schools, classes, students, teachers and administrators in 70/71 and 06/07

The final column in Table 1.6 shows the situation in the early 1970s. The phenomenal growth rate in less than four decades is quite remarkable. Nonetheless, this rate of change inevitably must generate stresses on the system where the numbers of teachers to be trained and then kept up to date is very large. In addition, there are huge financial and managements demands as new schools have been built and updated. The development is a great achievement but must generate its own problems by the sheer scale of growth.

1.2. The education system in Oman

There are two types of education in Oman. The first one is general education and it is of 12 years duration but it is being replaced gradually by the second type: basic education. In 1997, the Ministry of education began replacing the three levels of general Education system (primary, preparatory and secondary) with the basic education system. The old system of General Education (Grades 1-12) is still functioning side by side with the new Basic Education one (Ministry of Education, 2004) – see Figure 1.2.

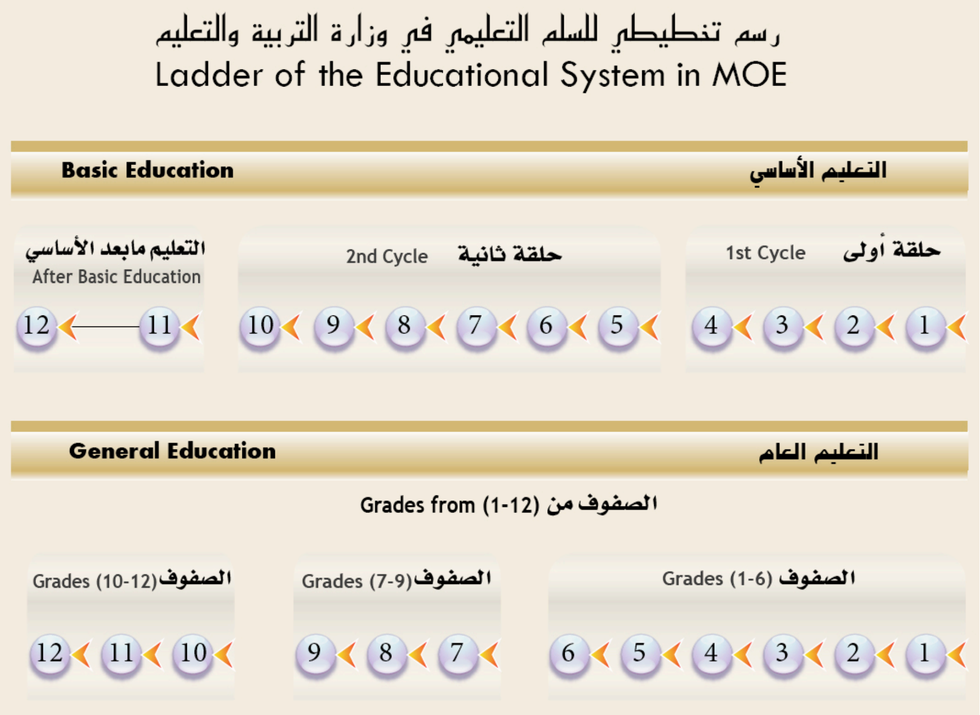

Figure 1.2: Ladder of the educational system in the Sultanate of Oman (Ministry of Education, 2004)

Basic education lasts for 10 years and those who will pass grade 10 successfully shall be promoted to the following level which gives two years of study and prepares the student for higher/further education studies and/or job market. The 10 years of Basic Education were divided into two cycles: the duration of the first cycle is four years while the second cycle covers six years. Figure 1.2 illustrates these two educational systems. In the next two sub-sections we will explore more about the General and Basic Education.

1.2.1. General education

General education means pre-university education, which is offered free to all citizens who are interested. It comprises three levels: primary, preparatory and secondary (Ministry of Education, 2004).

Primary education (Elementary)

Children aged not less than six and not more than eight are accepted in 1st elementary. The duration of this level is normally six years, at the end of which successful pupils progress to the next level known as preparatory level. This Primary level aims to assist children developing healthy and integrative behaviour and to acquire basic skills and knowledge to enable them understands the social, environmental and economic relations within their community. It also prepares pupils for the continuation of their education in the next level.

Preparatory education

Students, who successfully complete their elementary education, are admitted to this three-year level. This level forms the intermediate level between primary and secondary levels. This level aims at addressing the students' social and psychological needs relevant to their early adolescence. It also aims at enhancing the students' interests and abilities by providing the appropriate skills and knowledge and assists them to progress to secondary education.

Secondary education

Students who successfully complete their preparatory education are admitted to this three-year secondary level. This level aims at consolidating the students' spiritual, mental and social development and prepares them for higher education, employment and participative citizenship (Al-Nabhani, 2007). The first secondary year is the first opportunity to study science as three separate disciplines (biology, chemistry, and physics). In the second year the student will choose the arts stream or the science stream. The arts stream study a general science course while, in the science stream, science continues to be taught as three separate subjects.

1.2.2. Basic education

The definition of basic education

Within the framework of developing education in the Sultanate of Oman, Basic Education has been defined as *unified education provided by the state to all the children in the Sultanate at the age of education.* It lasts 10 years and provides basic educational needs as to information, aspects of knowledge and skills, as well as the development of objectives and values that enable the learners of continuing in education and training according to their tendencies, readiness and abilities (Ministry of Education, 2001).

The prospects of basic education

The ministry of education defines the prospects of basic education as (Ministry of Education, 2001):

- Education characterized by its thoroughness as to the development of all the factors of personality of the learner within a balanced and complementary framework.

- An education interested in the link between theory and practice, thought and work, education and life in accordance with the complementarities of experience.

- An education aiming at making the learner gain the skills of self-learning within the framework of continuous education and planting the necessary values and practices for the purpose of excelling in learning and teaching .

- An education characterized by flexibility in its orientation and outcomes since the learner is prepared to continue learning in further stages or it prepares him for the training of the work market according to his abilities, readiness and competence.

- An education that aims at preparing the learners to participate in the overall social development.

The aims of basic education

Basic education aims at making the learner gain necessary skills for life by developing his/her communication skills, self-learning ability and scientific style in thinking using criticism and dealing with sciences and modern technologies.

In addition to that, this education aims at enabling the learner to gain the values of work, production, excellence and the participation in public life; the ability to get on with the advances in society and cope with problems thoughtfully; knowledge of the environment and to protection of the environment and its resources; and the wise use of free time (Ministry of Education, 2009).

The two cycles in basic education

Basic Education covers a span of ten years and is divided into two cycles based on the pupils' age in each cycle and the characteristics and growth needs. The first cycle lasts for four years and consists of Grades 1 to 4. Pupils in this cycle are aged between 6 and 10. This cycle is concerned with providing the pupils with the knowledge and skills necessary for their age group and developing their attitudes and values to continue learning in the following levels. The Ministry has given particular attention to the first cycle because of its great importance as a foundation stage (Ministry of Education, 2009). The second cycle lasts for 6 years and consists of grades 5 to 10. Pupils in this cycle are aged between 11 and 15. It aims to teach communication and learning skills, critical thinking, science and modern technology (Al-Nabhani, 2007).

Secondary education

This level consists of two years (Grades 11 and 12). It is composed of both compulsory and elective subjects. It leads to the General Certificate in General Education and to the General Education Diploma in Post-Basic Education (Ministry of Education, 2009). The curricula have been changed totally to include practical as well as theory. Furthermore, curricula seek concentrate on problem solving, on world issues and on how to deal with real life situations. Moreover, all schools are equipped with a learning resource centre, with audio-visual systems, computers and other technical equipment (Al-Gharibi, 2008).

Characteristics of the education program as laid down by government statute

- *Diversity:* meets the needs of all students who wish to attend work or who intend to continue their studies.
- *Flexibility:* enables students to explore various areas before selecting their curriculum direction (for example arts or sciences).
- *Choice:* A selection opportunities for students and prepares them for the labour market and provide them with basic employment skills.
- *Meet the individual needs of students:* promotes the principle of individual learning and meet the needs of students with low academic capabilities and those who possess a high capacity.

1.3. Physics laboratories in Omani schools

In the basic education system in Oman, there is some simple science at earlier stages (age 5-10). Later on, physics is taught as part of science from age 11 to age 15 (grades 5-10). After that students may choose to take physics as a separate course until they leave school (grade 11 and 12). These courses are an introduction to the study of physics in a professional manner in the future (Ministry of Education, 2007b).

Physics in grade 11 provides students interested in studying science with an academic introduction to physics in terms of content and skills. This curriculum includes four topics. These are: motion and dynamics, circular and harmonic motion, conservation of energy and momentum, and forces and fields. Also, students use a series of activities to develop their understanding of the relevant topics (Ministry of Education, 2007b).

In grade 12, the physics curriculum also contains four main topics. These are: thermodynamics, waves, and electromagnetic and nuclear physics. Students use a series of activities to develop their understanding of the relevant topics such as: conservation of energy; the composition and the spread of light; sound and the relations between the components of the electromagnetic spectrum; and the nature of the atom (Ministry of Education, 2007b).

The world has seen an explosion of scientific knowledge in the past hundred years or so. The outcomes of this have brought immense changes to societies and to lifestyles: the communications revolution, the world of new materials, the development of medical advances, etc. All of these have depended on very highly skilled scientists, given the support and facilities to experiment and explore. The place of the laboratory in this has been critical and this has had an effect on the way the sciences are taught at school and university levels.

Hanif *et al*. (2008) noted that '*the 19th century saw the establishment and development of physics laboratories for students as well as for research purposes in all the main universities of all industrial countries'*. The first undergraduate university physics laboratory in the United Kingdom was established in the University of Glasgow by the future Lord Kelvin in 1855 (Gooday, 1990). School laboratories started to be seen in developed countries in the latter nineteenth century and Shah (2004) notes that by 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).

Thus, the scientific laboratory is seen as an important component of education in the sciences (Technology in Science Laboratories, 2006). Hart, *et al.* (2000) argue for the importance of discussion and reflection alongside the conduct of meaningful experiments.

In the light of this, the Ministry of Education in Oman incorporated laboratory work in school education right from the 1970s. There is a need to place emphasis on students being able to design and carry out experiments as an integral part of their courses in physics and to begin to appreciate the way scientific knowledge is gained and how the world of experimental physics seeks to solve problems. In secondary schools, teachers are asked to use laboratories as much as they can. They are provided with a 'teacher's guide book' to help them in teaching the curriculum. Also students are provided with a separate laboratory manual which includes materials, equipment and procedures for each experiment (Al-Shuaili, 2000). Also, the manual provides all required steps and have gap filling questions to be answered concerning their observation and sometimes questions beyond the experiments.

Also, the Ministry of Education in Oman laid strong emphasis on the use of information technology in experimental work. Therefore, the Ministry developed a project for the electronic laboratory as an integral practical system for analyzing and extracting the results of the scientific results of physics, chemistry, biology and general science using the computer. The Ministry aims to implement this project gradually in some selected secondary schools and then evaluate the results. Depending on the outcome of the results, the programme will be extended to all other schools (Ministry of Education, 2006).

1.4. Aims of the study

It has to be recognised that the empirical is the fundamental way in which science enquiry works and, therefore, has an important place in school teaching in a subject like physics. However, laboratory teaching is expensive in time, manpower and resources.

The major goal of this study is to explore students' perceptions of laboratory work in physics in after-basic education schools in Oman and to look at the differences between students' attitudes towards the physics laboratory and attitudes of teachers. Another thing is to achieve a general idea of development in Omani students' attitudes about physics laboratory from age 16 to 17 (grade 11 and 12) in which grade 11 is the first grade where physics is thought as a separate subject (in grades 5-10 physics is only part of the science subject along with chemistry and biology). On the other hand, grade 12 is the exit point to college level education.

The overall aim of this study is to enhance laboratory learning in Oman, based on sound pedagogical evidence, particularly in the context of teachers at secondary schools. This starts by looking at what is happening in Oman in some detail. However, before describing the measurements made, there is a brief overview of the place of the laboratory in physics teaching, the nature of learning and the way attitudes develop.

1.5. Thesis overview

After giving a brief overview about the education in Oman and the place of physics laboratories in Omani Schools, Chapters 2 to 4 of this thesis establish the necessary literature review related to learning in general and learning in laboratories. Development of attitudes and their methods of measurements are then discussed in Chapter 5.

Chapters 6 and 7 then analyse the survey conducted with 881 students and 39 teachers. A wide range of data was collected and statistically analyzed to investigate the attitudes towards laboratory work in physics in Omani schools.

In Chapter 8, Chi-Square is used as a contingency test to look at the differences and similarities in students' and teachers' perceptions to laboratory work. Teachers' interviews are also discussed in Chapter 8.

Finally Chapter 9 summarizes the findings and discusses some implications and possible future extensions to the current study.

All surveys and interviews are presented as appendices at the end of this manuscript.

Chapter 2

Learning in Laboratories

2.1 History of laboratories in physics education

The laboratory has been given a central and distinctive role in science education. Science educators have suggested that rich benefits in learning increase from using laboratory activities (Hofstein and Lunetta, 2003). However, questions arise: What is the nature of learning which can take place in the laboratory and how can agreed aims be achieved?

Bernard and Epp (1987) describe the laboratory:

> *"The laboratory is a workshop for students, the place where they get firsthand knowledge of physical principles and experimental methods through the handling of apparatus designed to demonstrate the meaning and application of these principles".*

It is approximately 160 years since laboratory work courses were first formally introduced by Liebig at Giessen and by Eton at the Rensselaer Polytechnic Institute (Shah, 2004). By the beginning of the 19th century, and specifically in 1806, practical work had been adopted in Germany at the University of Gottingen, the practical course being introduced by Friedrich Stromeyer (Al-Shuaili, 2000). Then, in 1808 in Stockholm (Sweden) at the Collegiums Medium, Berzellius 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. There is some uncertainty about the date and location of the first teaching laboratory in a British University (see Al-Shuili, 2000 and Gooday, 1990) although it is certain that Thomas Thomson (later Lord Kelvin) was involved. Later on by 1830, Thomas Graham had set up the first student laboratory in Britain at the Royal Technical College (Pilcher, 1914).

By 1876, we can say that there were 115 laboratories in existence offering practical instruction for students (Johnstone and Wham, 1980). However, it was the year 1869 which witnesses the introduction of the first required laboratory course work in physics by the Massachusetts Institute of Technology. It was here that E.C. Pickering prepared the first physics laboratory manual, published in 1873 (Phillips, 1981). Latter in 1886, Harvard University defined a set of forty experiments in physics, which students were expected to have completed before entry to the university. The "Harvard Forty" would be familiar to almost all tertiary teachers today and represent the classic demonstration of phenomena and principles in physics (Al-Shuaili, 2000).

Laboratory classes continue to gradually develop 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). In more recent times, almost all the major science curriculum developments of the 1960s and early 1970s prompted hands-on practical work as an enjoyable and effective form of learning (Hodson, 1990). Reid and Shah (2007) stated that:

> "Towards the end of the twentieth century, more sophisticated alternatives had been introduced to facilitate effective learning in the laboratories. These included pre-lab experiences, films, video experiments, computer based pre-labs, and computer simulations."
>
> (Reid and Shah, 2007)

2.2 Why have laboratories

Physics involves the study of the world around. Students need laboratory experiences to explore that world and to bring understand physics so that they can make sense of their world around. Hofstein and Lunetta (2003) argue that the laboratory allows students to learn with understanding and offers an opportunity to engage in a process of constructing knowledge by doing science. Moreover, laboratory work enhances attitudes, stimulates interest and motivates students to learn science.

However, Hudson (1990) expressed the opinion that "*practical work as conducted in many schools, is ill-conceived, confused and unproductive .It provides little of real education value*". Moreover, Hofstein and Lunetta (2003) argue that "*formal teaching results in greater understanding when students study a limited number of topics, in depth and with care rather than a large number of topics much more superficially, as is the practised in* *many science classrooms*". These quotations reveal a fundamental problem. The teaching laboratory has great potential as a place of learning but there is a risk that what is done does not allow the potential to be reached.

There is also another fundamental problem. The research laboratory in physics seeks to make genuine explorations of the physical world to lead to new understandings. This is difficult to achieve in the teaching laboratory in physics. Indeed, it may be an inappropriate aim. Thus, Wellington (1998) considers that teachers can do no more than simulate the methods followed by scientist. This is because the hypothesis is established by the teachers, and the student task can often end up arriving at predicted results.

Thus, the aims for a research laboratory are very different when compared to a teaching laboratory. The methods of science can be illustrated in the teaching laboratory. Learners can be encouraged to develop hypotheses and test them. However, it is more or less impossible for students to follow a research paradigm in a teaching laboratory for many reasons. Firstly, students are, by definition, still at an early stage of learning. Secondly, the organisational, financial and safety implications of genuine scientific enquiry make it very difficult, even at undergraduate level. Nonetheless, the teaching laboratory should be consistent with scientific enquiry, avoiding experiments which centre only round routine verification of known quantities.

The aim has to be to promote a more effective laboratory learning environment. Students' perceptions and behaviours in laboratories are influenced by teachers, assessment practices and the materials available in the laboratory. Shah (2004) has argued that laboratory work offers an important link between theory and observation. However, the word 'theory' needs clarification. The word can mean almost anything from vague asserted opinion across almost to the formal hypotheses of scientific enquiry. Shah was using the word to describe the formal teaching of the classroom or lecture hall. The laboratory can perhaps make this real to the student.

But there are some factors that inhibit learning in school science laboratories. Al-Madani (2004) stated some of them in his research on the situation in Kingdom of Bahrain: there is lack of equipment and the time allowed for student is not sufficient for the number of experiments set for the curriculum. Moreover, the time is quite inadequate to allow for group work or individual work in the laboratory.

Also, Hofstein and Lunette (2003) raised some factors: students fail to understand the relationship between the purpose of their investigation and the design of the experiment and many students think that "labs" means manipulating equipment but not manipulating ideas.

This is a very important point and is often not grasped by laboratory course designers. Frequently, course aims are specified in terms if practical skills to be mastered and, sometimes, the assessment reflects this. Thus, for example, the assessment of laboratory work in the Standard Grade courses in biology, chemistry and physics in Scotland (two year courses for approximately ages 14-16 in Scotland) lays great emphasis on the correct conduct of procedures. As a result, teachers teach towards that aim and it is rare for any student to fail to achieve a high grade.

Moreover, Jerry Wellington in his book (1998) sated an important factor:

> "One of the fundamental assumptions of much practical work in schools is that observation and experiment can provide certain knowledge about the universe. But because knowledge is assumed to derive directly from observation, emphasis becomes concentrated on doing rather than on thinking, and little or no time is set aside for discussion, argument and negotiation of meaning."
>
> (Wellington, 1998)

The National Science Teachers Association of Pakistan (1990) suggested these developments to improve the learning of science:

- A minimum of 40 percent of the science instruction time should be should be spent on laboratory related activities. This time includes pre-laboratory instruction in concepts relevant to the laboratory, hands on activities by the students and a post laboratory period involving communication and analysis, and teacher demonstrations are valuable but should not be substitutions for laboratory activities.
- Evaluation and assessment of student performance must reflect the laboratory experience
- An adequate budget for facilities, equipment and proper waste management must be provided to support the laboratory experiences
- Equipment and facilities must be maintained and updated on a regular basis.
- For some activities, funds for field experiences must also be included in the budget.

- The number of students assigned to each laboratory class should not be exceeding 24 and the students should have immediate access to the teacher in order to provide a safe and effective learning (Shah, 2004).

However, Shah, *et al.* (2004) cast considerable doubt if these highly desirable aims are being addressed, little less achieved in a Pakistan context. Nonetheless, such aims seem extremely important for all developing countries.

The many difficulties inherent in hindering the effective use of the teaching laboratory in physics in developing countries can be summarised:

* Students are not given sufficient time and opportunity for interaction and reflection;

* Many school science courses offer a ‘cook-book’ approach for the student to do the experiment. Thus, most students follow the instructions to reach the results without understanding either the purpose or the sequence of ideas in the experiment;

* Most teachers need more knowledge skills and resources in the laboratories;

* Assessment of student’s practical knowledge tends to be undervalued or focuses on aspects which are not the most important;

* There is a limitation in sources and materials in the laboratory.

Another issue is raised by Bernard and Epp (1987) who noted that,

> “*The efficiency of performance in the laboratory depends largely on the preparation made before the experimental work begins. The entire experiment should be read before any measurements are made. It is also advisable for the student to review sections in the class textbook that deal with the principles under investigation.”*
>
> (Bernard and Epp, 1987)

Those with any experience in running laboratories know that such an aim is unrealistic. Students simply tend not to read the manual before the laboratory session and will rarely consult a textbook on their own (see Carnduff and Reid, 2003)

2.3 Goals and objectives

In the literature on practical work, the terms objectives and aims are often used fairly synonymously to give a general description of performance of the practical work (Al-Shuaili, 2000). However, Sutton (1985) described aims as general statements of what the teacher intends to do while objectives are specific statement of what students should be able to accomplish as a result of being taught.

Miller, *et al.* (1999) claim that practical work with real objectives and materials not only helps learners to communicate information and ideas about the natural world but it also provides opportunities to develop students' understanding. There is no doubt that experimentation is one of the important means to gain understanding of the world around and, in order to examine the practical work, it is essential to examine its objectives.

The first thing to note is that the process of experimentation in learning is a natural process. The behaviour of any toddler exemplifies this. They spend much time playing with their environment to see what happens. This goes right on into the Primary school stages where experimenting with the physical world around as well as the world of relationships develops. Steadily, this moves from a dependence on the concrete to be able to conceptualise and imagine. This then moves from a conceptualisation of the concrete to the ability to play mentally with ideas. It is essential that this natural process is not stifled by the reduction of laboratory experiences to the satisfactory completion of set experiments, following some kind of recipe.

Objectives of practical work had been stressed from as far as the early nineteenth century and special attention had been given to practical work by the teachers and researchers (Shah, 2004). Hodson (1996a) has stated some of the purposes of the practical work in science education which are summarised here:

1) *To help students learn science means acquiring conceptual and theoretical knowledge;*
2) *To help students to learn about science means developing an understanding of the nature and methods of science;*
3) *To enable students to do science means engaging in expertise in scientific inquiry.*

This is very much in line with the view of Berry *et al.* (1999, page 27) when they say that, "*lab-work is a thinking task supported by laboratory equipment*", a view strongly endorsed by the work of Carnduff and Reid (2003). After a comprehensive review of the literature, they provide a set of possible reasons for the inclusion of practical work in undergraduate courses in chemistry. While these refer specifically to undergraduate chemistry work, the set of aims has wider significance and can be interpreted in terms of physics laboratories at school level:

1) *Making physics real: laboratory work make physics "come alive", allowing students to see, touch and handle chemicals and equipments, to see how data is gathered and to see how theoretical models can be tested.*
2) *Student have opportunities to see something of the way science operates as it seeks to gain answers from the physical world by means of the interpretation of experimental data. There are opportunities to discover, to explore, to confirm, to interpret and to challenge.*
3) *There are often opportunities for team working, planning, time management, discussion and debate. Good laboratory experiences can have a positive effect on student attitudes and motivation. Success leads to confidence and this frequently leads to positive attitudes towards physics with a stronger motivation to move on to more demanding tasks*
4) *The laboratory work provides considerable scope for experience in practical problem solving and the world of work will be a place where problems have to be faced.*

Many decades ago, attempts have been made to specify the outcomes of practical work. Many lists boiled down to a few basic aims. According to Johnstone and Wham (1980), practical work is done to:

1) *Teach manipulative skills*
2) *Encourage observations*
3) *Illustrate theory*
4) *Encourage problem solving skills*
5) *Help to distinguish between the immutable experimental facts and the more transitory theoretical explanations of the phenomena*

6) *Develop interpersonal skills of discussion and cooperation*
7) *Appreciate limits on results because of errors,*
8) *Make deductions from observed facts,*
9) *Show how a scientist solves problems – scientific approach.*

Finally, Bernard and Epp (1987) have compiled some specific objectives for practical work in physics:

1) *To acquire training in scientific methods of observation and recording of data*
2) *To acquire techniques in the handling and adjustment of equipment*
3) *To gain an understanding of the limitations and strengths of experimentation*
4) *To obtain experience in the use of graphical representation*
5) *To collect data and to develop confidence in one's ability to compute reliable answers or to determine valid relationships*

These three sets of aims are helpful in that they offer some clear guidance about the nature and purpose of laboratory work. However, the aims need to be translated into meaningful laboratory experiences and then there is a need to show that these experiences are, in fact, achieving the aims. In addition, it is important to see if the learners share such aims. Reid and Shah (2006) note the need to examine the perceptions of students about the purposes of practical work and how they match the perceptions of the 'experts'.

2.4 The role of laboratory work in learning

Today, people have potential access to vast amounts of information through the internet (and many other sources) but they need to be able to analyse and evaluate all this information for themselves. In addition, in terms of employment, technological changes and the move towards a knowledge-based economy mean that there is a requirement for employees with flexible, analytical and creative skills.

Science education must respond to these changes by modifying, amending or radically changing the content of the curriculum and its associated assessment (Gott and Duggan, 2002). Also, the laboratory should be a good place for learning and the general principles for enabling such learning to take place are now well known. A key is to allow teachers adequate time to develop good laboratory teaching skills. Much has been made of discovery learning but enthusiasm for this need to be tempered with the wise insights from Kirschner, *et al.* (2006) when they note the critical importance of taking cognitive load into consideration. Laboratories are, by their very nature, places where information overloading is highly likely. To minimise this problem, the activities must be structured carefully.

McDowell and Waddling (2000) propose a series of techniques to develop learning in the laboratory:

- Use of simple and precise language.
- Sequencing experimental procedures into numbered steps.
- Use of diagrams to complement or replace text.
- Written instructions in such away as to promote a problem solving approach.

There is something important that the students do not come to the laboratory with no experience of laboratory work, so the planners should know what is being done in previous years and how it was done so they can build on this. In this, the pre-laboratory experience has an important place. Such pre-lab exercises not only have the potential to reduce information overload in the laboratory, they also can structure new laboratory experiences so that they build on previous knowledge. To gain the maximum benefit from time in the laboratory, preparation by the learner is vitally important. An experiment with undergraduates in a physics laboratory has shown that thorough preparation before a laboratory session improves student's performance in the laboratory quite markedly and that follow-up work can lead to meaningful learning (Johnstone, *et al*, 1998).

However, pre-laboratory activities must not be too long in time terms or place excessive pressure on marking time (Shah, 2004). It needs to be remembered that the aim of the pre-labs is to prepare students to take an informed interest in the experiment. Part of this is by becoming aware of the purpose or destination of the experiment (Johnstone, *et al*, 1998). The same study also showed that the pre-lab experience fostered a positive attitude to the laboratory in general. Indeed, the change in attitudes was quite dramatic. In addition, the pre-labs helped the students to improve their understanding of the practical work.

Thinking in terms of university chemistry, Cardnuff and Reid (2003) have listed some topics and themes that might be important in pre-laboratory exercise:

- *Apparatus, glassware, instruments, handling procedures;*
- *Calculations, concentration, unit conversions;*
- *Equations, reactions, physical principles, concepts;*
- *Explaining, thinking out, applying theory, understanding of theory or procedure;*
- *Facts, formulae, data, physical constants;*
- *Planning of recording, tables, graphs, using real data, report, deduction, interpretation, diagrams.*

What happens after the experimental work is completed in the laboratory is also critical. Very often the writing up of a report is seen by the students as pointless, particular when it is marked for the production of a 'correct' result (Reid and Shah, 2007). Here, the importance of post-laboratory experiences can be seen. The post-lab gives the students the opportunity to plan and design their own strategy and draw conclusions from experimental results, think independently and develop skills in solving problems presented in the post-lab sheets.

Also, post-lab problems can be chosen from everyday life, to develop student interest in physics, to engage them more and to relate the subject to their own experiences, which could help them to develop a better understanding of the subject (Johnstone, *et al*, 1998).

So we can conclude that the idea needs to be instilled steadily that 'lab-work is a thinking task supported by laboratory equipment'. A gradual paced process of hearing, reading, thinking, and doing, seeing and thinking again offers the best recipe for effecting learning in and from the laboratory (Carnduff and Reid, 2003).

2.5 Conclusions

Practical work is an essential component of science teaching and learning, both for the aim of developing students' scientific knowledge and that of developing students' knowledge about science. Also, the practical work is likely to be most effective when:

- The learning objectives are clear, and relatively few in numbers for any given task.
- The task design highlights the main objectives and keeps 'noise' to the minimum.
- An explicit strategy is used to stimulate the students' thinking beforehand (Miller, 2004). This is known as a pre-lab exercise.
- Post-lab is given to the student when the experiment is completed in a laboratory.

Reid and Shah (2007) summarised in the following table what needs to be done in order to use time more efficiently and effectively in the laboratory.

Stage	**Activity**	**Tasks**
Planning	Clear aims	• Make physics real • Expose ideas to empirical testing • Develop skills of observation, deduction and interpretation • Develop general practical skills (e.g. team working)
	Background	• Know what happens in previous courses and why • Do not underestimate previous learning experiences
Before the laboratory	Pre-labs	• Share aims for the experiments • Establish background information • Plan experiments
During the laboratory	For the experimental	• Keep any lab manual or instruction sheet brief • Allow experimental freedom
After the laboratory	Post-labs	• Apply ideas learned in a 'real- world' setting • For assessment, look at process not right answer

Table 2.1: Making laboratories effective (Source: Reid and Shah, 2007, slightly amended)

Reid and Shah (2007) outlined some aims for what might be developed in the teaching laboratory. It is possible to summarise their aims:

- *Skills relating to learning*: for examples, making physics real, illustrating ideas, empirical testing ideas and teaching new ideas.
- *Practical skills*: for example, handling equipments and chemicals safety, measuring and observing carefully
- *Scientific skills*. learning skills of deduction and interpreting, seeing a science at work
- *General skills*: team working, reporting, presenting and discussing, developing ways to solve problems.

Chapter 3

Learning Science

Learning encompasses many skills and experiences. This chapter and the next one explore and discuss the role of practical work in the teaching and learning of science at school level. It may be useful to begin with some general remarks about science and science education so the nature of science will be reviewed. Then, the definition of learning and the kinds of learning which are possible in the laboratory will be discussed.

3.1 The nature of science learning

The word science is used in ordinary discourse in English to refer to a product (a body of knowledge), to a process (a way of conducting enquiry) and to an enterprise (the institutionalised pursuit of knowledge of the material world) (Miller, 2004). Researchers have also summarized the aims of science education as

- To help students to gain an understanding of an established body of scientific knowledge as is appropriate to their needs, interests and capacities.
- To develop students' understanding of the methods by which this knowledge has been gained and grounds for confidence in it.

It is possible to argue that everybody needs knowledge of science to live happily in a scientific society. Thus, it follows that it is important for everybody to know something of basic science knowledge. Unfortunately, learning sciences is attributed as a difficult task. This might be due to several factors as described by Johnstone (1991):

> "The fact that many pupils claim that science is hard to learn might suggest that it is not being successfully transmitted. The faults could lie in various places such as with the transmission system itself, the methods used and the facilities available or with the learners and the nature of their learning or even with the nature of the message itself".
>
> (Johnstone, 1991)

Several things might contribute to the difficulties faced while learning sciences and these are now discussed briefly.

1- The nature of science concepts: the common type of concepts with which children and adults are familiar are made up of tangible instances. Many scientific concepts are of a similar nature. However, ideas like the electron, bond energy, photons, structures and molecules are all beyond our senses and pupils have little or no experience in constructing such concepts.

2- Multilevel thought: This idea is proposed by Johnstone (1991). He argued that the science subjects can be seen as three levels or corners of a triangle although, originally, he was thinking only of chemistry. Nonetheless, his ideas apply to physics and have been extended to a tetrahedron for biology (Chu, 2008) and mathematics (Ali, 2008).

Figure 3.1 shows this triangle. The macro level is described as the first level of multilevel thought where the student can see and handle materials and describe their properties (e.g. moving objects). The micro level is the second level of thought. In physics, this involve the molecular, atoms, electrons, forces and reactions in which an attempt is made to give mental pictures of materials and objects which are described at the macro level. The symbolic level is the third level of thought in which the learner tries to represent ideas, objects and materials by formulas and their changes by equations (Shah, 2004). The teacher can move from one corner to another within the triangle but it is not the case for students (Johnstone, 1982). This is because of the limitations of working memory capacity. The novice learner cannot hold the ideas from all three corners simultaneously. The limitations of working memory capacity will be discussed later in chapter 4.

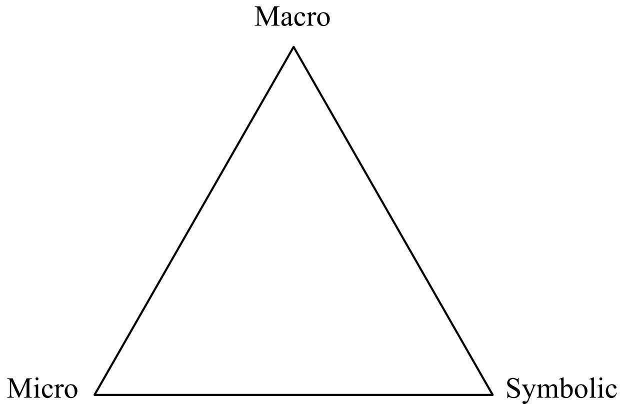

Figure 3.1: Science subjects can be seen as three corners of a triangle (Johnstone, 1991)

3- How helpful are experiments?: Experiments provides the teacher with an increased battery of teaching tools and gives the pupil a welcome break from written work or from listening.(Johnstone, 1982). However, Hofstein and Lunetta (1982) observed that this does not necessarily make the learning of science easier.

4- The language barrier: The ideas of the sciences are communicated by means of language. This has been explored extensively (Cassels and Johnstone, 1978; Johnstone, 1982). While some words are unique to the sciences and need to be learned, the real problem is in the way the ordinary words of daily language are often used in the sciences with very specific and precise meanings which do not necessarily match their normal everyday usage. Great care must be taken with these words in seeking to make the language, the vehicle for communication, easier for students.

3.2 Learning as memorisation or understanding

Learning can be defined in many ways. One of the simplest forms of learning is imitation. This means things produced as a copy of the real things. This type of learning has a useful place in the laboratory situation. Imitating encourages one to grow and pretend freely without risk of being wrong or embarrassed (Shah, 2004)

Boud *et al.* (1986) offer a wider insight when they say that,

> *"Learning outcomes have the same relationship to aims and objectives as learning experiences have to the learning plans. Learning outcomes are what the students attain from the course. The learning outcomes of the laboratory course are closely related to its aims. Commonly in laboratory courses, the learning outcomes which are tested are those which are the easiest to measure by pencil-and-paper tests"*
>
> (Boud *et al*, 1986)

Two main concepts are involved in learning practical tasks: knowledge and skills. Knowledge involves memory of materials such as words, numbers or diagrams and is said to be learned when it is memorised (Seymour and Hunter, 1998). On the other hand, skills are learned mostly when the students doing thing or see somebody do something. But the two things complete each other. Thus, if the students have some knowledge and basic information before the laboratory work begins then his/her performance will be better than those who do not have this (Pazzani, 1991). Moreover, Johnstone and Letton (1990) have discussed this point and they said that, "*to make sense of the experimental instructions and to interpret observations, the students must mentally reactivate the theoretical material through the experiment*". Thus, importance of both knowledge and skills needs to be emphasised. However, sometimes students can learn more from doing. In 1994, Maryam Alavi argued that doing is better than saying. She quoted Confucius, the Chinese philosopher, "*Tell me and I will surely forget, Show me and I might remember, But make me do it, and I will certainly understand*".

However, this is a dangerous argument. Johnstone and Wham (1980) have shown very clearly that much activity in the laboratory can often lead to almost no learning. Later work linked this to the limitations of working memory capacity: the students were conducting experiments and this took so much cognitive capacity that nothing was left for thought (Johnstone *et al*, 1998). Experimental work was reduced to the task of following laboratory instructions.

Thus, 'doing' in a laboratory will lead to better learning, provided that the 'doing' does not make thinking impossible. Reading, listening, thinking and discussing will all be important elements to be taken along with the conduct of the experiment. Also, it is important to remember that learning needs goals and this is particularly important in laboratory learning because from goals we can determine the way to better learning.

3.3 Different types of laboratory learning

Learning environment in the laboratory has different forms of instruction designed to promote the variety of aims in the laboratory. In this section, some different types will be discussed. In physics education, distinct styles of laboratory instructions have been in evidence: expository, inquiry, discovery and problem-based. These styles differentiate in three things, outcome, approach and procedure and these are shown in Table 3.1.

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

Table 3.1: Descriptors of the laboratory instruction styles (Johnstone and Al-Shuaili, 2001)

3.3.1 The expository laboratory

In this type of learning environment, the instructor defines the topics, relates it to previous work and this should direct students' actions. In a time of 2-3 hours, the learner follows a set of procedures from the manual and the outcome is already known to the learner. Lagowski (1990) noted that activities in this type of laboratory can be performed by a large number of students, with minimal involvement from the instructor and at a low cost.

Although that expository laboratory is a "cookbook" to collect data and it gives no room for planning an experiment, it has been reported by Meester and Maskill (1994) that most university laboratory uses this type of the laboratory. However, this type is designed so that students spend more time determining if they have obtained the correct results than they spend thinking in planning the experiments. Also, it is designed to facilitate the development of lower-order cognitive skills such as rote learning and algorithmic problem solving.

3.3.2 Inquiry laboratory

This type of laboratory is suitable for a more project-based approach. As shown in Table 3.1, inquiry laboratory needs the students to create their own procedures and define the outcomes for the experiments. Johnstone and Al-Shuaili (2001) argue for this type of laboratory and say that,

> *"It is more student-centred, contains less direction, and gives the student more responsibility for determined procedural options than the traditional format. It effectively gives students ownership of the laboratory activity, which can result in the students' showing improved attitudes towards laboratories."*
>
> (Johnstone and Al-Shuaili, 2001)

This kind of laboratory allows student to use more thinking skills: what Raths, *et al.* (1986) describe as explaining, criticising, analysing, judging evidence, inventing and evaluating augments. Thus, a real inquiry laboratory can come after certain knowledge of facts and practical methods have been gained. Also, the teachers have to determine how much content knowledge is necessary for learners to be able to engage in such a practical investigation. However, teachers can put this knowledge in what is called the "pre-laboratory" (see Johnstone, *et al*, 1994).

3.3.3 Discovery laboratory

In discovery laboratory teaching, students are required to generate their own questions for investigation. No laboratory manual is used and the teacher provides minimal guidance and the student is placed in the role of a discover (Shah, 2004).

Also, we can see from Table 3.1 that the discovery learning is inductive but differs with respect to the outcome of the instruction and in the procedures followed. Whereas, in inquiry, the outcome is unknown to both the teacher and the learner, in the discovery learning, the teacher guides learners towards discovering a desired outcome.

3.3.4 Problem- based instruction

Wright (1996) argued that, in this type of laboratory, the teacher adopts an active, stimulating role by posing a problem to the learners, providing the necessary reference materials and by occasional group meetings, carefully moving the students towards a successful solution to the problem. The teacher is very much a facilitator rather than a direct provider of student learning. Science educators have come to accept that there are certain basic steps that make up a scientific process:

- Identifying a problem for investigation and putting forward a tentative hypothesis.
- Designing an experiment to test a hypothesis.
- Performing the experiment and recording the results in an appropriate form.
- Interpreting the results and evaluating the conclusions with reference to the hypothesis to be tested (Johnstone and Al-Shuaili, 2001).

3.4 Discovery learning

Bruner's study (Bruner, 1966, 1967) into how cognitive processes added comprehension and organisation to experiences have been applied to education in the subjects of mathematics and science (Almadani, 2004). Bruner's model included the factors of learning content, process and individualisation in teaching. He proposed a general teaching guideline that relates to cognition. The active learning process was that of a social mechanism that formed new concepts in relation to prior knowledge (Bruner, 1966).

Later, in 1986, Bruner discussed how cognitive development is related to experience and not apparently to age. This needs to be clarified in that Piaget (Paighet and Inhelder, 1969) emphasised development with age and his outcomes are well supported. However, as Herron (1975) noted many years ago, the fact that the cognitive development has taken place does not mean, necessarily, that the person will operate at that level.

Bruner had a focus on the process of representation, how learners organise knowledge. He proposed three specific modes: enactive, iconic and symbolic. The first mode, muscles knew the actions to perform. In the second mode, internal visualisation represented situations and relations. The third mode involved comprehending a symbolic system, such as mathematics and a foreign language. Progression then occurs by transition of a concept through the modes that would result in greater comprehension when all modes are used simultaneously (Bruner, 1986). Thus, it is possible to say that Bruner has contributed the idea of discovery learning and this has been taken somewhat uncritically into laboratory work. However, there are limitations for school students and discovery has to be guided very carefully (Almadani, 2004).

Bruner (1971) contended that students, starting at early primary stages, should learn the structure of a body of knowledge instead of items of information which requires much memorisation. He also asserted that students should be taught and encouraged to discover information by themselves.

Hodson (1996b) described discovery instruction as not only philosophy unsound, but also pedagogically unworkable. He asserted that the learner could not discover something for which he is conceptually unprepared. The learner does not know where to look, how to look, or how to recognise it when he was found it.

However, it is important to remember many things in discovery learning. Granger and Hayward (1992) discuss that in order to learn about a body of knowledge; the curriculum should be designed in such a way that learning from stage to stage is carefully structured. As the child progresses in grade level, the body of knowledge being studied should progress in a way which he described as a spiralled curriculum. A spiralled curriculum is one in which each concept will spin into the next concept in line to produce an over expanding learning spiral. Also, Snelbecker (1974) told us that discovery learning requires that the student participates in making many of the decisions about what, how, and when something is to be learned and even plays a major role in making such decisions. Instead of being "told" the content by the teacher, it is expected that the student will have to explore examples and for them "discover" the principles or concepts which are to be learned.

3.5 Criticisms of discovery learning

Discovery learning in schools needs many things to be an effective type of learning. Indeed, it is not realistic to expect students to make discoveries in a few hours or in a few minutes in the laboratory when some of the best scientists in history took years, decades or even the combined effort many people over centuries. The aim of the school must be to allow the student to learn the methods and to open their minds to discover things by discovering small things at first. By this, they can make sense of the world around them.

Shah (2004) noted that discovery projects, to be successful, often require special materials and extensive preparations as well as a very considerable flexibility on the part of the teacher, often working with a small number of students. Moreover, the students should come to discovery laboratory with basic knowledge about the problem and know how to apply problem-solving strategies. Inevitably, many will not possess enough background knowledge and problem solving skills. Discovery methods may be difficult, inappropriate and not lead to success (Rowell and Dawson, 1988).

In an important paper, Kirshner, *et al.* (2006) cast considerable doubt on the whole approach, showing that cognitive load is the critical factor in enabling success to take place.

3.6 Conclusion

Johnstone and Al-Shuaili (2001) noted that the methods of allowing students to learn by discovering and by learning from their experiences, as advocated by Armstrong early in the twentieth century, could be considered as the basis of discovery laboratory teaching. However, they saw discovery learning very much as strongly guided discovery.

Bruner was the strong advocate of discovery learning. Shah (2004) noted that, "*From his studies, he found that the development of thinking was seen as a function of experience and was apparently independent of maturational factors".* However, this is probably only part of the story and developmental factors are almost certainly critical as well.

Bruner (1966) argued that the process of learning is an active structure in which learners attempt to build up new notions resting on prior information. The learner examines and gains knowledge, raises hypothesis, and reaches results depending on his prior cognitive structure. Thus, discovery learning encourages students to ask questions and formulate their own tentative answers, and to deduce general principles from practical examples or experience. Later on, in 1967, Bruner stated that discovery learning does not mean students are required to find out every bit of knowledge by themselves. Instead, they are asked to see the relationships between ideas and particles through employing what they know. But it is the teacher's job to implant a sense of self-confidence inside the student. After that Bruner (1971) suggested that primary school students should learn information from a constructivist perspective rather memorising familiar texts. He also stressed the point that students should be allowed to learn through discovering information themselves. However, the argument for a constructivist perspective is rather shallow. It is the natural way to learn and will happen whenever learners are seeking to make sense of the world around as can be deduced from the work of Piaget and Inhelder (1969).

Although it is possible to conclude that discovery learning has some similarities to the scientific model of enquiry (Shah, 2004). Students identify problems, generate hypotheses, test each hypothesis against collected data, and apply conclusions to new situations. Also, discovery learning encourages students actively to use their intuition, imagination, and creativity. However, this argument must be treated with some caution. The way a student learns is very different to the activities of the professional scientist. There is no certainty that the former models itself on the latter.

Chapter 4

Learning Science - II

4.1 Introduction

The assumption that laboratory experiences help students understand materials, phenomena, concepts, models and relationships, almost independent of the nature of laboratory experience, continues to be widespread in spite of sparse data from carefully designed and conducted studies. A more recent assertion is that laboratory experiences can help students develop ideas about the nature of a scientific community and the nature of science (Hofstein and Lunetta, 2003).

However, teachers are more expert learners whose understanding about how to learn the subject matter is what students need at least as much as they do the factual information (Hayes, 1988). There are many factors such as learning styles and facility with language which place limitations on the processing of information (Johnstone, *et al*, 1998). This chapter cannot address all the issues but focuses on the way the brain processes information and how this affects the learning. In the beginning the meaningful learning will be discussed. This will be based on a well established information processing model which can be applied predicatively to show how a laboratory environment can be arranged so that students learn more efficiently.

4.2 Meaningful learning

Based on extensive observation, Ausubel (1968) argued that learning of new knowledge is facilitated when explained and related to appropriate concepts in the learner's mind and this process is said to be meaningful when new concepts are related to previous ones in the learner's mind. He clearly indicated that his theory applies only to reception learning in school setting. He distinguished reception learning from rote and discovery learning. (Ausubel, 1968). According to Ausubel, people acquire knowledge primarily through reception rather than through discovery. Concepts, principles, and ideas are presented and understood, not discovered (Shah, 2004).

West and Fensham (1974) suggested that meaningful learning occurs when the learner’s appropriate existing knowledge interacts with the new learning. Rote learning occurs when no such interaction takes place.

For learning to occur and be meaningful, Ausubel (1969) indicated that three criteria must be fulfilled:

1) **Content**: They should be able to understand this and it has to relate to prior experience or using common sense.
2) **Knowledge**: for the meaning to be comprehended, sufficient prior knowledge should be available.
3) **Learner**: The intention should be to place new concepts in relation to prior knowledge for meaningful learning to occur, as opposed to rote learning.

But for rote learning, he proposed:

1) **Content**: Lack of meaning and logical presentation.
2) **Knowledge**: lack of related knowledge.
3) **Learner**: Lack of a learning set that is of meaning.

However, it has to be noted that both meaningful and rote learning were not perceived as separate entities: there is a gradation between two extremes (Almadani, 2004).

Contrary to Bruner’s idea of discovery learning, Ausubel (1968) stressed that it was essentially receptive skills that are utilised in gaining most types of information. These skills concentrated on comprehensible verbal types of learning, the learning increasing with more organised and clear information. He placed no emphasis on rote learning. His interest lay in meaningful learning and he saw this being best achieved not through discovery but through organised instruction from the teacher. The assumption made is that presentation from general to the detailed deductive is the aim, as opposed to Bruner’s proposed inductive method (Almadani, 2004).

4.3 Information processing

Piaget's theory of cognitive development has been a powerful influence for researchers in educational psychology. He saw cognitive development in terms of biological maturation and according to him, intellectual development is the development of schema and the number and quality of schema varies with age arising from biological maturation. He totally ignored the effect of environment on intellectual development (Shah, 2004).

A more recent powerful influence on understanding has been the development of research leading to the concept of information processing. This has explored the way information moves around the brain and has offered many predictions which have subsequently been supported. An overview is offered in a very recent journal where the entire issue was devoted to the subject (Reid, 2009). In all information processing models, there are three types of memory as in Figure 4.1. These are: long term memory, working memory, and perception filter as well as mechanisms for transferring information between them.

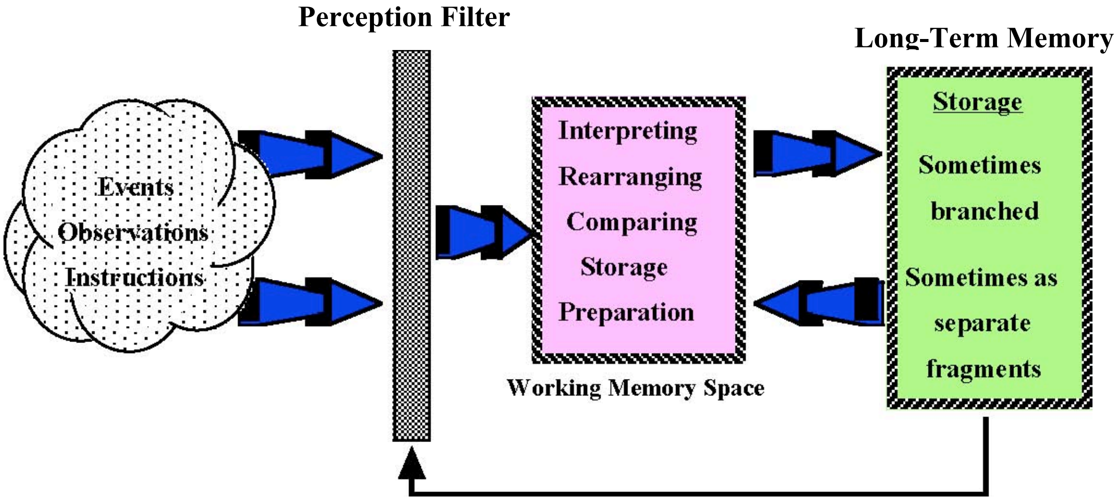

Figure 4.1: Information processing model of learning

Vianna, *et al.* (1999) described this figure:

> "*In any learning experience, what the perception filter identifies or perceives as being familiar or unfamiliar, important or unimportant depends on information that is stored in the long term memory (L.T.M). Information that passes through the filter enters the working space where it is interpreted or interacts with additional information that is retrieved from L.T.M. After the information that has been selected by the perception filter has been considered or thought about in the working space, new information may be stored in the L.T.M*"

4.3.1. Perception and attention

The "perception filter" receives all observations, circumstances and instructions. The perception filter is influenced by what is held in long term memory. It is impossible for everything to be selected but the basis of selection is previous beliefs, biases, likes and dislikes and prior concepts (Johnstone, 1993).

White (1988) argued that selection is also influenced by factors of ability, attitudes and prior concepts. Also, it depends upon:

a) *Attributes of events*: properties like absolute intensity of a stimulus, motion and relative intensity of a stimulus

b) *Attributes of the observer*: general level of alertness, range of cognitive strategies available to the observer.

c) *Interaction between events and observer*: selection is affected by whether the observer finds the events unusual, interesting or understandable, construction of patterns and seeing events as a collection of meaningful units. If it cannot be combined with a set of stimuli into a unit, it is not selected for attention (Bahar, *et al*, 1999).

4.3.2. Working memory

Some researchers use the term short term memory instead of working memory (Shah, 2004), but Johnstone (1988) explains the difference between them. For example, if someone has been asked to memorise a set of numbers then he will recalls them back in the same order within seconds. So, here there is no processing and the space is used completely as short term memory. In contrast, if someone is asked to memorise the numbers and do some processing with them (like multiplying the first two of them and subtract the result from the last number) then the space is called working memory.

Thus, Johnstone (1984) described the working memory as "*that part of the brain where we hold information, work upon it, organise it, and shape it, before storing it in the long term memory for further use*"

It is easily demonstrable that the "working memory", the conscious part of the brain where we hold and manipulate information, is of very limited capacity (Johnstone, 1986) Working memory has a limit of 7 ± 2 items. Also, information transferred to working memory can remain active 15-20 seconds without rehearsal (Shah, 2004). This means that, for adults (those over 16 years of age approximately), most can hold seven items at one time in their working memory. Some can hold 6 or 8 and a few can hold 5 or 9. Very few fall outside these limits. Thus, if a person has too much to hold, then there is little room for processing. Equally, if there is a lot of a lot of thinking and processing to do, the person can only handle a few things in memory at the same time (Johnstone, *et al*, 1998).

4.3.3. Long term memory

Deep meaningful learning occurs when new information is stored in long term memory by connecting it to existing information to form a branched network. The stored information will then be more readily available for use at a later time (Johnstone, 1994). We should remember that, the long term memory has an enormous capacity for storing information and is not prone to the same process of decay characteristic of the working memory and the perception filter (Child, 1986). Baddeley (1994) noted that there are theorists who believe that the material held in long term memory never decays but only becomes less accessible through time.

The working memory can pass on information to be stored in long term memory. However, the storage may occur in several ways, not all of which are ideal:

1) *Rote learning*: Non-connected learned concepts (Ausubel, 1978).
2) *Meaningful learning*: Logically connected learnt concepts to prior ones with addition association and simply access to them (Ausubel, 1978).
3) *Developing misconceptions*: Here new ideas may be linked incorrectly to previous knowledge leading to alternative frameworks or misconceptions.
4) *Storage may be in a sequence*: as with learning the alphabet, tables, or such skills as the procedures to carry out some practical operation.

4.4 Working memory and laboratory work

Humans all learn in fundamentally the same way. New knowledge and experiences have to be processed in the working memory. As this is limited and cannot be expanded, it has to be used efficiently (Reid and Shah, 2007).

In the laboratory, students often enjoy practical work, pick up hand skills with varying degrees of proficiency, but learn little of the theoretical information which practical work is alleged to illustrate or initiate. This happens because of many things. One of the reasons may be, learning is hampered in a high information situation in which the working memory is overloaded with incoming data and this is represented in Figure 4.2 (Johnstone and Wham, 1982)

During a laboratory experiment, the learner usually deals with a whole range of unfamiliar instructions, observations and deductions, and so on. Many facts and figures have to be collated and rearranged into some coherent form and hopefully understood by the end of the experiment. Sometimes students become completely overwhelmed with the sheer quantity of new material, before any real understanding of its purpose has taken place. When the amount of data exceeds the individual's working memory capacity, they may pursue some less demanding course of action, such as recipe following or copying from others (Shah, 2004).

Johnstone and Wham (1982) attempted to show that, when the quantity of information being presented to students in the laboratory was beyond their working memory capacity, then they eventually lost concentration and reached what was described as a 'state of unstable overload'. Therefore the limited capacity of the working space can be easily overloaded in practical work.

Figure 4.2 illustrates how the limited capacity of working space is overloaded, how the noise swamps the signal and lists the possible ways students act in order to reduce of overloading of working space (Shah, 2004). Thus, it is vitally important that the learners are prepared for what they are to do the laboratory. This preparation should include revision of theory, planning the experiment to some extent and discussion with others. (Al-Shuaili, 2000)

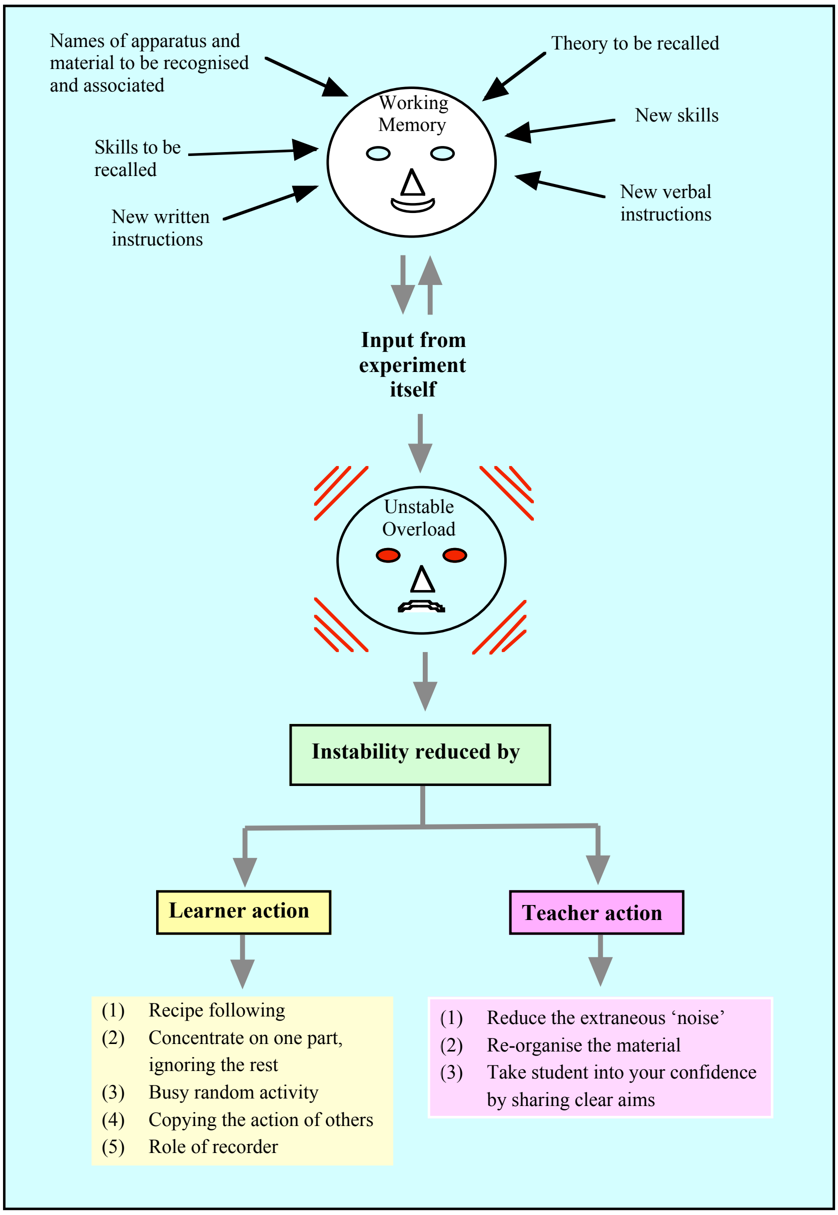

Figure 4.2: Unstable overload in practical work (Jonhnstone and Wham, 1982)

Johnstone, *et al*. (1998) discussed the importance of preparing the mind before coming to the laboratory and said "*If we want our students to have meaningful learning, our teaching has to create the atmosphere and the opportunities for such learning to take place.*"

Thus, the preparation of long term memory before learning is absolutely essential to enhance learning. The student has to be aware of what a laboratory is about, what the background theory is, what techniques are required, what kind of things to expect in the light of the theory. This is the basis for the development of the pre-laboratory exercise, seen as essential and not optional (Johnstone, *et al*, 1998).

The whole concept of the pre-laboratory has been summarised and reviewed by Carnduff and Reid (2003). The purposes are discussed, the ways to develop such exercises are outlined and the evidence to support their effectiveness is summarised.

4.5 Conclusions

Johnstone and Wham (1982) and Hodson (1993) discuss that learners are put into the position where they have to understand the nature of the problem and the experimental procedures, assemble the theoretical perspective, read, comprehend and follow the experimental directions, handle the apparatus, collect the data, recognise the difference between obtained results and expected results and interpret those results. Also, the learner should recall skills, theory and apparatus at the same time as absorbing new skills and written instructions.

All of these things happen in the laboratory. However, it is important to remember that the information processing model emphasises that the working memory is of limited capacity and this is the part of the brain used for thinking, understanding and solving problems. In the laboratory, the working memory has to cope with all the range of tasks listed above, making overload highly likely (Shah, 2004).

Reviewing the evidence, Johnstone (1992) offers some key pointers for conducting the laboratory work:

1) Long term memory has to be prepared so that it can control the perceptual process and enable the students to separate ‘signals from noise’.
2) The student must play an active part in planning the experiment, so as to fully understand what is being investigated and have a feeling of being a participant.
3) The student should already be skilled in the manual techniques involved so that handling the apparatus does not intrude on the thinking process, thus freeing the working space for interpretation and understanding.

Working with first year university chemistry students, he put these principles into practice, with some very positive effects (Johnstone, *et al,* 1994).

Chapter 5

Developments of Attitudes

There is a very large literature that talks about the nature and the developments of attitudes. This chapter seeks to offer a brief overview of the main outcomes from the work of social psychology in relation to attitude research as well as the definitions for attitudes and their development. Then, the importance of attitudes and factors affecting them are outlined. Later on, attitude measurement is discussed and finally reliability and validity of attitude measurement are outline.

5.1 Attitude definition and its development

It took many decades to move from seeing an attitude as essentially affective or as essentially the same as behaviour to an understanding that an attitude involves the cognitive, the affective and behavioural. Brandwein, *et al.* (1958) saw attitudes as representing the emotional orientation of an individual toward the topic at hand. This tended to follow the much earlier line adopted by Thurstone when he described an attitude as "*the affect for or against the psychological object*" (Thurstone, 1929). After three years, Likert (1932) described attitudes as "*the certain range within which responses move*", a more behavioural approach.

In 1935, Allport gave a definition for the attitude that combined ideas from both Thurstone (1929) and Likert (1932) and said "*a mental and neural state of readiness to respond, organized through experience, exerting a directive and or dynamic influence on behaviour*". This definition is still widely used today. Later on in 1948, Krech and Crutchfield took a new approach suggesting that attitudes have aspects of problem solving and, therefore, were more like to learning. Similarly, Doob (1947) suggested that attitudes were '*attempts at solution*'. In other words, attitudes allow the person to make sense of something. They offer some kind of evaluation and analysis so that a person knows how to react. Step by set the concept of attitude was being clarified, the place of the cognitive, affective and behavioural being more apparent.

Thus, many (e.g. Bagozzi and Burnkrant, 1979; McGuire, 1985) have noted that attitudes have three components:

1) a knowledge about the object, the beliefs, ideas components (Cognitive)
2) a feeling about the object, like or dislike component (Affective); and
3) a tendency-towards action the object component (Behavioural)

Thus, attitudes will affect behaviour, influencing what the learner selects from the environment, how they will react to teachers, the materials being used and the other students. This selection and the processing of the input of information which follow it are strongly influenced by the instructor's expectations, attitudes and concepts (Dunham, 1974). This stresses the key importance of attitudes in relation to learning in the sciences (and, more generally, to learning). Many decades ago, this was recognised by Hurd, (1969). The description of attitudes in relation to science education was developed by Reid (1978).

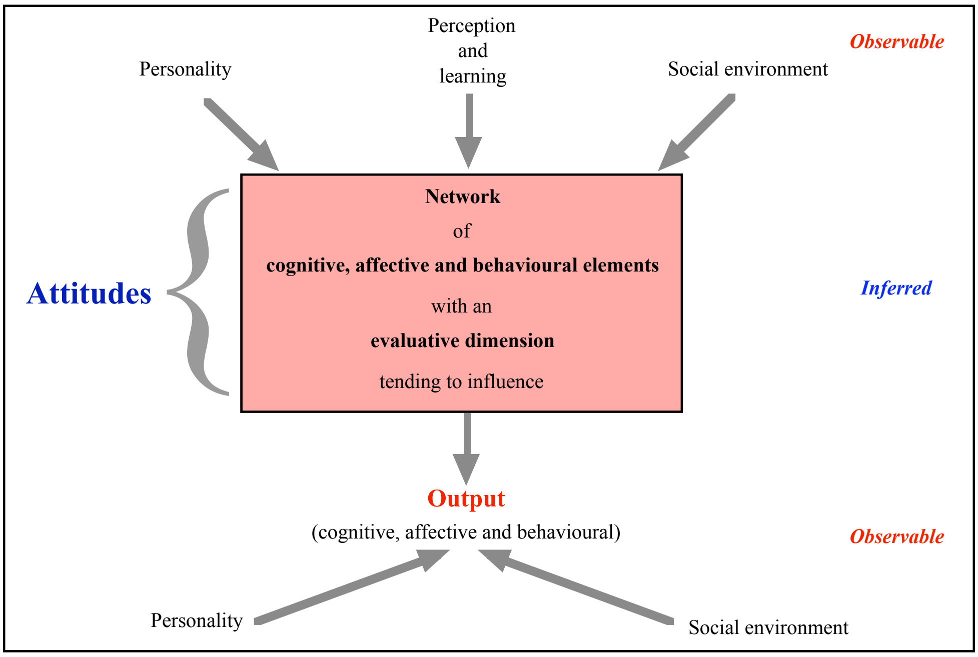

Figure 5.1: Attitude description (Reid, 1978)

The description in figure 5.1 emphasizes the construct nature of attitudes: they cannot be observed directly. They can only be inferred from observed behaviour. The description also shows how the cognitive, affective and behavioural interact and also illustrates how the various components work together in some kind of consistency.

The consistency emphasis is widespread in the research literature. For example, Heider (1944) and, later, Osgood (1967) appreciated the importance of the learner holding consistent views. Festinger (1954) took this much further when he developed the key idea of dissonance which he described as some kind of inconsistency between attitude and behaviour. Later on, Reid (1978) took the idea of Festinger and others further when he suggested that a likely key to attitude development was the bringing together of cognitive and affective elements in such a way that dissonance could occur. Reid (1978) then developed teaching resources which aimed to do this in the context of social attitudes relating to a school chemistry syllabus. He was able to show quite large attitude developments took place when these materials were used and he attributed it to the generation of dissonance in the students.

Then, in 1980, Reid talked about internal mental interaction or what he called 'intra-activity'. This means that there is a suggested internal interaction between what is already held in long term memory and the new learning, feelings or experiences in the learning situation (Reid, 1980). Figure 5.2 summarizes how Reid (1978) saw the concept and shows that attitude development will only occur if new input actually mentally interacts with attitudes already held in long term memory.

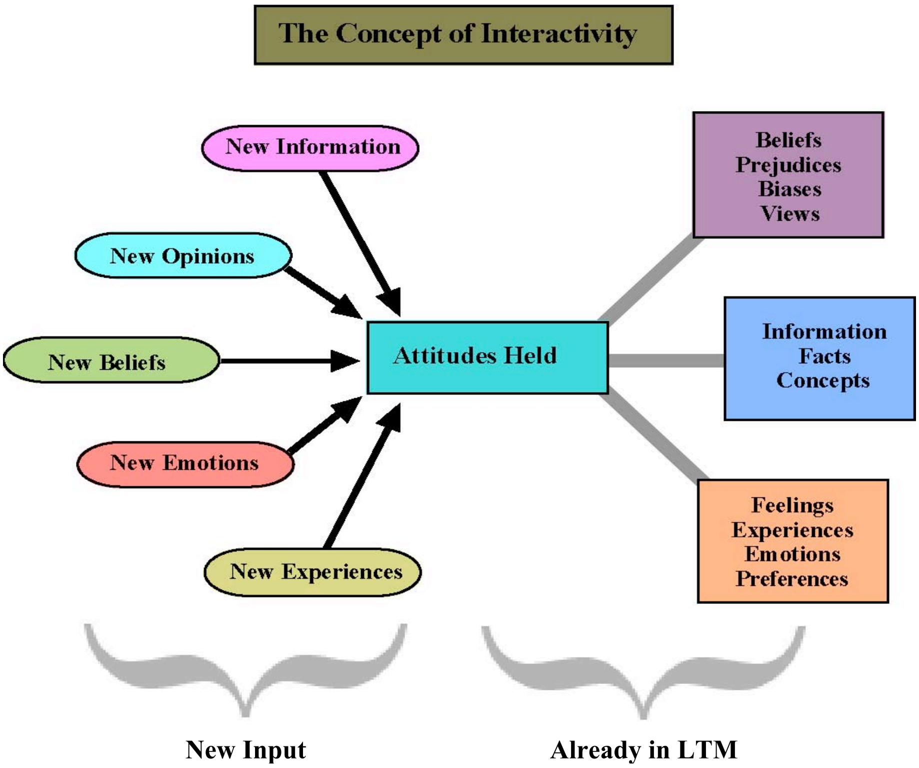

Figure 5.2: The concept of intra-action (derived from Reid, 1978)

5.2 Importance of attitudes

Reid (2003) noted that,

> "*Attitudes are important to us because they cannot be neatly separated from study. It is a relatively quick series of steps for a student with difficultly in a topic to move from that to a belief that they cannot succeed in that topic, that it is beyond them totally and they, therefore, will no longer attempt to learn in that area. A bad experience has led to a perception which has led to an evaluation and further learning is effectively blocked.*"

Many years before, Katz (1960) considered the purposes for holding attitudes. Overall, attitude development helps people to:

1) *Understand themselves*: bringing beliefs, feeling and behaviours into a logical and rational wholeness of meaning.
2) *Understand the world around*: in concepts of knowledge, feelings and behaviours.
3) *Understand relationships*: deciding satisfactory patterns of social interaction.

It is well known that attitudes help people to understand the world around but that will happen if they can make sense of themselves and others at first. For instance, looking at physics, students might develop positive attitudes if they see their physics course as making sense of their world around, leading to a desired career possibility or stimulating their curiosity and interest. Negative attitudes may well arise if the subject is perceived as irrelevant, they cannot pass examinations or even receive any praise from the teacher (Katz, 1960).

Much research has explored that a student's attitude towards a subject indicates whether the student will continue to study the subject or not (Reid, 2003). So, during a course of study, for example, students will develop attitudes towards laboratory work, towards certain studies of teaching and learning, towards their teachers, their demonstrators, specific topics and etc. As a result, students will develop attitudes towards the study and later towards the work. There is an important point that Hindal (2007) has discussed: in school education much of what the students are taught, and then memorized and reproduced in examinations is largely forgotten a few years later. However, attitudes towards their studies, teachers or subjects often remain for years to come. So, the development of such attitudes is part of the preparation of students for life beyond school.

5.3 Factors affecting attitudes

Ramsay and Howe (1969) said that "*A student's attitude towards science may well be more important than his understanding of science, since his attitude will determine how he will use his knowledge*". But students need a level of security in learning, so they can have positive attitudes. For example, a good learning environment affects more positive attitudes. Also, students need to know what is expected of them and feel that their learning is meaningful and making sense for them (Shah, 2004).

There are many factors that influence attitude. Khan and Weiss (1973) gave a useful diagram (shown in Figure 5.3) to describe attitudes and its relationship with all the variables. These variables could be divided into two categories:

a- *Internal factors*: personality, intelligence, achievement, gender, age

b- *External factors*: teacher and classroom atmosphere, home, background, the curriculum and instructional variables.

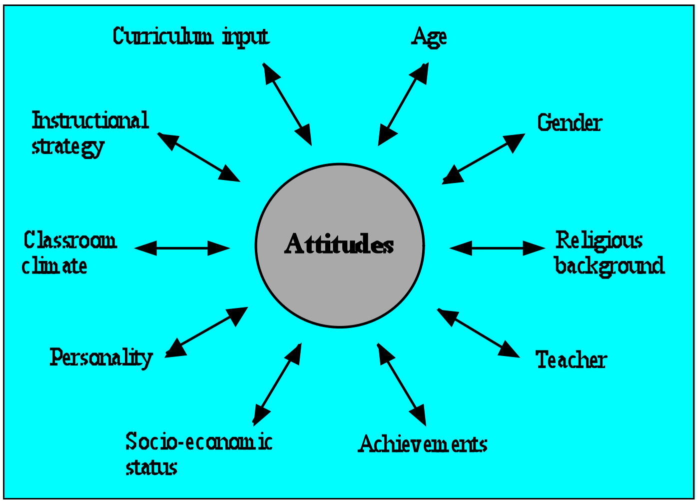

Figure 5.3: Variables influencing attitude development

The key thing to note is that most of these variables are not open to change in any easy way. The key variables which can be changed include: curriculum input, instructional strategy and classroom climate.

An important factor that influences attitudes is age. Piburn and Baker (1993) as well as Ramsden (1998) found similar patterns of school students' attitudes towards science with age and that, "*as pupils grow up their attitudes towards science decline*". There also seems to be a change of attitudes within each academic year. According to Simpson and Oliver (1985), attitudes towards science decline rapidly from the commencement of the academic year to the middle of the year and slowly from the middle to the end.

Another important factor affecting attitude is achievement. Many researchers study how attitude and achievement are linked. For example, Barrington and Henderriks (1988) studied attitudes towards science of both gifted and average students from third, seventh and eleventh grades in the USA and they found that there are indeed differences in the amount of knowledge the students possess with regards to scientific terminology and concepts. They also discovered that gifted students found their high school classes more gripping than the average students. However, the relationships found in this and many other studies do not indicate cause and effect. Do positive attitudes cause better performance; or, does better performance cause the development of positive attitudes? It is much more likely that each influences the other. They simply go together.

Weinberg (1995) looked at gender issues and found that, "*as attitudes became more positive, achievement tended to increase*". This is certainly unsurprising. However, she noted gender differences, concluding that, "*a positive attitude is more necessary for girls in achieving high scores than for boys*". However, this implies cause and effect, not easily demonstrated.

At a general level, Gardner (1975) observed that, "*Sex is probably the single most important variable related to pupils' attitudes to science*". It is well established that, among upper primary and secondary school students, boys tend to have interest in physical science and girls tend to have interest in biology (Clarke, 1972). On the other hand, chemistry attracts boys and girls approximately equally (Reid and Skryabina, 2002). Reid and Skrtabina went further in noting that, in relation to physics, there was no intrinsic reason why attitudes should differ by gender. Boys and girls were found to be equally interested in topics in physics. However, the topics of interest for boys were not always the same as those for girls, boys enjoying the more technical while girls enjoy topics which have social applications. Perhaps the curriculum emphasises the first type of topic more than the second.

Finally, the classroom environment and the teacher are the external important factors that influence attitudes towards science. For example, students' attitudes towards science are influenced by the teacher's personality, ability in and commitment to the subject and how they encourage, motivate and support the students (Harlen and Holroyd, 1997). Also, it has been shown in (Reid and Skryabina, 2002) that teacher quality is one of the most important factors to develop students' attitude towards science. For instance, students tend to develop enthusiasm for science if the teacher has positive attitude towards the subject (Haladyna and Shaughnessy, 1982). Also, at school level, the pupils' perception of the teacher may be influenced by factors outside the teachers' control. For example, two of the most important of these are: the pupils' previous experience of physics teachers and teaching. These may have encouraged the development of certain expectations towards the present 'role performer'. Secondly, the predominant attitude towards teachers and schools in the communities which are served by the school will be important (Shah, 2004). In fact, the teacher can create a positive classroom atmosphere for students because he/she can stimulate students' minds by making the lesson more interesting for them.

5.4 Attitude measurement

For many centuries it was thought that attitudes could not be measured. Indeed attitudes are hidden and not able to be observed directly. Thurstone (1928) noted that attitudes are complex and not describable by any one numerical index. In 1929, he made the first serious attempt on measurement. Most attitude measurement has to rely on observation of behaviour and then attempt to deduce the underlying attitudes. For example, in some countries physics is not seen as popular and this negative attitude for many is easily observed in their behaviour: they choose not to continue with physics studies (Reid, 2003). Thus, on observing and assessing the response of people when placed under certain conditions, attitudes can be formulated. However, the attitudes under investigation must be defined carefully otherwise there is a danger that, "*attitudes are what attitude measuring devices actually measure*" (Johnstone and Reid, 1981).

In the context of education, questionnaires and interviews are the most widely used approaches although observed behaviour has its place. Questionnaires are faster as it is easy to collect a large amount of information through their use while, with interviews, the information is often rich and revealing although based on a small selected number of interviews.

5.4.1 Interviews

One of the methods to measure attitude is interviews. Reid (2006) discusses the place of interviews and noted:

> *"Interviews can offer very rich insights. They can be highly structured or totally open, but often interviews can be described as semi-structured. Here the interviewer has a set of questions for discussing but there is freedom to elaborate or move from the agenda as appropriate. If the interview is highly structured, then data analysis can be simpler."*

Thus, in highly structured interviews, all questions are decided beforehand. This is rather like a verbal questionnaires but it has the advantage of allowing some kind of check for misunderstanding and misinterpretation. Also, there is another type of interview which is totally open. Here, the respondents talk freely but some preliminary questions may be needed so that each respondent will be confident to talk freely. Another type of interviews can be semi-structured which is mix between defined questions and open questions. This allows some measure of freedom but, if conversation dries up, the interviewer can feel back on the next question (Reid, 2003).

An interview is a powerful research tool and has some advantages: it helps to minimise potential misunderstanding and imprecision in answering questions (Almadani, 2004). On the other hand, the interviews have some disadvantages. Reid (2003) summarizes them: interviews take time from both the researcher and the respondent. In contrast questionnaires take shorter time and can involve very large numbers. Also, it is difficult to summarize evidence from interview.

5.4.2 Written tests

These are often called questionnaires and there is a common view that such questionnaires are highly unreliable and of limited value. A well-constructed questionnaire can provide extremely accurate insights into how students think and the way they evaluate situations and experiences (Reid, 2003). So, a questionnaire is,

> "*An important instrument of research, a tool for data collection.... It can be considered as a set of questions arranged in a certain order and constructed according to specially selected rules. The questionnaire has a job to do; its function is measurement*"
>
> (Oppenheim, 1992, p.100)

Questionnaires may include two kinds of questions:

a) *Open-ended*: here, the respondent enjoys full freedom in writing down what she/he thinks (Almadani, 2004). Open-end questions allow the respondents to express their opinions in their own words. Such questions can lead to in-depth study especially of individual issues (Blaxter *et al*., 1996). However, it is difficult to analyse and interpret.

b) *Closed:* here, there are anticipated answers offered by the designer. These may be harder for a designer to form; however, they are much simpler to analyse. Nonetheless, they sometimes do not allow the respondents to say exactly what they think and there is no freedom to generate other answers.

In planning a questionnaire, the researcher needs to have a clear idea what attitudes are being explored. Questions have to be developed and clear. It is helpful for the questions to be examined critically by other researchers or by teachers who know the pupils who will be tested. Also, the questions which are appropriate to the pupils are being asked, should be reflecting their language, thought forms and covering the types of issues of relevance to them (Suzuki, 2007).

The fundamental problem with all questionnaires is to know the extent at which the responses reflect the actual situation. Danili and Reid (2004) describe what they call the 'reality-aspiration' problem. Here, the respondents indicate what they would like a situation to be rather than basing their responses on the actual situation. This can be a problem with younger respondents but seems rarely to occur with older students. Of course, if the respondents think there is some hidden agenda (for example, their teacher will not be pleased with certain responses) then responses may well not reflect reality at all. It is thus, critical that respondents either complete the questionnaire completely anonymously or they are confident that their responses will not affect either their work or the teacher-student relationships.

It is also important that students should be allowed sufficient time to complete the questionnaire without feeling rushed. Moreover, instructions should be unambiguous and clear. Statistically, samples selected should be large and reflect the population under consideration. In these ways, the responses are likely to reflect reality and be highly reproducible. Indeed, reliability is fairly well assured under good conditions (Reid, 2003).

5.5 Methods of measurement

There are many methods for designing the questions for a questionnaire. The question designs developed by Thurstone, Likert and Osgood have all been used widely and are outlined briefly here. The traditional approaches to marking are discussed later and better alternatives suggested.

5.5.1 Thurstone method

Thurstone's study was published in 1928 entitled 'Attitudes can be measured'. However it is rarely used. His method involves the following steps:

1. Collect a wide range of statements (about 100-150) related to attitude under consideration.
2. Edit them down to about 40-60 statements from previous ones seeking that each statement should have validity, with the range covering a wide range of opinion and including neutral position.
3. Find around 300 people who can give opinions relating to the attitude under consideration.
4. The 300 were each asked to divide these statements into 11 categories: from extremely positive to extremely negative including neutral. The aim was that the interval between each category should be equal.
5. Select those statements where the 300 were in agreement. This gave about 20 statements.
6. Respondents were asked to pick those statements with which they agree. Their score was the sum of the category values of the statements chosen.

Because the method is cumbersome, it is rarely used today. However, it did demonstrate that attitude measurement was possible.

5.5.2 Likert method

Likert published his paper in 1932; he described a more efficient means to use questionnaires in order to measure attitudes. For each question, the candidate is allowed to select one answer: strongly agree, agree, neutral, disagree or strongly disagree (or sometimes very strongly agree at the beginning and very strongly disagree at the end). These rating are then scored numerically as 1 to 5 (or -2 to +2) assuming all the questions are positive as follows:

Strongly agree = 5, agree = 4, neutral = 3, disagree = 2, strongly disagree = 1

This was seen as a means to provide more accurate information about the respondent's level of agreement or disagreement with a statement. The respondent's attitude is found by adding up the scores obtained. Each question is asking about a different aspect and it is important to analyze each question on its own. The Likert method is brilliant and ingenious but it makes many assumptions and the scoring method is open to much criticism (Reid, 2006). An example (taken from this study) of Likert's method is shown below

In each line, tick the box that most closely reflects your views		*Strongly agree*	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*
(1)	I feel that the physics curriculum includes enough practical experiments					
(2)	I feel that our teacher enjoys teaching physics in laboratory					
(3)	Most students don't interact with the teacher during teaching physics in the laboratory					
(4)	Our teacher walks around the laboratory to supervise students while preparing experiments					
(5)	I believe that teaching physics is not fulfilled without using physics laboratory					
(6)	Physics teachers use varied teaching methods inside the physics laboratory					
(7)	When I came to the physics laboratory I find it's ready to do the experiments					

Table 5.1: Example of Likert type questions

The Likert approach is the one which is used most today although his original scoring approach relies on evidence of uni-dimensionality, rarely observed in educational contexts (Reid, 2006).

5.5.3 Semantic differential method (Osgood method)

This is also known as the Osgood method, after the senior author of the paper (Osgood, *et al.* 1967). This is now one of the most popular and useful methods. Heise (1970) appreciated this method and said: "*Osgood's method is eminently suitable in terms of sample, administration, easy design, high reliability and validity when compared to other methods*." In this method the respondent is asked to think of some idea and then tick boxes placed between adjectival pairs of words (or adjectival phrases). An example from this study illustrates the design.

How do you describe the practical work in physics curriculum?

Useful	☐	☐	☐	☐	☐	☐	Waste of time
Understandable	☐	☐	☐	☐	☐	☐	Not understandable
Satisfying	☐	☐	☐	☐	☐	☐	Not satisfying
Interesting	☐	☐	☐	☐	☐	☐	Boring
Enjoyable	☐	☐	☐	☐	☐	☐	Not enjoyable
Easy	☐	☐	☐	☐	☐	☐	Difficult
Experiments are clear	☐	☐	☐	☐	☐	☐	Experiments are not clear
Mostly done	☐	☐	☐	☐	☐	☐	Often omitted
Important	☐	☐	☐	☐	☐	☐	Not important
The best part of physics	☐	☐	☐	☐	☐	☐	The worst part of physics

Table 5.2: Example of Osgood type questions

The method originally had a seven-point rating scale. Respondents ticked one box on each line. Later, Heise (1970) modified from seven-point scale to four or five-points. This modification makes this method quicker and easier for both the respondent and the analyzer and takes a shorter time to answer questions than with the Likert approach. In this research we used Osgood method with six-point scale as this forces the surveyed students and teachers to make a decision in one direction or another. There is another advantage for this method, that it is useful for young children (Reid, 1978). However, six points are used here as this forces a decisions in one direction or the other.

5.5.4 Other written forms

Reid (2003) discusses another approach which he calls '*rating questions'*. In rating questions, the respondent is offered a set of responses and asked to place them in some kind of order or to pick a small number of greatest significance against some criterion (Reid, 2003). There are many forms of rating questions. An example is shown below:

Here are several reasons why physics laboratory work is part of most physics lessons.

Place them in order, using the letters, showing which is most important for yourself.

(A) Experimental work stimulates and maintains interest in physics ……..………………..…
(B) Experiments illustrate theory and material taught in classes ……………………………..
(C) Experiments help learning theoretical material not taught in the classes ………………...
(D) Experimental work helps learning practical skills …………….………………………….
(E) Laboratory work allows testing and validating ideas ……………………………………..
(F) Experiments familiarize with important physical measurement techniques …………...…
(G) Laboratory work trains making deductions from measurements and experimental data ...

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Most important Least important

Table 5.3: Example of rating questions

In this example, the respondents place all the responses in order from A to G. Other methods of rating are also available (Reid, 2003).

5.6 Reliability and validity

Two of the problems in all educational measurement relate to validity and reliability. In other words, the results are reproducible and the questionnaire is testing what it is intended to test (Oppenheim, 1992). Eagly and Chaiken summaries the meaning of reliability and validity as,

> *"The reliability of a measuring instrument refers to the extent to which that instrument yields consistent scores or values over repeated observations. The validity of a measuring instrument refers to extent to which that instrument measures what it claims to measure"*
>
> (Eagly and Chaiken, 1993)

The reliability of any measurement is essentially the confidence the researcher has that the measuring device will give the same or similar results on more than one equivalent occasion (Suzuki, 2007). In other words, reliability is the extent to which the measurement gives similar outcomes if repeated under similar circumstances.

However, validity is much more important and more difficult to assess. Validity looks at whether the questions are implemented as the designer planned and means that the extent to which the test measures what is intended to measure. Reid (2006) notes that validity can be checked by:

a) Seeking opinions of a group of those who know the population, the attitudes being considered and the social contexts.
b) Developing questions based on the population.
c) Sample interviewing.
d) Comparing any conclusion drawn from the attitude measurements with other independent observations.

However, reliability can be checked by test and re-test procedures (Reid, 2006). Although this does not give a statistical check, reliability is generally well assured by:

a) Using large samples
b) Careful pre-testing
c) Checking that test conditions are sociality acceptable.
d) Using enough questions, with cross checks (e.g. repeated questions, similar questions).

5.7 Scoring questionnaires

The traditional method of scoring often allocates numbers to the various responses and then adds these numbers up to give a final score. This is only valid of all the questions are measuring the same underlying construct. This is rarely true in educational contexts and the usual approaches of correlation or factor analysis are open to considerable criticism as offering evidence of uni-dimensionality (Reid 2006). Fundamentally, ordinal numbers are being added and this is mathematically invalid. The better approach is to analyse outcomes from each question separately and build up a picture of the underlying attitudes.

5.8 Conclusions

This chapter has illustrated the development of definitions of attitudes. It has been demonstrated that attitudes are very important in that they can influence learners considerably, affecting future learning. Also, this chapter reviewed briefly how to measure attitudes and the validity and reliability in such measurements.

It has to be recognized that attitudes cannot be ignored by curriculum planners and teachers. Inevitably, school pupils will develop attitudes but there are ways by which the learning experiences can encourage the development of more positive attitudes. Finally it is important to remember that the adults of tomorrow will live in a rapidly changing technological environment, and their attitude to that change will influence their ability to cope with it in emotionally as well as in material ways. An important element in generating positive attitudes will be pupil attitudes towards laboratory work (Shah, 2004).

Chapter 6

Analysis of the Attitudes of Students towards Physics Laboratory

6.1 Introduction

The purpose of this project was to gain insights into the place of laboratory work in secondary schools in Oman and to explore how laboratory work might be enhanced, particularly in the context of the needs in Oman. The project looked at what was happening with physics students at secondary schools and what physics teachers' attitudes were to using the laboratory in teaching physics at secondary schools in Oman. This chapter is devoted to the analysis of the students' survey while the next chapter analyses the teachers' opinions. More comparisons and the differences between the students' and teachers' responses along with the analysis of teachers' interviews will be presented in Chapter 8.

Focusing on students' responses, the student survey, discussed in this chapter, aimed to gain insights into students' views about the following issues:

- An evaluation of the practical work in the physics curriculum
- The style of conducting the experiments during the laboratory sessions
- The best ways of using laboratory in teaching school physics
- The reasons behind using laboratory work in learning physics
- Technical and administrative support for laboratory work

The survey employs a variety of approaches, depending on those developed by Likert (1932), Osgood *et al.* (1967) and those described by Reid (2003). This follows the recommendation proposed by Reid (2006) when he stated that,

> "*There are numerous paper-and-pencil approaches: based on Likert, Osgood as well as rating questions and situational set questions; interviews can offer useful insights."*

The survey was developed, following the guidelines offered by Reid (2003). Firstly, the aims of this project were listed. Many questions were developed in various formats and these were refined. Then, the set of questions was given to experienced teachers for comment and the survey modified slightly in the light of comments. Later on, the survey was used with a small sample to check for timing and general clarity. Very minor modifications were incorporated. Then, the whole survey was translated into Arabic and the translation checked. Finally each question was analyzed on its own. By taking these steps, it was hoped that the validity would be high. At the same time, by using large samples under good conditions, the reliability was assured (Reid, 2003).

The survey was applied in April 2006 in twenty nine schools, eighteen boys' schools and eleven girls schools in the Al-Dhahira region in Oman (almost all the schools in the Region). The students took approximately 20 to 25 minutes to complete the survey. It was stressed to the pupils that their responses would not affect their school grades in any way. In this way, it was hoped that an honest picture would emerge. A total of 881 surveys returned (almost all) and they are summarized in Table 6.1 below.

Age of the students	*Number of the students*
16 (Grade 11)	342
17 (Grade 12)	539
Total	**881**

Table 6.1: Summary of sample size of the survey

6.2 Analysis and discussion

The results from each question are now discussed in turn. Each question is shown as in the survey and the data are shown as parentages for the whole sample of 881. The English version of the survey and the Arabic version are shown in Appendix I.

The data are presented as percentages for clarity. On occasions, the totals do not always add up to 100% because of rounding errors.

Question 1: In the left column indicate how do you have been doing the experiments in the physics lab. And in the right column indicate the best way to conduct the experiments?

49	The teacher does the experiment and the students watch the demonstration	11
7	Each single student does the experiment and the teacher supervises	28
14	Each group of two or three students does the experiment and the teacher supervises	40
42	Each group of more than three students does the experiment and the teacher supervises	37

Table 6.2 Responses to Question 1 of the students' survey

This question investigates the teaching style used in physics laboratory (left column) and the preferred style as seen by the students (right column). Participants are allowed to tick more than one option and that is why the percentages do not add up to 100%. As it is clear from the left column of the table, almost half of the students in the sample indicated that the teacher does the experiment and the students watch the demonstration. Similarly about 42% of the students surveyed confirmed that teachers group students into more than three to do the experiments. It is likely that teachers opt to these two options (i.e. demonstration or large groups) to overcome the space, time and resource limitations. This will be confirmed after looking the teachers' responses (See Chapter 7).

Contrary to the current teaching style in the physics laboratory, students seems to favour working individually or in small groups to conduct the experiments as around 68% indicated this. Nonetheless, larger group sizes are also acceptable with around 37% of the sample.

Question 2: How do you describe the practical work in physics curriculum?

Tick one box only in each line as shown above

Useful	61	20	11	2	1	3	Waste of time
Understandable	38	29	17	8	3	4	Not understandable
Satisfying	29	25	20	11	7	5	Not satisfying
Interesting	36	22	18	9	5	7	Boring
Enjoyable	41	21	14	9	5	6	Not enjoyable
Easy	16	26	23	13	9	10	Difficult
Experiments are clear	23	25	23	14	6	7	Experiments are not clear
Mostly done	37	20	15	9	8	8	Often omitted
Important	57	19	10	6	3	3	Not important
Well organized	26	28	22	9	6	7	Not organized
The best part of physics	33	21	21	11	7	5	The worst part of physics
Help students be perfect and precise	48	24	14	6	4	2	Does not help students be perfect and precise
Promote critical thinking	61	17	11	4	3	3	Does not promote critical thinking

Table 6.3: Responses to Question 2 of the students' survey

In questions 2 and 3, data from the left two columns are combined to reflect the agreement with the statement on the left while the data from the right two columns are combined to reflect the agreement with the statement on the right.

The aim of question 2 was to find out students opinions towards the practical experiments in the laboratory at school. It is clear that the students hold positive views towards physics laboratory. For example, 81% (columns 1 and 2) of the students believe that the practical work is useful and 66% said that it is understandable. Similarly, 76% of the sample sees the experiments to be important, help them achieve perfection and precision (72%) and promote their critical thinking (78%).

However, only around half of the surveyed students believed that the practical work is satisfying, interesting, well organized and the best part in physics. Although about 42% of the students in the sample agreed that experiments are easy, the other columns of the table show that the difficulty is a concern with a high proportion of the students. This might also explain why only 62% of the students think that the experiments are enjoyable. Only 57% of the students agreed that the experiments are mostly done and about 48% of them said that the experiments are clear. Moreover, less than 55% of the students in the sample believed that the experiments are well organized.

Question 3: What is the best way to use the physics laboratories in teaching?

Tick one box only in each line as shown above

More frequently	40	22	20	8	4	5	Less frequently
With pupils doing the experiments	47	19	15	7	3	6	By demonstrations by the teachers
To learn practical skills	50	19	10	5	3	10	To illustrate ideas
Linked closely to class teaching	45	17	14	6	5	10	As a separate course
Following a laboratory textbook	47	20	12	7	4	9	Not following a laboratory textbook
More quantitative experiments	24	17	18	14	9	16	Less quantitative experiments

Table 6.4: Responses to Question 3 of the students' survey

This question aims to exploring the student's opinions towards the best way to use the laboratory in learning physics. As it is seen about 62% of them want the laboratory sessions to be more frequent. In line with the results presented in Question 1, 66% of the surveyed students prefer to do the experiments themselves as opposed to watching a demonstration. Moreover, almost 70% of the students say that they consider physics laboratories as more useful in learning skills than in illustrating ideas. About 62% of the students would like the experiments to be closely linked to the class teaching. Almost two thirds of the surveyed sample prefers to follow a laboratory textbook but only 41% favour more quantitative experiments.

Question 4: According to previous research, here are several reasons why physics laboratory work is part of most physics lessons. If you agree with the statement, tick the appropriate box (Agree, Not sure, Disagree). If you think you have achieved this aim, tick the box under "Achieved".

		Agree	Not Sure	Disagree		Achieved
(1)	Experimental work stimulates and maintains interest in physics …………..	60	27	5		29
(2)	Experiments illustrate theory and material taught in classes ………………….	70	18	2		32
(3)	Experiments help learning theoretical material not taught in the classes …….	50	34	10		18
(4)	Experimental work helps learning practical skills ……………..………………	65	21	6		23
(5)	Experiments help understanding some physical phenomenon ………………	51	30	9		22
(6)	Experimental work helps solving scientific problems …..………………….....	53	31	9		18
(7)	Experiments familiarize with important physical measurement techniques …	72	15	3		29
(8)	Laboratory work trains making deductions from experimental measurement .	61	22	8		24
(9)	Laboratory work allows testing and validating of theoretical concepts ………	61	23	6		28

Table 6.5: Responses to Question 4 of the students' survey

This question investigates the student's opinions on some potential reasons why physics laboratory work is part of most physics lessons. Students in the sample tend to have positive attitudes toward physics laboratories in that 60% of the students have chosen the reason, *"experimental work stimulates and maintains interest in physics"* and 70% of them have chosen the reason, *"Experiments illustrate theory and material taught in classes"*. Similarly, nearly half of the sample believes that experimental work help understanding some physical phenomenon and solve scientific problems. It can be seen from the table, however, that only less than 10% disagreed with the above two reasons and the remaining are either not sure or they did not respond to the question. Moreover, about 72% believed that *"Experiments familiarize with important physical measurement techniques"*. Also, about 61% of the students in the sample have chosen the reason, *"Laboratory work trains making deductions from experimental measurements"* and the reason *"Laboratory work allows testing and validating theoretical concepts"*.

In an attempt to evaluate how much of the above reasons have been achieved, the last column in the above table indicates the percentage of students who actually achieved the corresponding reason. The data shows that the level of achievement is in the range of twenties only with the reason *"Experiments illustrate theory and material taught in classes"* scoring the highest level of achievement (32%). This is a serious issue that should be investigated further to for better understanding. Several causes can lead to such low level of achievement including, availability of resource, teachers, style and technical support.

(5)	In each line, tick the box that most closely reflect your view	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
(8)	Physics curriculum includes enough practical experiments	20	39	16	17	7
(9)	I think our teacher is not interested in the practical work and experiments	9	10	20	26	32
(10)	Most students don't interact with the teacher during the laboratory sessions	18	31	24	14	10
(11)	Our teacher conducts the experiments himself and does not let the students participate	8	8	10	34	38
(12)	I believe that teaching physics is not fulfilled without using physics laboratory	58	22	8	6	3
(13)	Physics teacher uses various teaching methods inside the physics laboratory	27	32	21	11	7
(14)	When I came to the physics laboratory I find it ready to do the experiments	44	29	11	7	5
(15)	The teacher moves around in the lab and supervises students while they do the experiments	49	32	8	5	4
(16)	The aims of experiments are explained at the beginning of each session	54	28	8	5	2
(17)	Presentation of practical work in physics books encourages the application of the experiments	20	27	23	16	10
(18)	Students are encouraged and allowed to participate in laboratory sessions	44	31	10	6	4
(19)	Safety precautions including safety training are not enough	23	19	26	16	12
(20)	Usually the marks for experimental work are not counted towards students final grade	16	11	20	20	29
(21)	The results of experiments are discussed with pupils at the end of each laboratory session	45	30	9	6	5
(22)	Laboratory technical staff do not provide sufficient support while conducting the experiments	15	14	18	28	4
(23)	I feel that the material and devices needed for experiments are adequate and available	14	19	23	16	25

Table 6.6 Responses to Question 5 of the students' survey

The aim of this question was to find out the attitudes of students towards physics laboratory in schools. The picture obtained is quite mixed. There is much that is positive. Talking about the curricula, for instance, 59% of the students in the sample are convinced that the physics curriculum includes enough practical experiments. Moreover, 81% of the students in the survey believe that the aims of experiments were explained at the beginning of each laboratory session and 75% of the sample is confident that the results of experiments are discussed with pupils at the end of each laboratory session. Furthermore, 80% believed that teaching physics is not fulfilled without using physics laboratory.

Similarly, students seem to hold positive attitude towards their physics teachers. This can bee seen from statements 2 and 6 where 59% of the sample agrees that physics teachers are interested in practical work in teaching physics and 58% believes that physics teachers use various teaching methods inside the physics laboratory.

The results show that 76% of the sample believed that students are encouraged and allowed to participate in laboratory sessions. Meanwhile, Statement 4 indicates that students favour and actually practice doing the experiments themselves as 72% of the students disagrees that teachers do the experiments and students watch the demonstration. Similarly, statement 8 reveals that 81% of the students agree that the teacher is moving around in the lab and supervises students while they do the experiments themselves. This is apparently in contradiction to the results obtained from question 1 (See Table 6.1) where 49% indicated that the teacher actually does a demonstration and they watch. Our explanation is that the responses to this question could be the student's aspirations rather than a reflection of their views. This is supported by the fact that other statements are quite negative as can be seen from Table 6.6. For example, only around half of the surveyed students agree that they interact with the teacher during the laboratory sessions.

Despite the positive views shown above, responses to some components of this question highlight some potential issues with less positive attitudes. For example, students raised concerns about the presentation of practical work in their physics books with only 47% of the sample agreeing that the presentation of experimental work encourages them to apply the experiments practically. Moreover, there is a variety of views among the students when it comes to including the practical work as a component in their final grades. Only 48% wish that the marks for practical work are counted towards their final grades while 47% are unconvinced or are not sure about it.

Looking at the technical support, 74% of the sample confirmed that they find the physics laboratory ready to do the experiments. On the other hand, only 32% from the sample believed that laboratory technical staff provides sufficient support while conducting the experiments. Although sounds contradicting, the above two percentages can be explained by the high number of students, resource limitations, and low frequency of laboratory sessions. Apparently it is possible for the technical staff to prepare the labs for the experiments (due to less frequent sessions) but once the students are in the lab doing the practical work, the technicians cannot cope with large number of students to provide sufficient support. Moreover, only 34% of the students agree that material and devices needed for various experiments are adequate and available. This is a major issue that should be addressed by the Ministry of Education in the Sultanate. This, as well, might contribute the technical staff not being able to provide sufficient support while conducting the experiments.

6.3 Open questions

In the student's survey, space was left for open responses. Two questions were asked and participants were asked to express there answer candidly. The first question was *"What are you looking forward to in your physics laboratory?"* and the second question was *"Please give any further comments about your physics laboratory"*. However, in this section we combined responses from both questions as we observed some overlapping between the answers for each of them. Therefore, students' suggestions and comments were classified into four main areas related to curricula, teaching style, technical support and attitudes. Each of these classifications is considered separately. Table 6.7 summarizes the student's responses. It is worth noting that not all students responded to the open questions (368 answered the first question and 307 answered the second question), Therefore, the responses are percentages of the answered questions.

Curricula

23.8% of the students indicated that they would like their laboratory work to be connected to the theoretical lessons so that it helps them understand the concepts and apply different physics laws. Very few students (less than 2%) requested to increase the contribution of the practical work in the final grade. This is probably a reflection of their unhappiness with the laboratory setup and how it is being conducted.

Attitudes

48% believed that (and would like) the physics laboratory helps them understand scientific theories, some natural phenomena, broaden their scientific horizons and help them in their everyday life. 18% would like the practical work in physics to help them acquire skills of measurements to enhance there competency for future careers.

Teaching style

More than 10% of the students who answered the open questions indicated that the length of the laboratory sessions should be extended or alternatively to increase the number of laboratory sessions. Meanwhile only 6 students out of 881 surveyed indicated that the experiments should be minimized because they are "boring" as described by them.

6% of the students pointed out that experiments should be understandable. They have also requested to enrich the practical laboratory book with necessary graphics and illustrations required to carry out the experiments. 12% would like to see the teacher interact more with the students and use a variety of teaching styles during the laboratory session.

Technical support

A large number of students (62%) mentioned different suggestions to the setup of the laboratory and their technical quality. This includes providing comfortable seating chairs, air conditioning, illustration posters, teacher's microphone, computers, projectors, instruments and tools. Moreover, around 19% of the students indicated that technical staff should provide more support to the students while conducting the experiments and they requested either a dedicated lab tutor or more technical staff. Security and safety including devoting special lectures for this purpose at the beginning of each school year was also raised by about 13% of the students.

Area	**Topic**	**%**
Curricula	Laboratory work connected to theoretical lessons and help understand physics laws	24
	Increase the marks for practical work	2
Attitude	Physics laboratory is good to understand scientific theory, natural phenomena, and help in everyday life.	48
	Physics laboratory help acquire measurements skills and enhance future careers.	18
Teaching style	Longer and/or more frequent laboratory sessions	10
	Experiments should be understandable and laboratory book should be clear and contain more illustrations	6
	Teachers should interact more with the students and use different methods of teaching in the lab	12
Technical support	Enhance laboratory environment: comfortable chairs, air-conditioning, computers, projectors, microphones, illustration posters …	62
	Technicians should provide more support. Increase the number of technicians or hire laboratory tutors.	19
	Safety precautions should be enhanced including giving proper training for students at the beginning of each school year	13

Table 6.7: Summary of students' responses to the open questions

6.4 Conclusions

Results of the students' survey show positive attitude towards laboratory work in the physics curriculum. All regarded experimental work as essential part without which teaching physics cannot be fulfilled. Despite this positive attitude towards physics laboratory, there have been some issues and concerns that should be addressed to assure proper laboratory work.

In contrary to the dominating way of conducting experiments (by demonstration), individual and small group work is preferred by students. Even though students believe that experiments are not clear or well organized, they have no doubt that laboratory work is useful and help to promote critical thinking.

Students would like the experimental work to be closely linked to their class teaching and to be able to learn practical skills. They also demand to have more laboratory sessions, and to use a dedicated laboratory textbook.

As to why laboratory is part of most physics curriculum, students think that was because the *"experiments familiarize with important physical measurement techniques"*. They also regarded the reason *"experiments illustrate theory and material thought in classes"* equally important.

Students seem satisfied with the pre and post lab activities and they hold positive views towards their physics teachers. Moreover, they are also confident that they find the laboratory ready to conduct the experiments. However, they were not happy with the presentation of the practical experiments in physics book and there in uncertainty whether the marks for practical work would be included in their final grades. They also raised some concerns about the technical support while they do their experiments. This could be because the technicians cannot cope with large number of students to provide sufficient support. Inadequacy and unavailability of material and devices required by some experiments was also a major issue that has been pointed out by the majority of students.

In the next chapter we analyse the teachers' views and opinions towards the physics laboratory.

Chapter 7

Analysis of Teachers’ Attitude towards Physics Laboratory

7.1 Introduction

The survey was designed to gain insights into teachers’ opinions about:

- Their practical experiments in the physics curriculum.
- Their preferred style of working and the present style.
- Their best way in using physics laboratories in teaching.
- The reasons why physics laboratories work as part of most physics lessons.
- Technical support in the laboratory sessions.

The survey was applied in April 2006 in Al-Dhahira region in the Sultanate of Oman. Thirty nine completed surveys were returned from twenty nine schools, almost all the schools in the region. The original form of the survey is shown in Appendix I both in English and Arabic.

7.2 Analysis and discussion

In this section, each question of the survey is analysed separately and the results are discussed to gain insights about the teachers’ attitudes towards physics laboratories. Like the student’s survey and, for the sake of clarity, results for all questions are presented as percentages of the total number of teachers (i.e. 39) unless otherwise stated.

Question 1: In the left column indicate how do you always ask students to do the experiments in the physics lab. And in the right column indicate the best way to conduct the experiments?

31	The teacher do the experiment and the students watch the demonstration	2
6	Each single student do the experiment and the teacher supervises	23
6	Each group of two or three students do the experiment and the teacher supervises	56
56	Each group of more than three students do the experiment and the teacher supervises	19

Table 7.1: Responses to Question 1 of the teachers' survey

This questions aims at exploring the style used by the teachers to run the physics laboratory. Moreover, it investigates the teacher's preferred method of teaching in the laboratory, should he/she have the possibility to apply it.

The right-hand column of the above table shows that most of the surveyed teachers prefer that groups of students conduct the practical work and the teacher supervises and facilitates. Although teachers' opinions vary when it comes to group size, it is clear from the presented data that the majority of teachers (about 56%), however, prefers to group students into two or three. In line with this, only 2% of the sample prefers the demonstration style.

In contrast to what the teachers prefer, however, they opt either to the demonstration style (31%) or to large size groups (56%). Apparently this discrepancy between what the teachers prefer and what they actually do is probably due to resources limitations (for example instruments and tools) and large number of students in the laboratories. This will be clearer in the discussions on later questions.

Question 2: How do you describe the practical work in physics curriculum?

Useful	67	26	5	3	0	0	Waste of time
Understandable	51	33	13	3	0	0	Not understandable
Satisfying	41	41	13	3	0	0	Not satisfying
Interesting	39	44	15	3	0	0	Boring
Enjoyable	36	39	21	5	0	0	Not enjoyable
Easy	15	18	26	23	13	5	Difficult
Experiments are clear	21	46	23	5	3	3	Experiments are not clear
Mostly done	59	23	10	8	0	0	Often omitted
Important	72	15	13	0	0	0	Not important
Well organized	23	33	26	10	3	0	Not organized
The best part of physics	31	36	18	10	5	0	The worst part of physics
Help students be perfect	46	21	31	3	0	0	Does not help students be perfect
Promotes critical thinking	36	44	18	3	0	0	Does not promote critical thinking

Table 7.2: Responses to Question 2 of the teachers' survey

The aim of this question was to find out teachers' opinions towards the practical experiments in the laboratory at school. Before analyzing the results, it is worth mentioning that in questions 2 and 3, data from the left (right) two columns are combined to reflect the agreement with the statement on the left (right). It is noted here that there is a high proportion of teachers were positive about the practical work being useful (92%), understandable (85%), satisfying (82%), interesting (82%), enjoyable (74%), important (87%) and the best part in physics (67%). Also, most of them see that most of the experiments are done (82%) and help the students to be perfect (67%) and promote critical thinking (80%).

These positive views are not too surprising, perhaps reflecting the view that the teachers see themselves as doing a good job. Nonetheless, their views about the easiness of the experimental show wide variations. This may reflect how the teachers perceive the prescribed experiments or it may reflect how they think the students find them. Perhaps, overall it does indicate some unease over the clarity of laboratory books, availability of resources and technical support.

They are also not so convinced that this is the best part of physics, this perhaps indicating some of the same concerns as above, and their views on organisation arte less clear. No doubt, they recognise that poor organization can lead to difficulty in conducting the experiments bit is highly unlikely that they are criticising their own organisational abilities.

The problem probably lies in the way the curriculum is specified and the resources available.

Question 3: What is your opinion about the best way to use the physics laboratories in teaching?

More frequently	28	39	23	5	3	3	Less frequently
With pupils doing the experiments	69	23	8	0	0	0	By demonstrations by the teachers
To teach practical skills	64	31	5	0	0	0	To illustrate ideas
Linked closely to class teaching	59	15	13	8	5	0	As a separate course
Following a laboratory textbook	59	33	8	0	0	0	Not following a laboratory textbook
More quantitative experiments	28	23	31	13	3	3	Less quantitative experiments

Table 7.3: Responses to Question 3 of the teachers' survey

This question tries to reveal the teacher's opinions towards the best way to use physics laboratories in teaching physics. Two thirds of the teachers in the survey want the laboratory sessions to take place more frequently and this can be seen as an indication of the belief in the high importance of the laboratory in teaching physics at school level. This is also in agreement to their views in the previous question as 87% indicated that the practical work is important.

Also, almost all of them (92%) want the experiments to be carried out by students and not demonstrated. Moreover, almost 95% of the sample sees the experiments as having the role of teaching experimental skills not illustrating ideas only. This reveals a problem; Most of the students will never need or use such skills again in their lives. The teachers need to see that the skills of the experimental are a means to show how a science gains its answers. The skills, by themselves, are not so important.

Experienced teachers see the value of the experimental linked tightly to the class teaching. However, the majority of teachers favour that the students follow the laboratory text book. This may well reflect insecurity in more open experimental approaches.

Question 4: According to previous research, here are several reasons why physics laboratory work is part of most physics lessons. If you agree with the statement, tick the appropriate box (Agree, Not sure, Disagree). If you think you have achieved this aim, tick the box under "Achieved".

		Agree	*Not Sure*	*Disagree*		*Achieved*
(10)	Experimental work stimulates and maintains interest in physics ……..……	72	15	0		39
(11)	Experiments illustrate theory and material taught in classes ……………..…	82	13	0		33
(12)	Experiments help learning theoretical material not taught in the classes …...	51	33	13		15
(13)	Experimental work helps learning practical skills ……………..…………….	90	8	0		31
(14)	Experiments help understanding some physical phenomenon ……………..	56	31	8		15
(15)	Experimental work helps solving scientific problems …..………………….....	64	31	5		15
(16)	Experiments familiarize with important physical measurement techniques …	92	3	0		28
(17)	Laboratory work trains making deductions from experimental measurements	87	8	3		23
(18)	Laboratory work allows testing and validating theoretical concepts …………	72	21	0		18

Table 7.4: Responses to Question 4 of the teachers' survey

The aim of this question was to gin insights into how teachers see the purposes for laboratory work in physics. It is clear that their dominant emphases lie in seeing laboratory work in terms of measurement techniques and skills development. As these will be unimportant for most of the students in their futures, this is a somewhat limited view. It is more encouraging seeing the importance they place on making deductions and the ideas of testing concepts. One of the most powerful uses for laboratory work is that it offers opportunities to make the physics tangible and real and the teachers see the importance for illustration.

It is very marked to notice how the ratings for achievement lag so far behind the aspirations. This is especially marked for: *Experiments familiarize with important physical measurement techniques, Laboratory work trains making deductions from experimental measurements* and *Experimental work helps learning practical skills*. This may reflect frustration with they way the experimental work is being handled as controlled by the curriculum, the time available, resource limitations, large numbers of students in laboratory sessions, lack of proper training for teachers and technical staff, clarity of practical work presentations in the text books and inadequacy of instruments and tools.

	Question 5: In each line, tick the box that most closely reflect your view	*Strongly agree*	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*
(1)	Physics curriculum includes enough practical experiments ……………………………………	3	36	18	36	8
(2)	The Physics inspector is not interested in practical work in teaching physics …………………	8	3	13	59	18
(3)	Most students don't interact with the teacher during the laboratory sessions …………………	10	28	3	54	5
(4)	I need more training courses on the practical experiments in the physics curriculum …………	51	26	13	10	0
(5)	I believe that teaching physics is not fulfilled without using physics laboratory ………………	82	18	0	0	0
(6)	I don’t like experiments because their results may contradict with my theoretical knowledge ..	0	8	15	28	49
(7)	Technicians always make the laboratory ready for the experiments ……………………………	21	46	26	5	3
(8)	The number of students in the laboratory is large leaving no room for supervising all pupils …	41	36	5	8	10
(9)	The aims of experiments are explained at the beginning of each session ………………………	67	33	0	0	0
(10)	Presentation of practical work in physics books encourages the application of the experiments	13	28	26	33	0
(11)	Students are encouraged and allowed to participate in laboratory sessions ……………………	45	50	5	0	0
(12)	Safety precautions including safety training are not enough ……………………………………	13	28	23	36	0
(13)	Usually the marks for experimental work are not counted towards students final grade	5	5	8	46	36
(14)	The results of experiments are discussed with pupils at the end of each laboratory session ……	51	41	3	5	0
(15)	The technical support during the laboratory sessions is sufficient ……………………………	31	28	23	15	3
(16)	I feel that the material and devices needed for experiments are adequate and available ……….	8	8	10	39	36

Table 7.5: Responses to Question 5 of the teachers’ survey

The aim of this question was to find out the attitudes of the teachers towards physics laboratory in schools. For instance, the curriculum and the methods in the physics laboratory are seen and how the technician is helpful in the laboratory. The results reveal substantial diversity in the views. There is much that can be seen as positive attitude. For example, all surveyed teachers, as might be expected, believe that teaching physics is not fulfilled without laboratory work and all of them agreed on explaining the aims of the experiments at the beginning of each laboratory session. Similarly, the vast majority (92%) of the sample discusses the results of the experiments with pupils at the end of each laboratory session. The above two points show that the teachers are doing their best in implementing pre-lab and post-lab techniques (see Carnduff and Reid, 2003). More than three quarters of the sample agree that the physics inspector is interested in practical work in teaching physics. Moreover, students are encouraged and allowed to participate in laboratory sessions according to almost all the teachers. There is also a very high proportion of the sample which thinks that the marks for experimental work are counted towards students’ final grade.

Nevertheless, the above results raise serious concerns about physics laboratory in Omani schools. For example, the sample is almost partitioned into two equal groups when it comes to their judgment of the adequacy of the number of experiments in the physics curriculum; 39% says that the number of experiments is adequate while 44% see it the other way around. The remaining 17% are not sure. This might have adverse effect on the efficiency of laboratory teaching.

Looking at student interaction in the laboratory, 59% of the teachers in the sample agree that most students interact with the teacher during the laboratory sessions. Maybe that percentage can be explained with the following observations from the above table:

- Almost 77% from the sample agree that the number of students in the laboratory is large leaving no room for supervising all pupils.
- Only 41% of the sample confirmed that presentation of practical work in physics books encourages the application of the experiments.
- Apparently, safety during lab sessions is a concern as only 41% of the sample agreed that safety precautions including training are sufficient.

The majority of teachers seems confident that the experimental results will not contradict with their theoretical knowledge and that is why about only 8% do not like to do the experiments. However, they send a clear message that the majority (77%) needs more training courses about practical experiments in the physics curriculum.

Moving to technical support, about 67% of the sample believed that technicians always make the laboratory ready for the experiments. Also, 59% confirmed that the technical support during the laboratory sessions is sufficient. However, the main thing here is that 16% of the teachers in the sample believed that, the material and devices needed for the experiments are adequate and available.

7.3 Open questions

Like the student's survey, space for two open questions was provided. The two questions *"What are you looking forward to in your physics laboratory?"* and *"Please give any further comments about your physics laboratory"*. In this section we combined responses from both questions and classify them into four main areas: curricula, teaching style, technical support and attitudes. Some of the important responses to the open questions are now considered.

53% of teachers would like to link the physics laboratory closely to what they described as "theoretical lessons" and for the practical results to be in conformity with the physics curriculum.

A large portion of teachers (37%) would like to increase the number of experiments in the curriculum and the number or the length of the laboratory sessions. They also insisted in better and clearer laboratory books. Around 57% of the teachers made it clear that they prefer to have small number of students where they can supervise the students efficiently while they conduct the experiments in small size groups. This is in agreement with results obtained above.

25% of the surveyed teachers stressed, further, that the physics laboratory helps students acquiring measurement skills, get used to tools and instruments, understand natural phenomena, and becoming more acquainted with scientific methods for problem solving. However, they did not describe clearly what they meant by scientific methods. 89% of the teachers pointed out that the number of physics laboratories should be increased and equipped with all needed materials, tools and technical support. Many (65%) request to have more technicians in the laboratory, get trained on practical work, receive more technical support and acquire the necessary technology to conduct laboratory sessions properly.

7.4 Conclusions

Like students, teachers also hold positive views towards physics laboratory. As they regarded experimental work as useful and important. Nonetheless, their views about the easiness of the experimental show wide variations. This may reflect how the teachers perceive the prescribed experiments or it may reflect how they think the students find them. Perhaps, overall it does indicate some unease over the clarity of laboratory books, availability of resources and technical support. They are also not so convinced that practical work is the best part of physics, this perhaps indicating some of the same concerns as above, and their views on organisation arte less clear. No doubt, they recognise that poor organization can lead to difficulty in conducting the experiments bit is highly unlikely that they are criticising their own organisational abilities. The problem probably lies in the way the curriculum is specified and the resources available.

Teachers prefer that students work in small groups and they supervise them. They also would like to see more laboratory sessions linked closely to class teaching and to teach practical skills. The majority of teachers favour that the students follow the laboratory text book. This may well reflect insecurity in more open experimental approaches.

It is very marked to notice how the teacher's ratings for achievement of laboratory goals lag so far behind the aspirations. This is especially marked for: *Experiments familiarise with important physical measurement techniques, Laboratory work trains making deductions from experimental measurements* and *Experimental work helps learning practical skills*. This may reflect frustration with the way the experimental work is being handled as controlled by the curriculum, the time available, resource limitations, large numbers of students in laboratory sessions, lack of proper training for teachers and technical staff, clarity of practical work presentations in the text books and inadequacy of instruments and tools.

Having looked at the general patterns of responses of both teachers and students, the next chapter investigates the differences between their responses towards physics laboratory. The next chapter also presents the analysis of an interview conducted with physics teachers.

Chapter 8

Students' versus Teachers' Attitudes towards Physics Laboratory

Having looked at the general patterns of responses of both teachers and students in the previous two chapters, this chapter investigates the differences and similarities in their views towards the physics laboratory. An analysis of an interview conducted with physics teachers is also discussed.

8.1 Introduction

In this chapter we attempt to shed some light on the similarities and differences between students' and teachers' responses towards the physics laboratory in Oman. All students' responses were compared with all teachers' responses. Chi-square was used as a contingency test (no control group). The following table shows details of the sample used in this study.

Students	**881**
Teachers	**39**
Total	**920**

Table 8.1: Sample size of students and teachers

Each question is independently analysed and data are presented as percentages for clarity. However, actual frequencies were used in all statistical calculations. The Chi-square value, degrees of freedom used and statistical significance are shown.

The chi-square test is widely used test for analysing statistical data. It is a nonparametric test: no distribution pattern is assumed. It is commonly used as a contingency test where two groups are compared. Each of the groups may have two or more categories which are independent of each other. The data for this comparison are generated from the frequencies in the categories. In this study, the chi-square as a contingency test was used to compare two independent samples: the teacher's responses and the student's responses to see if the responses are statistically different.

Details of the ways of using chi-square are shown in Appendix III. However, with the samples here, there is a problem. Chi-square can handle very different sample sizes. However, the smallness of the teacher sample makes it likely that some categories of responses will fall too low. In these cases, data grouping is required. Inevitably, the sample size will mean that some cases where significant differences are probable cannot be demonstrated statistically.

8.2 Analysis and discussion

8.2.1. Best way of doing experiments

	%	
Category	**Students**	**Teachers**
Teacher does the experiment and students watch the demonstration	11	2
Each single student does the experiment and teacher supervises	28	23
Each group of two or three students does the experiment and teacher supervises	40	56
Groups of more than three students do the experiment and teacher supervises	37	19

Table 8.2: Best way of doing experiments

It looks like the students and teachers see things somewhat differently. Indeed, a chi-square value of 8.8 (df3) is obtained and this is significant at $p < 0.05$. However, the numbers of teachers opting for the first choice and the fourth choice are too low to make the chi-square value safe and grouping is not possible in that the four categories are quite discrete.

Thus, it looks like teachers and students hold similar views as they are both in favour of working in groups while conducting the experiments although it may be that students quite like larger groups. Interestingly, a minority of students still prefer demonstrations.

8.2.2. Practical experiments in physics school laboratory

Question 2: How do you describe the practical work in physics curriculum?									χ^2	**df**	**p**
Useful	Students	61	20	11	2	1	3	Waste of time	0.8	2	ns
	Teachers	67	26	5	3	0	0				
Understandable	Students	38	29	17	8	3	4	Not understandable	5.1	2	ns
	Teachers	51	33	13	3	0	0				
Satisfying	Students	29	25	20	11	7	5	Not satisfying	12.3	2	< 0.01
	Teachers	41	41	13	3	0	0				
Interesting	Students	36	22	18	9	5	7	Boring	11.8	2	< 0.01
	Teachers	39	44	15	3	0	0				
Enjoyable	Students	41	21	14	9	5	6	Not enjoyable	6.3	2	< 0.05
	Teachers	36	39	21	5	0	0				
Easy	Student	16	26	23	13	9	10	Difficult	3.9	4	ns
	Teacher	15	18	26	23	13	5				
Experiments are clear	Student	23	25	23	14	6	7	Experiments are not clear	8.1	2	< 0.05
	Teacher	21	46	23	5	3	3				
Mostly done	Student	37	20	15	9	8	8	Often omitted	9.2	2	< 0.01
	Teacher	59	23	10	8	0	0				
Important	Students	57	19	10	6	3	3	Not important	3.0	2	ns
	Teachers	72	15	13	0	0	0				
Well organized	Students	26	28	22	9	6	7	Not organized	2.0	3	ns
	Teachers	23	33	26	10	3	0				
The best part of physics	Students	33	21	21	11	7	5	The worst part of physics	5.1	3	ns
	Teachers	31	36	18	10	5	0				
Help students be perfect and precise	Students	48	24	14	6	4	2	Does not help students be perfect and precise	1.0	2	ns
	Teachers	46	21	31	3	0	0				
Promote critical thinking	Students	61	17	11	4	3	3	Does not promote critical thinking	18.7	2	< 0.001
	Teachers	36	44	18	3	0	0				

Table 8.3: Practical experiments in physics school laboratory

The opinions of both students and teachers can be regarded as positive in all parts of this question. In all except one question where there are statistically different response patterns, the teachers are more positive. In that question, the students are much more positive in seeing the practical experiments in the physics laboratories as promoting critical thinking. It is possible that students and teachers understand critical thinking differently. It is also possible that the students are gaining more from the laboratories than their teachers expect.

It is noteworthy that teachers regard physics experiments more satisfying, interesting and enjoyable than students. Even though students and teachers agreed that experiments are mostly done, there are still about 16% of the students who believe that the experiments are often omitted. None of the teachers, however, accepts that claim, perhaps in hesitation to admit that they sometimes omit the experimental occasionally to save time.

8.2.3. Best way to use laboratory in teaching physics

Question 2: How do you describe the practical work in physics curriculum?									χ^2	df	p
More frequently	Students	40	22	20	8	4	5	Less frequently	5.8	2	ns
	Teachers	28	39	23	5	3	3				
With pupils doing the experiments	Students	47	19	15	7	3	6	By demonstrations by the teachers	6.2	1	< 0.05
	Teachers	69	23	8	0	0	0				
To learn practical skills	Students	50	19	10	5	3	10	To illustrate ideas	2.2	1	ns
	Teachers	64	31	5	0	0	0				
Linked closely to class teaching	Students	45	17	14	6	5	10	As a separate course	2.8	3	ns
	Teachers	59	15	13	8	5	0				
Following a laboratory textbook	Students	47	20	12	7	4	9	Not following a laboratory textbook	1.8	1	ns
	Teachers	59	33	8	0	0	0				
More quantitative experiments	Student	24	17	18	14	9	16	Less quantitative experiments	8.6	3	< 0.05
	Teacher	28	23	31	13	3	3				

Table 8.4: Best way to use laboratory in teaching physics

The above table compares the students and teachers opinions about the best way to use laboratory in teaching school physics. Both groups want more frequent laboratory session and with the students doing the experiments. They also (students and teachers) agreed that physics laboratory should be used to learn practical skills as opposed to illustrating ideas with teachers perhaps being more confident although it cannot be shown statistically. This is quite typical, the practical skills being thought useful although, in fact, very few students will ever use these practical skills again.

It is worth noting that even though students and teachers would like to see more quantitative experiments, some students (25%) actually prefer the opposite. Surprisingly the students are less keen on doing the experiments themselves, perhaps reflecting fear or uncertainty while their views about the quantitative also differ.

8.2.4. Role of physics laboratory work

			A	N	D	$\chi2$	df	p
(1)	Experimental work stimulates and maintains interest in physics.	Students	60	27	5	4.4	1	< 0.05
		Teachers	72	15	0			
(2)	Experiments illustrate theory and material taught in classes.	Students	70	18	2	1.7	1	ns
		Teachers	82	13	0			
(3)	Experiments help learning theoretical material not taught in the classes.	Students	50	34	10	0.3	2	ns
		Teachers	51	33	13			
(4)	Experimental work helps learning practical skills.	Students	65	21	6	Calculation invalid		
		Teachers	90	8	0			
(5)	Experiments help understanding some physical phenomenon.	Students	51	30	9	0.1	1	ns
		Teachers	56	31	8			
(6)	Experimental work helps solving scientific problems.	Student	53	31	9	0.8	1	ns
		Teacher	64	31	5			
(7)	Experiments familiarize with important physical measurement techniques.	Students	72	15	3	Calculation invalid		
		Teachers	92	3	0			
(8)	Laboratory work trains making deductions from exp'l measurement.	Students	61	22	8	Calculation invalid		
		Teachers	87	8	3			
(9)	Laboratory work allows testing and validating of theoretical concepts.	Student	61	23	6	1.8	1	ns
		Teacher	72	21	0			

Table 8.5: Role of physics laboratory work

At least 50% of the surveyed sample (both students and teachers) agree with the nine reasons given above with some variations. Sometime this percentage goes up to 92%. The reason "Experiments familiarize with important physical measurement techniques" scores the highest teachers percentage of 92% and also highest students' percentage with 72%. Students, also regard "Laboratory work allows testing and validating of theoretical concepts" equally important (72%). In all nine reasons, but the last one, teachers agree more than students with difference as high as 26% in some cases. It is worth noting that reasons "help understanding theoretical material not thought in class" and "help understanding some physical phenomenon" are regarded the least important by both students and teachers.

In every question, the teachers rate the aim more highly than the students. The only question where the response patterns can be shown to be statistically different relates to stimulating and maintaining interest in physics (1). Students are not quite as positive as the teachers.

8.2.5. Attitudes towards physics laboratory

Question 5: In each line, tick the box that most closely reflect your view		*Strongly agree*	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*			
Physics curriculum includes enough practical experiments	Students	20	39	16	17	7	8.8	2	< 0.05
	Teachers	3	36	18	36	8			
Most students don't interact with the teacher during the laboratory sessions	Students	18	31	24	14	10	23.4	1	< 0.001
	Teachers	10	28	3	54	5			
I believe that teaching physics is not fulfilled without using physics laboratory	Students	58	22	8	6	3	7.5	1	< 0.01
	Teachers	82	18	0	0	0			
The aims of experiments are explained at the beginning of each session	Students	54	28	8	5	2	1.9	1	ns
	Teachers	67	33	0	0	0			
Presentation of practical work in physics books encourages the application of the experiments	Student	20	27	23	16	10	1.0	2	ns
	Teacher	13	28	26	33	0			
Students are encouraged and allowed to participate in laboratory sessions	Students	44	31	10	6	4	0.0	1	ns
	Teachers	45	50	5	0	0			
Safety precautions including safety training are not enough	Students	23	19	26	16	12	4.0	3	ns
	Teachers	13	28	23	36	0			
Usually the marks for experimental work are not counted towards students final grade	Student	16	11	20	20	29	19.4	2	< 0.001
	Teacher	5	5	8	46	36			
The results of experiments are discussed with pupils at the end of each laboratory session	Students	45	30	9	6	5	0.2	1	ns
	Teachers	51	41	3	5	0			
Laboratory technical staff do not provide sufficient support while conducting experiments	Students	15	14	18	28	4	18.0	3	< 0.001
	Teachers	31	28	23	15	3			
I feel that the material and devices needed for experiments are adequate and available	Student	14	19	23	16	25	19.5	2	< 0.001
	Teacher	8	8	10	39	36			

Table 8.6: Attitudes towards physics laboratory

Table 8.6 shows the questions on attitudes which were common for students and teachers. It can be seen that, in a number of areas, students and teachers hold very different views. Teachers wish more practical work while there is clearly a greater variety of teacher-student interaction in the eyes of the teachers. Teachers are more convinced than the students that the aims of physics education need laboratory work while there seems to be a considerably discrepancy in views about how laboratory marks are used. Students seem much happier with the level of technician support and this is reflected in the greater wish of teachers to have more resources.

Many of these differences are as expected while in 5 of the items, no statistical differences were apparent.

8.3 Teachers interview results

Interviewing can often be used to validate a questionnaire and to gather information on what the interviewees know, think or like. The opportunity to go deeper into responses is one of the main advantages of the interviews. The interview is also flexible in a way that the interviewer can clarify the questions and ensure that the interviewees understand them (Henreson *et.al,* 1987). In contrast with the survey questions, the interview in this study gave the chance for the interviewer to ask for clarifications about some points and reasons behind some other points.

There was an opportunity to interview physics teachers to gather information about the effectiveness of physics laboratory and to obtain further insights and clarifications into the perception of practical work in school physics. A total number of forty-two physics teachers were interviewed individually, each for about 25 minutes. All interview questions can be found in Appendix II. The interviews covered over four main areas: training of teachers, physics curriculum, technician support in the laboratory and, finally, the attitudes towards physics laboratory. The answers to interviews were built around the following questions:

8.3.1. Training

- *Do you think that teachers are in need for training courses on the practical experiments proposed by physics curriculum in grade 11 and 12? Why?*

Thirty-nine (about 93%) respondents confirmed that teachers are in need of continuous training courses and workshops on the proposed practical experiments in the physics curriculum. This is in conformity with the results obtained from the survey where 77% of the teachers believe that they need training (See the analysis of Question 5 in Chapter 7). In response to this question, teachers heightened some important reasons as to why they need training. These reasons are summarized below in Table 8.7.

Three of the interviewers, however, said that they did not need training in the experiments. Two of them said that was because the experiments are very easy but one of the teachers gave the reason that the technicians should stay with the student to do the experiments, not the teachers. Nonetheless, there is a clear message that teachers want in-service training and for very sensible reasons.

Responses	Reasons
28	To master new experiments and devices in order to get valid results
10	Teacher's preparation institutes do not provide all the skills needed in the laboratory and new teachers require hands-on experience
5	To be able to use different laboratory devices and equipments correctly and to help student care for the equipments
3	To be able to conduct alternative experiments or use alternative tools and devices if the specified ones are not available
3	Sharing experiences between teachers gives teachers greater confidence in the work of their students, especially when the textbook is not helpful

Table 8.7: Reasons behind the need for training

8.3.2. Curricula

- **Do you think that it is useful to have user guide to utilize laboratory tools, material and equipments? Why?**
- **Would you like to see an increase in physics classes in the laboratory? Why?**

The majority wanted a guide book related to the manner of using laboratory tools and instruments in teaching physics. On the other hand, only four teachers rejected the need for a user guide. One of them said that was because the experiments in the curriculum are easy and the attendance at a workshop is enough. Another teacher insisted that it is the technician who needs the manual book, not the teacher. The other two argued that the physics book covers contains enough details about the experiments and there is no need for a separate manual.

The reasons, mentioned by the interviewees, behind the need for a guide book are summarized in Table 8.8 below.

Responses	Reasons
16	To facilitate the performance of some experiments and provide time for the teachers
6	To make sure that the results are valid and thus giving the correct information to students
5	To know how to avoid unsafe usage and minimize the experiments risks
5	The make up for the absence, insufficiency and inexperience of the laboratory technician
2	Sometimes it is difficult to attend training workshops and sometimes they are not sufficient

Table 8.8: Reasons for having a guide book

Moving to the other question, twenty five of the interviewed teachers (about 60%) wanted an increase in the laboratory classes while the remaining was opposed to this. The interviewees who said ‘yes’ gave some reasons that are summarized in Table 8.9.

Responses	Reasons
11	The curriculum is intensive so the teachers do not have enough time for the experiments
8	Some of the experiments take a long time to do and assess so the students need more time to understand them
4	To enable the student to acquire more skills and knowledge in the performance of the experiments

Table 8.9: Reasons for having more laboratory sessions

Of the 40% of teachers who denied the need for extra laboratory sessions, only few gave some reasons. Although none of the teachers mentioned it explicitly, by looking at their timetables, it seems that the driving force for their decision was the fear of being asked to carry extra teaching load as schools are already have a shortage of physics teachers and technicians.

Responses	Reasons
2	It is the teacher’s responsibility to manage the time in the laboratory
1	The semesters are bounded and there is no time for extra classes
1	It is not possible as there is a shortage in the numbers of teachers and technicians
1	The laboratory classes are linked to the theoretical classes in physics

Table 8.10: Reasons for not having more laboratory sessions

8.3.3. Technicians support

- **Do you think the laboratory technicians are helpful and facilitate using the laboratory in the teaching of physics? How?**

Thirty-two of the interviewees said that the laboratory technician effectively collaborates in the laboratory but seven of them reject this while three of them said ‘rarely’. The interviewees who said ‘yes’ gave some clarifications of their opinions and these can be found in Table 8.11.

Responses	How
11	Making the materials ready for the experiment and receives and organizes students
6	Cooperation between him and teachers to explain and simplify the theoretical concepts and providing the teacher with all required tools and materials
4	Watching and helping teachers and students in how to use devices and tools
3	Giving the students the opportunity to borrow materials for the implementation of projects related to curriculum or emerging from it
2	They are prepared to find alternative experiments if there are difficulties in the current one
2	Through the work of some of the posters and leaflets for the laboratory and the establishment of some of the workshop

Table 8.11: How technicians help in the physics laboratory

Some of the interviewed teachers pointed out that technicians cooperate effectively with the teacher but not with students. If the experiments were conducted in a demonstration manner then the cooperation between the technician and students is expected to be minimized.

8.3.4. Attitudes towards physics laboratory

- **Do you believe that teaching physics is not fulfilled without the utilization of physics laboratory? Why?**

The majority of the interviewees regarded laboratory work as an essential part of physics teaching and learning. Thirty-eight of them (about 90%) indicated this and gave varied reasons. These are summarized in Table 8.12

Responses	Reasons
14	The practical side refines the theoretical side, therefore development of student thinking.
8	Practical aspect is important in the development of student performance and in understanding the physics curriculum.
4	Physics primarily is an experimental science and teaching physics abstractly leaves students uncertain about some theories.
4	It is important for students to experience reaching conclusions and establishing facts based on experimental results.
3	Experimental work is important to explain and understand some physical phenomena and some difficult theoretical concepts.

Table 8.12: Reasons for using laboratory in teaching physics

It is worth noting that the majority of the teachers (14 responses) believe that teaching physics cannot be fulfilled without laboratory work due to the fact practical work refines the theoretical side. This is quite different from the opinions of 95% of students who believe (according to Question 4 on page 70) that laboratory work must be used to illustrate ideas.

Only four of the interviewed teachers thought that teaching physics is fulfilled without utilization of the physics laboratory. Some of them argued that physics theories can be developed and understood without practical side, while others argued that physics laboratory is not important for students who do not intend to study physics further. Another important observation was to replace the conventional physics labs with computer-based labs.

8.4 Conclusions

It is clear from the above analysis that both students and teachers hold positive views about the physics laboratory. Even though this might be more of an aspiration rather than reality, it shows a very good potential towards physics laboratory work in Omani schools.

Interviews of more than forty physics teachers show strong conformity between the teacher’s survey results and the results obtained from these interviews. The interviews also gave teachers a chance to express different concerns related to physics curriculum, technical support, training and attitudes related to the use of laboratory in teaching school physics.

Chapter 9

Conclusions and Future Work

9.1 Overview of the project

Learning science at school level is not the discovery or construction of ideas that are new or unknown. Rather it is making what others already know your own. Miller (2004) expressed this sentiment and this is true in Omani schools. Therefore, students need the opportunity to manipulate ideas, sufficient equipment and materials to do the experiments, adequate time, frequent help from the technicians and teachers and good environment to do the experiments. If the opportunities to do this are offered, then attitudes towards the whole laboratory experience may be positive.

Laboratory work has been central to school science instruction for over a century (Jenkins, 1998; Nott, 1997). In this study, laboratory work refers to teaching and learning activities during which the teacher and or students perform experiments or physically manipulate and observe objects and materials.

There is a vast amount of research literature about attitudes in different science topics. Areas of interest include existence of attitudes, their formation, change, relative stability, nature, measurement and development. Attitudes involve cognitive, affective and behavioural elements held in long-term memory and the key feature is that attitudes will always involve some kind of evaluative dimension. Attitudes are important in that they lead to the development of values and world views and, even more importantly, they will influence behaviour.

According to Katz (1960) and Reid (2003), the purpose of attitudes in an educational context is to help the student to make sense of himself, the world around him, and relationships. Thus, if the students see the laboratory work help them to understand the natural world around and bring their ideas and understandings closer to those of the scientific community, then their attitude towards practical work may will be positive. That means they may really gain great benefits from their work during a laboratory session. However, if their attitudes are negative, then it is much more difficult to motivate and stimulate the students to work effectively and efficiently.

Within the framework of developing education in the Sultanate of Oman, Basic Education has been defined as *unified education provided by the state to all the children in the Sultanate at the age of education.* It lasts 10 years and provides basic educational needs as to information, aspects of knowledge and skills, as well as the development of objectives and values that enable the learners to continue in education and training according to their abilities and interests (Ministry of Education, 2001). The ten years of basic education is followed by 2 years of secondary education (Grades 11 and 12). It is composed of both compulsory and elective subjects. It leads to the General Certificate in General Education and to the General Education Diploma in Post-Basic Education (Ministry of Education, 2009). The curricula have been changed totally to include practical as well as theory. Furthermore, curricula seek to concentrate on problem solving, on world issues and on how to deal with real life situations.

The Ministry of Education in Oman considered the development of the laboratory in school education right from the 1970s. There is a need to place emphasis on students being able to design and carry out experiment as an integral part of their courses in physics and to begin to appreciate the way scientific knowledge is gained and how the world of experimental physics seeks to solve problems.

The major goal of this study is to explore students' perceptions of laboratory work in physics in after-basic education schools in Oman. Another thing is to achieve a general idea of development in Omani students' attitudes about physics laboratory from age 16 to 17 (grade 11 and 12). Ultimately, the overall aim of this study is to enhance laboratory learning in Oman, based on sound pedagogical evidence, particularly in the context of teachers at secondary schools.

9.2 Adopted methodology

This study focuses on exploring students' (aged 16 and 17) and teachers' attitudes towards physics laboratory in Oman. At first, education in Oman was reviewed. Then, Physics laboratories in Omani Schools, learning in general, learning in laboratories and developments of attitudes are discussed. Later on, the survey and interview analysis are established.

The aim is to gather insights about students' and teachers' views about physics laboratory, and how students and teachers perceptions differ.

The attitudes of 881 Omani students and 39 teachers were explored using a survey designed in line with the methods of Osgood *et. al* (1957) and Likert (1932) (see Chapter 5 for more details). The sample came from 29 public Omani schools in Al-Dahera Region. Each survey took about 20 minutes to be completed and it was emphasised to the students that the results will be used solely for scientific research and shall not affect the student's grades. Data were then collected in two spreadsheets (one for students and the other for teachers) and summarized. Each question was then separately analysed to give a clear and accurate picture (Reid, 2006).

It is known that finding the attitudes of an individual with an acceptable degree of accuracy is not feasible using the available techniques. Therefore, the aim of this study was to present a picture of the attitudes based on the patterns of responses of large samples. This allows investigating the trends with students and teachers differences. The results are interpreted in terms of the position of the physics laboratory in Omani Schools.

The analysis of the surveys evolved in two directions. First the general patterns of responses of both teachers and students were presented. Second, the differences and similarities between teachers' and students' responses towards physics laboratory were investigated.

Furthermore, more than forty physics teachers were interviewed individually, each for about 25 minutes. The interviews also gave teachers a chance to express different concerns related to physics curriculum, technical support, training and attitudes related to the use of laboratory in teaching school physics.

9.3 Limitations of the study

The survey relied on some questions used in previous studies (see for example, Al-Madani, 2004; Suzuki, 2007) and the validity of these questions was well established. Since the question of validity is important for all surveys, the surveys used in this study were carefully checked by experienced teachers. However, there is no assurance that the target audience responded exactly in way that reflects the attitudes they really had. Nonetheless, interviews with more than forty teachers offered valuable insights and confirm the general picture painted by the surveys. Time limitations however, prevented widening the study to consider others outside the target group of teachers and students.

To maintain a high level of reliability, the number of students and teachers used is the study is very large. Being drawn from typical schools, the sample did reflect the population under consideration. Since the aim is to paint an overall picture of patterns and trends, no attempt has been made to evaluate the attitudes of individual students and teachers. Moreover, there is no certainty that the students answered it honestly although there is no evidence that they were not being honest in that their responses made sense the context of Oman.

9.4 General findings and implications

Results of the students' survey show positive attitudes towards laboratory work in the physics curriculum. All regarded experimental work as essential part without which teaching physics cannot be fulfilled. Despite this positive attitude towards physics laboratory, there have been some issues and concerns that should be addressed to ensure proper laboratory work.

Contrary to the dominant way of conducting experiments (by demonstration); individual and small group work is preferred by students. Even though students believe that experiments are not clear or well organized at times, they have no doubt that laboratory work is useful and help promoting critical thinking.

Students would like the experimental work to be closely linked to their class teaching and to be able to learn practical skills. They also demand to have more laboratory sessions, and to use a dedicated laboratory book.

As to why laboratory is part of most physics curriculum, students think that was because the “experiments familiarize with important physical measurement techniques”. They also regarded the reason “experiments illustrate theory and material thought in classes” equally important.

Students seem satisfied with the pre and post lab activities and they hold positive views towards their physics teachers. Moreover, they are also confident that they find the laboratory ready to conduct the experiments. However, they were not happy with the presentation of the practical experiments in physics book and there in uncertainty whether the marks for practical work would be included in their final grades. They also raised some concerns about the technical support while they do their experiments. This could be because the technicians cannot cope with large number of students to provide sufficient support. Inadequacy and unavailability of material and devices required by some experiments was also a major issue that has been pointed out by the majority of students.

Like students, teachers also hold positive views towards physics laboratory and they regarded experimental work as useful and important. Nonetheless, their views about the easiness of the experimental show wide variations. This may reflect how the teachers perceive the prescribed experiments or it may reflect how they think the students find them. Perhaps, overall it does indicate some unease over the clarity of laboratory books, availability of resources and technical support. They are also not so convinced that practical work is the best part of physics, this perhaps indicating some of the same concerns as above, and their views on organisation are less clear. No doubt, they recognise that poor organization can lead to difficulty in conducting the experiments bit is highly unlikely that they are criticising their own organisational abilities. The problem probably lies in the way the curriculum is specified and the resources available.

Teachers prefer that students work in small groups and they supervise them. They also would like to see more laboratory sessions linked closely to class teaching and to teach practical skills. The majority of teachers favour that the students follow the laboratory text book. This may well reflect insecurity in more open experimental approaches.

It is very marked to notice how the teacher's ratings for achievement of laboratory goals lag so far behind the aspirations. This is especially marked for: *Experiments familiarize with important physical measurement techniques, Laboratory work trains making deductions from experimental measurements* and *Experimental work helps learning practical skills*. This may reflect frustration with the way the experimental work is being handled as controlled by the curriculum, the time available, resource limitations, large numbers of students in laboratory sessions, lack of proper training for teachers and technical staff, clarity of practical work presentations in the text books and inadequacy of instruments and tools.

Chi-square analyses shows that both students and teachers hold positive views about the physics laboratory. Although this might be more of an aspiration rather than reality, it shows a very good potential towards physics laboratory in Omani schools.

Interviews with more than forty physics teachers show strong conformity between teachers' survey results and the results obtained from these interviews. The interviews also gave teachers a chance to express different concerns related to the physics curriculum, technical support, training and attitudes related to the use of laboratory in teaching school physics

9.5 Future work

It would be useful to interview a sample of students to be able to know why they choose their answers. This would test the validity of the conclusions drawn from the surveys. Moreover, it would be interesting to look at how attitudes towards science laboratory develop with age: perhaps extending this study to cover younger age groups (for example grades 6 to 10).

It has been shown in other studies (see for example Suzuki, 2007; Al-Gharibi, 2008) that boys and girls have different perceptions related to their scientific and social studies in different contexts. This study, however, does not distinguish between students' genders. It might be good to explore how boys and girls look at their laboratory work in physics.

In this study, opinions of teachers with different experiences were surveyed. Due to lack of time, it was not possible to see how the teacher's experience may affect his/her perception towards laboratory work and teaching physics in general. Therefore, an important extension to this study would be to compare between attitudes of teachers with different number of years of experience. The aim would be to investigate whether teachers' attitudes towards physics laboratory decline or otherwise increase in Omani schools in relation to teachers' experience.

The Ministry of Education in Oman laid strong emphasis on the use of information technology in experimental work. Therefore, the Ministry developed a project for the electronic laboratory as an integral practical system for capturing data and analyzing results, for physics, chemistry, biology and general science, using the computer. The Ministry aims to implement this project gradually in some selected secondary schools and then evaluate the results. Depending on the outcome of the results, the programme will be extended to all other schools (Ministry of Education, 2006). Another avenue of potential future extension to this study would be to compare between students views towards conventional labs and computer-based labs.

This study shed some light into the students' attitudes towards the laboratory work in physics in Oman. It is hoped that the outcomes of this study will be useful to the education system in Oman. It is also evident that much more research is needed to study the different aspects of laboratory work in physics curriculum in Oman.

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Appendix I

Surveys used

Physics Laboratory Work
What do you think?

Dear student,

This questionnaire intends to find your opinions about laboratory work in physics: to what extent it satisfies your interest and enthusiasm. Your answers will be treated: they will not affect your school grades in any way. Please take your time to answer the following questions in the most accurate way you can.

School Name: …………………………………………… **Class:** ……………………………..

(1) In the left column indicate how do you have been doing the experiments in the physics lab.

And in the right column indicate the best way to conduct the experiments?

How I've been doing experiments		Best way of doing experiments
☐	The teacher do the experiment and the students watch the demonstration	☐
☐	Each single student do the experiment and the teacher supervises	☐
☐	Each group of two or three students do the experiment and the teacher supervises	☐
☐	Each group of more than three students do the experiment and the teacher supervises	☐

This is an Example: How do you describe a "racing car":

Quick	☑	☐	☐	☐	☐	☐	Slow
Important	☐	☐	☑	☐	☐	☐	Not important
Safe	☐	☐	☐	☐	☑	☐	dangerous

The position of the tick between the word pairs shows that you describe the car as ***very*** quick, ***slightly*** more important than unimportant and ***quite*** dangerous.

Use the same method of ticking to answer the questions 3 and 4 below.

(2) How do you describe the practical work in physics curriculum? ***Tick one box only in each line as shown above***

Useful	☐	☐	☐	☐	☐	☐	Waste of time
Understandable	☐	☐	☐	☐	☐	☐	Not understandable
Satisfying	☐	☐	☐	☐	☐	☐	Not satisfying
Interesting	☐	☐	☐	☐	☐	☐	Boring
Enjoyable	☐	☐	☐	☐	☐	☐	Not enjoyable
Easy	☐	☐	☐	☐	☐	☐	Difficult
Experiments are clear	☐	☐	☐	☐	☐	☐	Experiments are not clear
Mostly done	☐	☐	☐	☐	☐	☐	Often omitted
Important	☐	☐	☐	☐	☐	☐	Not important
Well organized	☐	☐	☐	☐	☐	☐	Not organized
The best part of physics	☐	☐	☐	☐	☐	☐	The worst part of physics
Help students be perfect and precise	☐	☐	☐	☐	☐	☐	Does not help students be perfect and precise
Promote critical thinking	☐	☐	☐	☐	☐	☐	Does not promote critical thinking

(3) What is the best way to use the physics laboratories in teaching? ***Tick one box only in each line as shown above***

More frequently	☐	☐	☐	☐	☐	☐	Less frequently
With pupils doing the experiments	☐	☐	☐	☐	☐	☐	By demonstrations by the teachers
To learn practical skills	☐	☐	☐	☐	☐	☐	To illustrate ideas
Linked closely to class teaching	☐	☐	☐	☐	☐	☐	As a separate course
Following a laboratory textbook	☐	☐	☐	☐	☐	☐	Not following a laboratory textbook
More quantitative experiments	☐	☐	☐	☐	☐	☐	Less quantitative experiments

(4) According to previous research, here are several reasons why physics laboratory work is part of most physics lessons.

If you agree with the statement, tick the appropriate box (Agree, Not sure, Disagree)

If you think you have achieved this aim, tick the box under "Achieved".

		Agree	Not Sure	Disagree		Achieved
(1)	Experimental work stimulates and maintains interest in physics ……..…….					
(2)	Experiments illustrate theory and material taught in classes …………………					
(3)	Experiments help learning theoretical material not taught in the classes ….					
(4)	Experimental work helps learning practical skills ……………..……………					
(5)	Experiments help understanding some physical phenomenon …………..					
(6)	Experimental work helps solving scientific problems …..………………......					
(7)	Experiments familiarize with important physical measurement techniques					
(8)	Laboratory work trains making deductions from experimental measurements					
(9)	Laboratory work allows testing and validating theoretical concepts ………					

(5) In each line, tick the box that most closely reflect your view

		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
(1)	Physics curriculum includes enough practical experiments	☐	☐	☐	☐	☐
(2)	I think our teacher is not interested in the practical work and experiments	☐	☐	☐	☐	☐
(3)	Most students don't interact with the teacher during the laboratory sessions	☐	☐	☐	☐	☐
(4)	Our teacher conducts the experiments himself and does not let the students participate	☐	☐	☐	☐	☐
(5)	I believe that teaching physics is not fulfilled without using physics laboratory	☐	☐	☐	☐	☐
(6)	Physics teacher uses various teaching methods inside the physics laboratory	☐	☐	☐	☐	☐
(7)	When I came to the physics laboratory I find it ready to do the experiments	☐	☐	☐	☐	☐
(8)	The teacher moves around in the lab and supervises students while they do the experiments	☐	☐	☐	☐	☐
(9)	The aims of experiments are explained at the beginning of each session	☐	☐	☐	☐	☐
(10)	Presentation of practical work in physics books encourages the application of the experiments	☐	☐	☐	☐	☐
(11)	Students are encouraged and allowed to participate in laboratory sessions	☐	☐	☐	☐	☐
(12)	Safety precautions including safety training are not enough	☐	☐	☐	☐	☐
(13)	Usually the marks for experimental work are not counted towards students final grad	☐	☐	☐	☐	☐
(14)	The results of experiments are discussed with pupils at the end of each laboratory session	☐	☐	☐	☐	☐
(15)	Laboratory technical staff do not provide sufficient support while conducting the experiments	☐	☐	☐	☐	☐
(16)	I feel that the material and devices needed for experiments are adequate and available	☐	☐	☐	☐	☐

(6) What are you looking forward in your physics laboratory? *(Use back of the sheet for extra space)*

(7) Please give any further comments about your physics laboratory? *(Use back of the sheet for extra space)*

Thank you for your help
Best wishes in your studies

Physics Laboratory Work
What do you think?

Dear teacher,
This questioner intends to identify your opinion about laboratory work and to what extent it would help in teaching physics. Your answers will be treated confidentially as they shall solely be used for research purposes. Please take your time to answer the following questions in the most accurate way you can.

School Name: ………………………………………… **Classes thought :** ……………………………

Please indicate your teaching experience:

☐ Less than 3 years ☐ 3-7 years ☐ 8-15 years ☐ More than 15 years

(1) In the left column indicate how do you always ask students to do the experiments in the physics lab.
And in the right column indicate the best way to conduct the experiments?

How I've been doing experiments		Best way of doing experiments
☐	The teacher do the experiment and the students watch the demonstration	☐
☐	Each single student do the experiment and the teacher supervises	☐
☐	Each group of two or three students do the experiment and the teacher supervises	☐
☐	Each group of more than three students do the experiment and the teacher supervises	☐

This is an Example: How do you describe a "racing car":

Quick	☑	☐	☐	☐	☐	☐	Slow
Important	☐	☐	☑	☐	☐	☐	Not important
Safe	☐	☐	☐	☐	☑	☐	dangerous

The position of the tick between the word pairs shows that you describe the car as ***very*** quick, ***slightly*** more important than unimportant and ***quite*** dangerous.

Use the same method of ticking to answer questions 2 and 3 below.

(2) How do you describe the practical work in physics curriculum? ***Tick one box only in each line as shown above***

Useful	☐	☐	☐	☐	☐	☐	Waste of time
Understandable	☐	☐	☐	☐	☐	☐	Not understandable
Satisfying	☐	☐	☐	☐	☐	☐	Not satisfying
Interesting	☐	☐	☐	☐	☐	☐	Boring
Enjoyable	☐	☐	☐	☐	☐	☐	Not enjoyable
Easy	☐	☐	☐	☐	☐	☐	Difficult
Experiments are clear	☐	☐	☐	☐	☐	☐	Experiments are not clear
Mostly done	☐	☐	☐	☐	☐	☐	Often omitted
Important	☐	☐	☐	☐	☐	☐	Not important
Well organized	☐	☐	☐	☐	☐	☐	Not organized
The best part of physics	☐	☐	☐	☐	☐	☐	The worst part of physics
Help students be perfect and precise	☐	☐	☐	☐	☐	☐	Does not help students be perfect and precise
Promote critical thinking	☐	☐	☐	☐	☐	☐	Does not promote critical thinking

(3) What is the best way to use the physics laboratories in teaching? ***Tick one box only in each line as shown above***

More frequently	☐	☐	☐	☐	☐	☐	Less frequently
With pupils doing the experiments	☐	☐	☐	☐	☐	☐	By demonstrations by the teachers
To learn practical skills	☐	☐	☐	☐	☐	☐	To illustrate ideas
Linked closely to class teaching	☐	☐	☐	☐	☐	☐	As a separate course
Following a laboratory textbook	☐	☐	☐	☐	☐	☐	Not following a laboratory textbook
More quantitative experiments	☐	☐	☐	☐	☐	☐	Less quantitative experiments

(4) According to previous research, here are several reasons why physics laboratory work is part of most physics lessons.

If you agree with the statement, tick the appropriate box (Agree, Not sure, Disagree)

If you think you have achieved this aim, tick the box under "Achieved".

		Agree	**Not Sure**	**Disagree**		**Achieved**
(1)	Experimental work stimulates and maintains interest in physics …………………	☐	☐	☐		☐
(2)	Experiments illustrate theory and material taught in classes …………………	☐	☐	☐		☐
(3)	Experiments help learning theoretical material not taught in the classes ….	☐	☐	☐		☐
(4)	Experimental work helps learning practical skills ……………………………	☐	☐	☐		☐
(5)	Experiments help understanding some physical phenomenon …………..	☐	☐	☐		☐
(6)	Experimental work helps solving scientific problems ………………………	☐	☐	☐		☐
(7)	Experiments familiarize with important physical measurement techniques	☐	☐	☐		☐
(8)	Laboratory work trains making deductions from experimental measurements	☐	☐	☐		☐
(9)	Laboratory work allows testing and validating theoretical concepts ………	☐	☐	☐		☐

(5) In each line, tick the box that most closely reflect your view		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
(1)	Physics curriculum includes enough practical experiments ……………………………	☐	☐	☐	☐	☐
(2)	The Physics inspector is not interested in practical work in teaching physics …………	☐	☐	☐	☐	☐
(3)	Most students don't interact with the teacher during the laboratory sessions ……………	☐	☐	☐	☐	☐
(4)	I need more training courses on the practical experiments in the physics curriculum ……	☐	☐	☐	☐	☐
(5)	I believe that teaching physics is not fulfilled without using physics laboratory …………	☐	☐	☐	☐	☐
(6)	I don't like experiments because their results may contradict with my theoretical knowledge	☐	☐	☐	☐	☐
(7)	Technicians always make the laboratory ready for the experiments ………………………	☐	☐	☐	☐	☐
(8)	The number of students in the laboratory is large leaving no room for supervising all pupils	☐	☐	☐	☐	☐
(9)	The aims of experiments are explained at the beginning of each session ………………	☐	☐	☐	☐	☐
(10)	Presentation of practical work in physics books encourages the application of the experiments	☐	☐	☐	☐	☐
(11)	Students are encouraged and allowed to participate in laboratory sessions ……………	☐	☐	☐	☐	☐
(12)	Safety precautions including safety training are not enough ……………………………	☐	☐	☐	☐	☐
(13)	Usually the marks for experimental work are not counted towards students final grad	☐	☐	☐	☐	☐
(14)	The results of experiments are discussed with pupils at the end of each laboratory session	☐	☐	☐	☐	☐
(15)	The technical support during the laboratory sessions is sufficient …………………………	☐	☐	☐	☐	☐
(16)	I feel that the material and devices needed for experiments are adequate and available …	☐	☐	☐	☐	☐

(6) What are you looking forward in your physics laboratory? *(Use back of the sheet for extra space)*

(7) Please give any further comments about the physics laboratory? *(Use back of the sheet for extra space)*

Thank you for your help
Best wishes in your teaching

استبانة حول مختبر مادة الفيزياء

عزيزي الطالب / عزيزتي الطالبة ،
يهدف هذا الإستبيان إلى إستطلاع رأيك حول مختبر مادة الفيزياء، وأهميته في العملية التعليمية. نتائج الإستبيان ستكون فقط لغرض البحث العلمي وستعامل كل البيانات بسرية كاملة ولن تؤثر مطلقا على نتائجك الدراسية. الرجاء قراءة كل سؤال بتمعن والإجابة عليه حسب وجهة نظرك الشخصية بالطريقة المبينة إزاء كل سؤال.

اسم المدرسة .... الصف الدراسي: ....

(1) في العمود الأيمن ضع علامة صح على الطريقة التي كنت تقوم بها بالتجارب فيما مضى من مختبرات الفيزياء.
وفي العمود الأيسر ضع علامة صح على الطريقة التي ترى أنها هي الأنسب للقيام بهذه التجارب.

كيف كنت تقوم بالتجارب		الطريقة الأنسب للقيام بالتجارب
☐	المعلم يقوم بالتجربة والطلاب يتابعون	☐
☐	كل طالب يقوم بالتجربة بنفسه والمعلم يشرف عليه	☐
☐	كل مجموعة من طالبين او ثلاثة يقومون بالتجربة والمعلم يشرف عليهم	☐
☐	كل مجموعة تتكون من أكثر من ثلاث طلاب يقومون بالتجربة والمعلم يشرف عليهم	☐

هذا مثال فقط: كيف تصف سيارة السباق؟

سريعة	☑	☐	☐	☐	☐	☐	بطيئة
مهمة	☐	☐	☑	☐	☐	☐	غير مهمة
آمنة	☐	☐	☐	☐	☑	☐	خطيرة

موقع علامة الصح بين العبارتين في كل سطر يوضح ان سيارة السباق **سريعة جداً** ، وهي مهمة **قليلا** ، لكنها **خطيرة إلى حد ما**.

استخدم نفس الأسلوب للإجابة على السؤالين التاليين رقم 3 ورقم 4.

(2) كيف تصف التجارب العملية في مادة الفيزياء؟ ***في كل سطر ضع إشارة صح في مربع واحد فقط من المربعات الستة كما في المثال أعلاه***

ذات فائدة كبيرة	☐	☐	☐	☐	☐	☐	فقط مضيعة للوقت
قابلة للفهم	☐	☐	☐	☐	☐	☐	غير قابلة للفهم
تلبي حاجات الطالب	☐	☐	☐	☐	☐	☐	لا تلبي حاجات الطالب
تثير ميول الطالب	☐	☐	☐	☐	☐	☐	لا تثير ميول الطالب
يستمتع الطالب بها	☐	☐	☐	☐	☐	☐	لا يستمتع الطالب بها
يسهل اداءها على الطالب	☐	☐	☐	☐	☐	☐	يصعب على الطالب القيام بها
واضحة	☐	☐	☐	☐	☐	☐	غير واضحة
قمنا بأغلبها	☐	☐	☐	☐	☐	☐	لم نقم بأغلبها
مهمة لتعليم الطالب	☐	☐	☐	☐	☐	☐	غير مهمة لتعليم الطالب
منظمة بشكل جيد	☐	☐	☐	☐	☐	☐	غير منظمة بشكل جيد
أفضل جزء في مادة الفيزياء	☐	☐	☐	☐	☐	☐	أسوأ جزء في مادة الفيزياء
تساعد الطالب على الدقة والإتقان	☐	☐	☐	☐	☐	☐	لا تساعد الطالب على الدقة أو الإتقان
تطور مهارات التفكير لدى الطالب	☐	☐	☐	☐	☐	☐	لا تطور مهارات التفكير لدى الطالب

(3) ما هي الطريقة الأفضل لإستخدام المختبر في مادة الفيزياء؟ ***في كل سطر ضع إشارة صح في مربع واحد فقط كما في المثال أعلاه***

الإكثار من حصص المختبر	☐	☐	☐	☐	☐	☐	التقليل من حصص المختبر
الطلبة يقومون بالتجربة بأنفسهم	☐	☐	☐	☐	☐	☐	الطلبة ينظرون للمدرس وهو يقوم بالتجربة
استغلال المختبر لتعلم المهارات العملية	☐	☐	☐	☐	☐	☐	استخدام المختبر لتوضيح المادة العلمية
يجب ان يرتبط المختبر بالحصص النظرية	☐	☐	☐	☐	☐	☐	يجب ان يدرس المختبر كمادة مستقلة
يجب استخدام كتاب المختبر	☐	☐	☐	☐	☐	☐	لا داعي لإستخدام كتاب المختبر
الإكثار من التجارب ذات النتائج الرقمية	☐	☐	☐	☐	☐	☐	عدم الإكثار من التجارب ذات النتائج الرقمية

(4) تجد أدناه بعض الأهداف المرجو تحقيقها من استخدام المختبر في تدريس مادة الفيزياء حسب ما ذكر بعض الباحثين. حدد مدى موافقتك على كل هدف بوضع إشارة صح في المربع المناسب (أوافق بشدة ــ غير متأكد – لا أوافق). وإذا كنت تعتقد انك حققت هذا الهدف، فضع إشارة صح أمام مربع "تحقق لي"

		أوافق بشدة	غير متأكد	لا أوافق	تحقق لي
(1)	التجارب تشجع و تثير الإهتمام بمادة الفيزياء وتحبب إليها	☐	☐	☐	☐
(2)	التجارب توضح وتبسط النظريات العلمية المشروحة في الحصص	☐	☐	☐	☐
(3)	التجارب تساعد على تعلم بعض النظريات التي لم يتم التطرق إليها في الحص	☐	☐	☐	☐
(4)	التجارب في مادة الفيزياء تساعد على تعلم بعض المهارات العملية	☐	☐	☐	☐
(5)	التجارب تساعد على فهم بعض الظواهر الكونية والطبيعية	☐	☐	☐	☐
(6)	التجارب تساعد على إيجاد حلول للمسائل العلمية	☐	☐	☐	☐
(7)	التجارب تساعد على تعلم استخدام أدوات القياس المختلفة	☐	☐	☐	☐
(8)	المختبر يدرب على استخلاص الإستنتاجات من نتائج التجارب	☐	☐	☐	☐
(9)	المختبر يساعد على التحقق من صحة الأفكار النظرية	☐	☐	☐	☐

(5) قيم العبارات التالية حسب وجهة نظرك بوضع إشارة صح في المربع المناسب.

		أوافق بشدة	أوافق	غير متأكد	أعارض	أعارض بشدة
(1)	يحتوي منهج الفيزياء على عدد كافي من التجارب العملية	☐	☐	☐	☐	☐
(2)	أشعر أن المعلم لا يهتم بالمختبر والتجارب العملية	☐	☐	☐	☐	☐
(3)	معظم الطلاب لا يتفاعلون مع المعلم أثناء مختبر الفيزياء	☐	☐	☐	☐	☐
(4)	المدرس يقوم بالتجارب بنفسه ولا يسمح للطلاب بالمشاركة في أداءها	☐	☐	☐	☐	☐
(5)	أعتقد أن تدريس الفيزياء بشكل صحيح لا يكتمل بدون استخدام المختبر	☐	☐	☐	☐	☐
(6)	المدرس يستخدم أساليب متنوعة أثناء تدريسنا في مختبر الفيزياء	☐	☐	☐	☐	☐
(7)	عندما نحضر للمختبر نجده دائما مجهز للقيام بالتجارب المقررة	☐	☐	☐	☐	☐
(8)	يقوم المعلم بالتجول بين الطلاب ويشرف على أداءهم للتجارب	☐	☐	☐	☐	☐
(9)	يقوم المعلم بشرح أهداف كل تجربة قبل القيام بها عمليا	☐	☐	☐	☐	☐
(10)	التجارب مشروحة في الكتاب بطريقة سهلة وتشجع على القيام بالتجارب	☐	☐	☐	☐	☐
(11)	المعلم يشجع الطلاب ويسمح لهم بالمشاركة الفعلية في تنفيذ التجارب	☐	☐	☐	☐	☐
(12)	إجراءات السلامة (مثل مخارج وطفايات الحريق) غير كافية في المختبرات	☐	☐	☐	☐	☐
(13)	درجات المختبر لا تحتسب في الدرجة الكلية للطالب في مادة الفيزياء	☐	☐	☐	☐	☐
(14)	في نهاية كل تجربة يقوم المعلم بمناقشة نتائجها مع الطلاب	☐	☐	☐	☐	☐
(15)	فنيو المختبر لا يقدمون المساعدة الكافية أثناء مختبر الفيزياء	☐	☐	☐	☐	☐
(16)	أعتقد ان المواد والأجهزة الازمة للقيام بالتجارب كافية ومتوفرة في المختبر	☐	☐	☐	☐	☐

(6) مالذي تطمح إلى تحقيقه من من خلال مختبر مادة الفيزياء؟ (*استخدم ظهر الورقة كمساحة إضافية*)

(7) إذا كان لديك اي ملاحظات أخرى حول مختبر مادة الفيزياء ، ارجو أن تكتبها هنا. (*استخدم ظهر الورقة كمساحة إضافية*)

شكرا لك على تعاونك معنا ونتمنى لك عاما دراسيا موفقا

استبانة حول مختبر مادة الفيزياء

عزيزي المعلم / عزيزتي المعلمة ،

يهدف هذا الإستبيان إلى إستطلاع رأيك حول مختبر مادة الفيزياء، وأهميته في العملية التعليمية. نتائج الإستبيان ستكون فقط لغرض البحث العلمي وستعامل كل البيانات بسرية كاملة. الرجاء قراءة كل سؤال بتمعن والإجابة عليه حسب وجهة نظرك الشخصية بالطريقة المبينة إزاء كل سؤال.

اسم المدرسة: .... **الفصول التي تدرسها:** ....

سنوات الخبرة في حقل التعليم:

☐ أقل من 3 سنوات ☐ من 3 إلى 7 سنوات ☐ من 8 إلى 15 سنة ☐ أكثر من 15 سنة

(1) في العمود الأيمن ضع علامة صح على الطريقة التي كنت تدير بها التجارب فيما مضى من مختبرات الفيزياء.
وفي العمود الأيسر ضع علامة صح على الطريقة التي ترى أنها هي الأنسب للقيام بهذه التجارب.

كيف كنت تقوم بالتجارب		الطريقة الأنسب للقيام بالتجارب
☐	المعلم يقوم بالتجربة والطلاب يتابعون	☐
☐	كل طالب يقوم بالتجربة بنفسه والمعلم يشرف عليه	☐
☐	كل مجموعة من طالبين او ثلاثة يقومون بالتجربة والمعلم يشرف عليهم	☐
☐	كل مجموعة تتكون من أكثر من ثلاث طلاب يقومون بالتجربة والمعلم يشرف عليهم	☐

هذا مثال فقط: كيف تصف سيارة السباق؟

سريعة	√											بطيئة	موقع علامة الصح بين العبارتين في كل سطر يوضح ان سيارة السباق **سريعة جداً** ، وهي **مهمة قليلاً** ، لكنها **خطيرة إلى حد ما**.
مهمة					√							غير مهمة	
آمنة									√			خطيرة	

استخدم نفس الأسلوب للإجابة على السؤالين التاليين رقم 3 ورقم 4.

(2) كيف تصف التجارب العملية في مادة الفيزياء؟ ***في كل سطر ضع إشارة صح في مربع واحد فقط من المربعات الستة كما في المثال أعلاه***

ذات فائدة كبيرة	☐	☐	☐	☐	☐	☐	فقط مضيعة للوقت
قابلة للفهم	☐	☐	☐	☐	☐	☐	غير قابلة للفهم
تلبي حاجات الطالب	☐	☐	☐	☐	☐	☐	لا تلبي حاجات الطالب
تثير ميول الطالب	☐	☐	☐	☐	☐	☐	لا تثير ميول الطالب
يستمتع الطالب بها	☐	☐	☐	☐	☐	☐	لا يستمتع الطالب بها
يسهل اداءها على الطالب	☐	☐	☐	☐	☐	☐	يصعب على الطالب القيام بها
واضحة	☐	☐	☐	☐	☐	☐	غير واضحة
قمنا بأغلبها	☐	☐	☐	☐	☐	☐	لم نقم بأغلبها
مهمة لتعليم الطالب	☐	☐	☐	☐	☐	☐	غير مهمة لتعليم الطالب
منظمة بشكل جيد	☐	☐	☐	☐	☐	☐	غير منظمة بشكل جيد
أفضل جزء في مادة الفيزياء	☐	☐	☐	☐	☐	☐	أسوأ جزء في مادة الفيزياء
تساعد الطالب على الدقة والإتقان	☐	☐	☐	☐	☐	☐	لا تساعد الطالب على الدقة أو الإتقان
تطور مهارات التفكير لدى الطالب	☐	☐	☐	☐	☐	☐	لا تطور مهارات التفكير لدى الطالب

(3) حسب رأيك ما هي الطريقة الأفضل لإستخدام المختبر في مادة الفيزياء ***في كل سطر ضع إشارة صح في مربع واحد فقط من المربعات الستة***

الإكثار من حصص المختبر	☐	☐	☐	☐	☐	☐	التقليل من حصص المختبر
الطلبة هم الذين يقومون بالتجربة	☐	☐	☐	☐	☐	☐	الطلبة فقط ينظرون للمدرس وهو يقوم بالتجربة
استغلال المختبر لتعليم المهارات العملية	☐	☐	☐	☐	☐	☐	استخدام المختبر لتوضيح المادة العلمية
يجب ان يرتبط المختبر بالحصص النظرية	☐	☐	☐	☐	☐	☐	يجب ان يدرس المختبر كمادة مستقلة
يجب استخدام كتاب المختبر	☐	☐	☐	☐	☐	☐	لا داعي لإستخدام كتاب المختبر
الإكثار من التجارب ذات النتائج الرقمية	☐	☐	☐	☐	☐	☐	عدم الإكثار من التجارب ذات النتائج الرقمية

(5) تجد أدناه بعض الأهداف المرجو تحقيقها من استخدام المختبر في تدريس مادة الفيزياء حسب ما ذكر بعض الباحثين. حدد مدى موافقتك على كل هدف بوضع إشارة صح في المربع المناسب (أوافق بشدة ــ غير متأكد – لا أوافق). وإذا كنت تعتقد انك حققت هذا الهدف، فضع إشارة صح أمام مربع "تحقق لي"

	أوافق بشدة	غير متأكد	لا أوافق	تحقق لي
(1) التجارب تشجع و تثير الإهتمام بمادة الفيزياء وتحبب إليها ……………………				
(2) التجارب توضح وتبسط النظريات العلمية المشروحة في الحصص ……………				
(3) التجارب تساعد على تعلم بعض النظريات التي لم يتم التطرق إليها في الحص ….				
(4) التجارب في مادة الفيزياء تساعد على تعلم بعض المهارات العملية …………				
(5) التجارب تساعد على فهم بعض الظواهر الكونية والطبيعية ……………………				
(6) التجارب تساعد على إيجاد حلول للمسائل العلمية ………………………………				
(7) التجارب تساعد على تعلم استخدام أدوات القياس المختلفة …………………				
(8) المختبر يدرب على استخلاص الإستنتاجات من نتائج التجارب ………………				
(9) المختبر يساعد على التحقق من صحة الأفكار النظرية ………………………				

(6) قيم العبارات التالية حسب وجهة نظرك بوضع إشارة صح في المربع المناسب.

	أوافق بشدة	أوافق	غير متأكد	أعارض	أعارض بشدة
(1) يحتوي منهج الفيزياء على عدد كافي من التجارب العملية ……………………	☐	☐	☐	☐	☐
(2) موجه أو مشرف مادة الفيزياء لا يهتم بالمختبر والتجارب العملية …………	☐	☐	☐	☐	☐
(3) معظم الطلاب لا يتفاعلون مع المعلم أثناء مختبر الفيزياء ……………………	☐	☐	☐	☐	☐
(4) يحتاج المعلم إلى دورات عملية او مشاغل حول مختبر مادة الفيزياء …………	☐	☐	☐	☐	☐
(5) أعتقد أن تدريس الفيزياء بشكل صحيح لا يكتمل بدون استخدام المختبر ………	☐	☐	☐	☐	☐
(6) لا أحب التجارب لأن نتائجها قد تتعارض مع معلوماتي النظرية التي شرحتها للطلاب	☐	☐	☐	☐	☐
(7) يحرص فنيو المختبر على ان يكون المختبر جاهز دائما للقيام بالتجارب …………	☐	☐	☐	☐	☐
(8) المختبر مكتظ بالطلاب مما لا يساعد على الإشراف عليهم ومتابعة أداءهم للتجارب …	☐	☐	☐	☐	☐
(9) يقوم المعلم بشرح أهداف كل تجربة قبل القيام بها عمليا ……………………	☐	☐	☐	☐	☐
(10) التجارب مشروحة في الكتاب بطريقة سهلة وتشجع على القيام بالتجارب …………	☐	☐	☐	☐	☐
(11) المعلم يشجع الطلاب ويسمح لهم بالمشاركة الفعلية في تنفيذ التجارب …………	☐	☐	☐	☐	☐
(12) إجراءات السلامة (مثل مخارج وطفايات الحريق) غير كافية في المختبرات ………	☐	☐	☐	☐	☐
(13) درجات المختبر لا تحتسب في الدرجة الكلية للطالب في مادة الفيزياء …………	☐	☐	☐	☐	☐
(14) في نهاية كل تجربة يقوم المعلم بمناقشة النتائج مع الطلاب ……………………	☐	☐	☐	☐	☐
(15) الدعم الفني غير كافي أثناء مختبر الفيزياء ……………………………………	☐	☐	☐	☐	☐
(16) أعتقد ان المواد والأجهزة الازمة للقيام بالتجارب كافية ومتوفرة في المختبر ………	☐	☐	☐	☐	☐

(7) مالذي تطمح إلي تحقيقه من من خلال مختبر مادة الفيزياء؟ *(استخدم ظهر الورقة كمساحة إضافية)*

(8) إذا كان لديك اي ملاحظات أخرى حول مختبر مادة الفيزياء ، ارجو أن تكتبها هنا. *(استخدم ظهر الورقة كمساحة إضافية)*

شكرا لك على تعاونك معنا ونتمنى لك عاما دراسيا موفقا

Appendix II

Teacher’s Interview Questions

Interview With Teachers

My name is Amna Al-Abri a M.Sc. student in the Centre for Science Education University of Glasgow UK. This interview is part of my research and it will be treated confidentially and will just be used for research purposes only.

Name: position: teaching experience:

1) Do you think that teachers are in need of training courses on the practical experiments proposed by physics curriculum in grade 11 and 12? Why?

2) Do you think that it is useful to have user guide to utilize laboratory tools, material and equipments? Why?

3) Would you like to see an increase in physics classes in the laboratory? Why?

4) Do you think the laboratory technicians are encouraged to take advantage of the laboratory in the teaching of physics? How?

5) Do you believe that teaching physics is not fulfilled without utilization of physics laboratory? Why?

Appendix III

About The Chi-Square Test

The Chi-square Test ($\chi 2$)

The chi-square test is said to be one of the most widely used tests for statistical data generated by non-parametric analysis. There are two different of applications of chi-square test.

(1) Goodness of Fit Test

This tests how well the experimental (sampling) distribution fits the control (hypothesised) distribution. An example of this could be a comparison between a group of experimentally observed responses to a group of control responses. For example,

	Positive	**Neutral**	**Negative**	
Experimental	55	95	23	N(experimental) = 173
Control	34	100	43	N(control) = 177

(using raw numbers)

A calculation of observed and expected frequencies leads to:

	Positive	**Neutral**	**Negative**
fo = observed frequency	*55*	95	23
fe = expected frequency	33	97	42

Where *fe* = [N(experimental)/N(control)] X (control data) or (173/177) X (control data)

$$\chi 2 = \frac{(55-33)2}{33} + \frac{(95-97)2}{97} + \frac{(23-42)2}{42} = \mathbf{22.9.}$$

The degree of freedom (df) for this comparison is 2. This comparison is significant at two degrees of freedom at $p < 0.001$.

(2) Contingency Test

This chi-square test is commonly used in analysing data where two groups or variables are compared. Each of the variables may have two or more categories which are independent from each other. The data for this comparison is generated from the frequencies in the categories. In this study, the chi-square as a contingency test was used, for example, to compare two or more independent samples like, year groups, gender, or ages. The data is generated from one population group. For example,

	Positive	**Neutral**	**Negative**
Male (experimental)	55	95	23
Female (experimental)	34	100	43

(Actual data above)

	Positive	**Neutral**	**Negative**	**N**
Male (experimental)	55 (44)	95 (96)	23 (33)	**173**
Female (experimental)	34 (45)	100 (97)	43 (33)	**177**
Totals	**89**	**195**	**66**	**350**

(Expected frequencies above in red)

The expected frequencies are shown in red in brackets ( ), and are calculated as follows:

e.g. 44 = (173/350) x 89

$$\chi 2 = 2.75 + 0.01 + 3.03 + 2.69 + 0.09 + 3.03$$
$$= \mathbf{11.6}$$

At two degrees of freedom, this is significant at $p < 0.1$. (χ**2** critical at 1% level = 9.21)
The degree of freedom (df) must be stated for any calculated chi-square value. The value of the degree of freedom for any analysis is obtained from the following calculations:

df = (r-1) x (c-1)

*where **r** is the number of rows and **c** is the number of columns in the contingency table.*

Limitations on the Use of χ2

It is known that when values within a category are small, there is a chance that the calculation of χ2 may occasionally produce inflated results which may lead to wrong interpretations. It is safe to impose a limit on all categories. When the category falls below either of these, then categories are grouped and the df falls accordingly. In this study a limit of 5 was imposed on the data.