FEMALE HIGH SCHOOL STUDENTS' PERCEPTIONS OF THE ROLE OF PRACTICAL WORK IN SCHOOL SCIENCE EDUCATION

by

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ABSTRACT

The intent of this study was to probe female High School students' perceptions of the role of practical work in their school science education.

A total of 20 students were interviewed: four Grade 9 students and four Grade 12 students in the pilot study and six Grade 9 students and six Grade 12 students in the actual study. The students involved attended a girls' High School and had experienced at least two years of science education in an all girls environment. Each student was interviewed for between twenty and thirty minutes. The interviews utilised the 'Rapport Interview' technique. The interviews were audio-taped, transcribed and the information obtained collected under eight main category headings.

Among the significant findings of this study were:

1. Female High School students view practical work in science as an aid to learning and understanding science concepts, and as a memory aid.
2. Students view demonstrations as an inadequate replacement for hands-on practical work.
3. Students require some theoretical background knowledge before proceeding with practical work if they are to obtain the maximum benefit from the experience.
4. Students prefer to undertake a self-directed enquiry rather than a prescribed one if they have some familiarity with the material. This preference may change if the work is to be graded.
5. Female High School students, particularly in Grade 9, feel insecure when conducting practical work and feel more comfortable when working with a chosen partner.

6. Failure to obtain the 'correct answer' can result in female students' experiencing negative feelings about their abilities.

7. Dissection makes a powerful impression on female students and seems to stand apart from other types of practical work.

8. Safety is of considerable importance to Grade 9 female students and may be inhibiting their activities in the laboratory.

The findings of this study suggest that practical work is of considerable importance to female High School students for a variety of reasons but the most important is to further their understanding of science concepts.
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CHAPTER 1

Introduction

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

(Solomon, 1980, p13)

Few science teachers would quarrel with Solomon's statement, yet the importance of the laboratory in science education is imperfectly understood.

Almost all High School students studying science spend varying amounts of time in a laboratory carrying out practical work. (Practical work is generally considered to be any activity in which students are actively engaged in manipulating or using materials, apparatus or specimens, generally in a laboratory situation.) The time devoted to practical work varies from country to country. In England, practical work occupies between 40-80% of students' time with the academic student spending less time on it than the non-academic student (Beatty and Woolnough, 1982). In N. America practical work occupies considerably less time, generally less than 30% of the total time allocated to science teaching (Houndshell, 1986). In Western Australia approximately 40% of the time allocated to science lessons is devoted to practical work.
in Grades 8 and 9. In the senior grades where external examinations become imminent, considerably less time is spent on practical activities (Tobin, 1986).

The role of practical work in school science education has had a checkered history. The symbolic starting point for the development of modern science education has been identified by Brock (1975) as 1839 when Liebig arrived at the University of Giessen. The ideal of the research school he founded was research and inquiry for its own sake. This ideal gave rise to the concept of pure laboratory science that has dominated the school science curriculum throughout modern times (Hodson, 1987).

The intervening years have seen a tension develop between an emphasis on science content or knowledge of science facts with practical or laboratory work used in a confirmatory or supporting role, or an emphasis on science processes, with the concurrent laboratory activities forming the dominant thrust of the curriculum. In the latter case it was assumed that the students would, by carrying out the experiments themselves, reach the same explanation of the concept as that given by the currently accepted paradigm. Historically, science curricula take a position somewhere on this continuum that exists between content and processes, with the emphasis varying from content to processes and back again (Miller and Driver, 1987).

Science processes are generally identified as those skills which are used by all scientists in investigating the natural world i.e. observing, classifying, describing, communicating, drawing conclusions, making operational definitions, formulating hypotheses, controlling variables, interpreting data and experimenting (Gagne, 1965). Practical or laboratory exercises carried out in a school laboratory use some or all of these skills and practical work has therefore become the backbone of the science process approach of school science curricula. As a result practical work has became an
integral part of school science since science became an accepted part of the school curriculum in the 19th century. The type of practical work may have changed from a dependence on demonstrations by the teacher to students carrying out the activities themselves, and the amount of time devoted to it may vary but the importance of practical work has seldom been doubted.

Current Concerns

Although few teachers and curriculum developers have questioned that school science courses should contain a significant amount of practical work, some have questioned the type of laboratory work done (Hodson, 1988; Woolnough and Allsop, 1985) and the need for expensive laboratory equipment (Toothacker, 1983). These concerns about practical work today, identified by Woolnough and Allsop (1985), revolve around three issues.

First, most practical work involves little more than a series of restrictive exercises where the method and procedure to be followed are set out as a series of steps. The result can be a closed, convergent and often dull experience which contains little of the problem solving activity scientists engage in. The emphasis is on obtaining the 'correct' answer and the purpose which underlies the approach is 'knowing is more important than doing'.

Secondly, practical work is frequently designed to elucidate theory. Students however, approach science experiments with some firmly held views about many phenomena. They may have constructed their own explanations for the phenomena they have observed and these have proved to be tenaciously held and not easily displaced by accepted scientific theory. Practical work may reinforce their own
explanations and not displace them. Simply carrying out a prescribed practical exercise may not be enough to displace or replace a student's own explanation of the phenomena. Practical work has been shown to be an inefficient means of transmitting scientific concepts. Many students may be better served by dealing with theory at an abstract level only. Exposing them to a practical exercise may cloud the issue.

The third concern involves the amount of time and resources practical work requires. Teachers devote time to planning, setting up and marking laboratory exercises, time which could be used to develop alternative teaching strategies, discuss theoretical concepts with students or explore the relationship between science, technology and society. The building and equipping of science facilities and the replacement and maintenance of equipment is costly. One must ask if the expense can be justified by the benefits it brings to students. Is the expensive, modern equipment found in most physics laboratories really necessary for a student's understanding of a theory, is it for the teacher's benefit or does it have other benefits? There is evidence to show that students can become so involved manipulating the equipment that they lose sight of the theory. Information overload during practical work can become so overpowering that the selection of relevant observations becomes impossible (Johnstone and Wham, 1982). It is difficult to justify the time, efforts and costs involved if practical work does not assist in the development and elucidation of theory or lead to the development of other highly regarded and desirable skills. Yet the very fact that it occurs in all science curricula in varying amounts suggests teachers and curriculum developers value it.
Teachers' and Curriculum Developers' Views

Teachers' and curriculum developers' aims for practical work generally fall under four headings (Woolnough and Allsop, 1985).

The generation of interest and the motivation of students is seen as a very important feature of practical work. This motivation is seen as being extrinsic. The intrinsic motivation that accounts for learning is seldom mentioned. Given a choice between a one-hour lesson of theory (chalk and talk) and a one-hour lesson which included practical work, most students would prefer the latter. This may be because they get to stand up, talk to each other, move around and do something with their hands, all activities which will help to relieve boredom. Alternative teaching strategies may achieve the same end.

Secondly, they view practical work as necessary to develop skill in the manipulation of equipment. Science as viewed by Polanyi (1969) is a craft activity. Ravetz (1971) states that "scientific work is necessarily a craft activity, depending on a personal knowledge of particular things and a subtle judgement of their properties". The handling and use of equipment, some of it complex, can be viewed as the experience scientists have as they build up a personal, tacit feel for the materials, allowing them to develop a sense of appropriateness of action.

Thirdly, many teachers and curriculum developers value practical work as support of theoretical concepts. They feel that theory and practical work are interwoven. The practical supports and reinforces the theoretical concepts and forms an integrated whole.

Fourthly, it is thought that by doing practical work students will begin to feel like a scientist. The accepted definition of a scientist appears to deviate from
contemporary descriptions. The Baconian model is generally taken as the norm. Few teachers use Popper's ideas about scientists starting their investigations already holding a theoretical perspective (formulation of a hypothesis). The 'student as researcher' and the 'scientist as master of her/his craft' are also accepted models of the scientist but they are seldom used by teachers as a justification of practical work.

The practical work conducted in the school laboratory is significantly different from the experimental work conducted by practicing scientists (Hodson, 1988). In 'school science', practical work may be for demonstrating a phenomenon, illustrating a theoretical principle, collecting data for analysis, testing a hypothesis, developing basic skills, familiarization with apparatus or providing an entertaining event to pique students' interests. It therefore fulfills a large range of science teaching requirements, all quite different from a practicing scientist's reasons for carrying out practical work. The practicing scientist designs and conducts experiments to test the adequacy of a developing theory, to provide retrospective evidence for theoretical propositions and to guide the continuing development of theory towards coherence and completion. Students involved in laboratory activities may well have very different expectations about practical work than either their teachers or scientists. There may also be a difference in the expectations of male and female students as to the role of practical work in school science.

Girls and Practical Work

A case study of successful science teachers by Kahle (1984) revealed that laboratory-based science teaching is particularly effective in interesting girls in science. Successful teachers were especially good at getting girls to use science materials and the
girls enjoyed these classes because they were involved with experimental work. The HMI report on 'Girls and Science' (1980) also draws attention to the "high value girls placed on practical work". They stated "Even among those girls who had dropped science it was remarkable how many commented favorably on their attitude to the laboratory work of earlier years". Woolnough and Allsop (1985), on the other hand, have suggested that girls are not interested in practical work.

Various reports suggest that the experience of practical work is different for boys and girls with boys dominating the science class (GIST, 1986; Science Council of Canada, 1982). It therefore appears that an aspect of science education that is reported by some as being valued by girls may not be as readily available to them as it is to boys.

Girls are also known to be less confident of their abilities and to perceive science as a difficult subject (Kelly, 1987). Does this mean that the type of practical activity undertaken by girls should take into account these findings, or should both sexes have the same laboratory experiences, assuming this is possible in a male-dominated science class? One is left to ponder on the type of practical work which girls would prefer. Would they prefer the secure 'cookbook' approach where the practical work is set out in a very precise way and a 'correct' answer is required, or would they prefer a more open-ended, problem-solving approach where there may not necessarily be a single 'correct' answer? Very little research has been done to determine what students' perceptions of the role of practical work is, let alone to determine if there is a preference based on the sex of the student.
Students' Views

Students' views of the role of practical work have been seldom considered. It is assumed that they undertake practical work because it is interesting and motivating but there are many other ways of interesting and motivating students. Denny and Chennell (1986) and Tobin (1986) ascertained that students saw the most important role of practical work as being concerned with learning about science. However, both reduction of boredom and a sense of achievement and responsibility were also frequently mentioned.

The value of practical work may not always be a scientific one. Watts (1988) interviewed sixth-form students on their views about their science education between 11 and 16 years of age. They perceived satisfying science education as occurring when the teachers fostered practical work in such a way that it became a student's own genuine inquiry. Open-ended, practical enquiries were favoured over enquiries which confirmed 'facts'. There was also some suggestion that students wanted some input into the investigations to be undertaken. Student responses suggested that practical work which removes the element of surprise is common. Renner, Abraham and Birnie (1985) when exploring High School students' beliefs about the Physics Laboratory found all students reported favorable feelings towards it. There was a tendency to feel learning was more their own if they had experienced it in a practical setting and they could recall it when needed. It made physics' concepts more believable and understandable.

As students are the consumers of school science education and have been exposed to it for some years, their perceptions are valuable. By investigating their perceptions, light may be shed on the role of practical work in their developing
understanding of the concepts involved. An awareness of these expectations may assist teachers and curriculum developers in determining the type of practical work which meets the needs of both the teacher and student. There appears to be differences in the perceived role of practical work in science education but the root cause of these differences is unclear.

Summary

It appears that the role of practical work in school science is poorly understood. There is some confusion between teachers' and researchers' perceived importance of practical work and little is known about students' views on practical work. Differences in experiences in the laboratory as well as different learning characteristics between males and females may further complicate the matter.

Problem Area

The topic to be investigated is girls' perceptions of the role of practical work in school science education. A cross-grade study was undertaken which elicited the opinions of female students in Grade 9 and Grade 12. This age range was chosen because Grade 9 encompasses the time when female students' attitudes towards science education are declining (GIST, 1986), as well as the time when many emotional and social changes are occurring. Grade 9 students in British Columbia study a general science course which includes both the physical and the biological sciences. All students are required to study a science at the grade 11 level to meet graduation requirements. By Grade 12 most students have already made a career choice. Some may not attend science classes any longer but many do, either because of interest or
because it is a prerequisite for a course of study they wish to follow once they leave school.

Problem Statement

This study looked at the role of practical work in school science education from the female High School students' perspective. It aimed to explore the role of various aspects of practical work from the viewpoint of female students in an attempt to gain some understanding of the role it played in their science education. It addressed the following general question:

What are female High School students' perceptions of the role of practical work in their school science education?

This general question was probed by asking more specific questions which dealt with both the type of practical work undertaken and how it was carried out.

1. How effective are demonstrations versus hands-on practical work in meeting these students' expectations of practical work?
2. What role does a partner play in practical work?
3. How does the sequencing of theory and practical work affect students?
4. What effect does obtaining results that differ from the expected have on students?
5. What type of practical work do students prefer when offered a choice between a 'cookbook' approach and an inquiry approach?
6. What aspects of school science courses are particularly memorable and why?

Significance of Problem

Practical work has been an important part of science education for many years but the exact role of practical work appears to be debatable. Students' attitudes towards practical work have been reported seldom and most information comes from the teachers' views of the role of practical work. The student is the learner and to enable her/him to fully benefit from practical work it is important to understand their conceptions and their expectations of practical work in their science lessons. A better understanding of how students view practical work will assist the teacher in planning the type of practical work to be undertaken as well as assist in the development of science curricula. Some indication of how girls' view practical work could provide some insight into why girls are under-represented in the physical science fields. By undertaking practical work that more clearly meets the needs of girls, it may be possible to increase the participation of girls in the physical sciences.

Limitations of the Study

The sample consisted only of female students, some of whom will have spent all their school years in a single-sex school (approximately 10%) while others will have spent varying amounts of time in a co-educational setting. This sample will not reflect the views of the majority of female students who attend co-educational schools. Thus many of the factors which have been cited by a variety of researchers (Harding, 1985,
Kelly, 1987, Smail, 1987) as affecting girls' choice of, and success in school science are not applicable.

The science programme at this school may not be identical to those in other British Columbian High Schools. The reasons for this are twofold. First it as an academically orientated school with an entrance examination, accepting only those students who are academically able. Secondly, all the science teachers received their teacher training in Britain, and this is reflected in the type of science taught at the school.

The techniques used in gathering the data involved a researcher who was known, at least by sight, to the students. The students selected cannot be regarded as a totally random sample and involved a relatively small proportion of the student body.
Introduction

Since the earliest days of science instruction in schools, the relative importance of scientific content and scientific method have been almost continually under review (Millar, 1985). Few writers have seen the value of school science as lying completely in the realm of content or method and the history of school science reveals alternating emphasis on the methods of science and the content of science. This pattern appears to be general, crossing national boundaries (Millar and Driver, 1987). Although science has a place in the school curriculum that has been unchallenged for some time, it is unclear whether this position is unchallenged because science content and knowledge is valuable in itself, or whether the methods of science are of prime importance. Recently the term 'science processes' has appeared and displaced the term 'science methods'.

Science Processes

The term 'science processes' has begun to appear more frequently in school science curricula in both the UK and in Canada (HMI, APU, DES, Dept. of Education in BC). These processes are generally understood to include the skills used by scientists as they carry out experimental investigations. A process view assumes that the processes of science are identifiable, characteristic of the pursuit of science, and are generalisable across domains. There is in this approach an underlying assumption that students learn the concepts by imitating the way scientists work.

Science processes which include the activities undertaken during practical work, are seen as a "a sequence of events which are engaged when researchers take part in
scientific investigation - - - - observing, inferring, classifying, predicting, controlling variables and hypothesizing" (Screen, 1986). Many, but not necessarily all of these events will be engaged in when a student is undertaking practical or laboratory work. The idea that there are certain specific processes which are an integral part of science and are used by all scientists can be traced to Gagne (1965) who argued that prerequisite scientific concepts and principles are obtained only through the operation of science processes. He further argued that these processes can be learned by students and are transferred across content domains. The assumption that science can be characterized by its methods which are identifiable and transferable across domains is at the root of the process approach to school science education.

Millar and Driver (1987) suggest there are a number of different meanings for the term "processes" each with its associated claims. They identify these as: the processes scientists use, the cognitive processes involved in learning science and the pedagogical processes taking place in the classroom. The process of science is exemplified by the method of science set out in numerous school science texts i.e. define the problem, gather information, form a hypothesis, prove or disprove by experimentation designed to test the hypothesis, observe and record data from the experiment and draw conclusions. There is, however, almost no support from historians, philosophers or sociologists for this view of how scientists actually do science. The only principle that can be defended under all circumstances is that 'anything goes' (Feyerbend, 1975). A scientist is continually making judgements based on her/his own perception of how it should be and judgement calls have no rules to guide them. Rather they are guided by the accumulated knowledge of the scientists who are recognised as having expertise in that field of study.
As there is no specific scientific method that is employed by all scientists, there is no rationale for making the teaching of 'the scientific method' as set out in school texts a major influence in science curricula unless school science is seen as being significantly different from science in the world beyond the school. If, however, the processes of science are seen as a "toolkit of strategies" which can be used to obtain scientific knowledge then they may have a place in the science curriculum but these strategies may be characteristic of logical thought in general and are therefore not unique to science. Rather, they may be applicable to all educational endeavors.

Millar and Driver (1987) argue that the processes of science and the skills they embrace are content and context dependent. Observation is not unique to science and is as important in the art class as it is in the science class. It is now widely held that observation is theory dependent and is influenced to some extent by the theories we hold or the mind set we bring to the situation. For example, Brownian motion was first interpreted as a sign of life and an example of the life force found in all things. The richness of the observable world necessitates a theory to guide observation or we would be incapable of deciding what was important and what wasn't. Munby (1982) summarizes this viewpoint by stating "---scientific thinking ---is a human invention which involves using language to paint the perceptual world in a very particular disciplined fashion----we construct our own realities".

Students can, however, transfer what they have learned from one situation to another but it appears to be influenced by the distance between the context in which the learning took place and the new context, and the generability of the skill (Millar and Driver, 1987).
Students in school science classes are being trained in scientific observation which may not be the observation skills they will use outside the laboratory. Science skills per se may be closely related to both content and context that are unlikely to be met outside the laboratory setting. These skills will be used in practical work and are essential for the completion of most practical activity. To say skills are not readily transferable casts doubt on the validity of arguing that practical skills should be taught for their own sakes or that they should form the dominant thrust of the curriculum, but it does not detract from the necessity to teach them for use in the laboratory.

If one views the learner as an active participant in the construction of her/his own learning, then learning must depend on the representations a learner brings to a situation. What children observe and predict about their world may be crucially dependent on the way they construe their world. The selection of observations from an experiment will be influenced by student preconceptions. The student may be guided by the teacher and/or text towards the accepted, 'correct', observation which may assist in the student's conceptual development. The very process of experimentation is dependent on the learner's previous experience and knowledge but it may alter that experience and knowledge base.

Given the above arguments, it therefore appears that practical work cannot be justified solely because it involves various aspects of the scientific process. If there is no one recognizable scientific method, if skills identified as used by scientists are not readily transferable, and if prior conceptions guide current observations, then practical work must be valued because it has some other important function. Its importance may be because it involves active rather than passive learning where students are involved in doing things in their hands and head at the same time.
Laboratory Work in Science and School Science

The desirability of science pedagogy mirroring professional practice has had a major effect on the practical work done in school science (Millar, 1985). It has arisen from the commonly held views of science and scientists who are seen as having logical thought processes, forms of behavior and attitudes of mind. The assimilation of these characteristics by students and their transfer to novel situations are seen as being desirable.

Experimental practical work carried out by scientists and that carried out by students is done from different perspectives and for different reasons. Hodson (1988) stated that school science experiments tend to be cast in the simple inductivist role or a Popperian critical role and fail to acknowledge the idea that experimentation is part of theory construction. Theoretical speculation or Solomon's (1980) 'imaginative understanding' must represent the starting point of experimental practical work. In school science children are concerned with 'normal science', working within a particular paradigm which is widely accepted by the scientific community. Children lack the familiarity with the paradigm that scientists possess. While experiments in the realm of science are conducted primarily for theory development, Hodson (1988) suggested that experiments in school science classes can be conducted for a variety of pedagogic purposes: for teaching science content, teaching about science, teaching how to do science, teaching how to use equipment, developing scientific skills, building confidence and self-esteem in students. Laboratory work may provide suitable conditions for conceptual change. The exploration of phenomena which occur during practical work can play a major role in the shaping of conceptual change and may be
crucial in giving concrete illustrations and representation to prior abstractions. Practical work may have a role to play in assisting the exploration and manipulation of concepts and in making the concept manifest, comprehensible and useful. The experiment may simply provide the concrete evidence for conceptual exploration (Hodson, 1988).

It does appear, however, that the role of the laboratory in the pursuit of science and the role of the laboratory in the teaching of school science are very different. The former cannot be used to justify the latter. Rather the role of the laboratory in school science needs to be explored in terms of its pedagogical value.

Teachers' Perceptions of the Role of Practical Work

The learning experience of a student in the laboratory can be regarded as arising from the interaction between the student, the teacher and the apparatus (West, 1972). The nature of the practical work undertaken is determined by the objectives of the teacher. He/she needs to respond to the intended learning outcomes of the curriculum, the time available, the facilities at her/his disposal, the availability of equipment and the technical help available. Of considerable importance is the presence of an external examination. If practical work is examined one can expect to find an increased emphasis on practical work when compared to a situation where practical work is not examined. The act of examining practical work may give it more status and thereby increase its value in both teachers' and students' eyes. Tobin (1986) found that in Western Australia, the amount of time devoted to practical work declined as the students approached external examinations and teachers felt pressured to cover the content of the course on which the examination was based.
Kerr (1963) surveyed teachers and former students in England and Wales and found considerable agreement among teachers as to the educational values arising from practical work. These values include motivation, support for theory, development of skills and acquiring the scientific approach. There was, however, a lack of consistency between these stated values and the actual form of practical work in practice at that time. At a later date, Hurd (1969) commented "from the fragmentary evidence available it appears that the importance of enquiry-orientated laboratory investigations described in the literature is not extensively reflected in teaching practice".

Teachers regarded investigative approaches to laboratory work to be of importance but there was little evidence that such objectives were met by the practical work undertaken by the students. Kerr (1963) suggested that the two main obstacles to full exploitation of practical work were the conditions under which the students were taught and the restrictions of examinations. West (1972) carried out a survey similar to Kerr's after the introduction of the Nuffield chemistry course in England and Wales and found similar results. There was a marked difference between the stated aims of the course and the actual practice in schools. He suggested that conditions within the schools may be inhibiting the practical implementation of theory. Tobin (1986) found that although both teachers and students thought that practical work was an effective way to learn science, teachers felt lower ability students tended to lose track of the experiment, and it was not an effective way to develop their content knowledge. Other factors also affected these teachers' perceptions. The lower ability students tended to break equipment, disregard safety procedures, and the value of the equipment being used was irrelevant to the students who used it carelessly. The behavior in the laboratory was often disruptive and the amount of off-task behavior was considerable.
Students paced the laboratory work, working at a pace that allowed the work to be completed in the allocated time. This was in contrast to other types of seat work where the teacher set the pace. The rule structure for laboratory work was not clearly defined and students took advantage of this to meet their two agendas: to complete the work and interact socially with other members of the class. Some students described the laboratory activities as being chaotic and most teachers will agree it is more difficult to keep a class under control while they are engaged in practical work than it is when they are engaged in seat work.

Hounshell (1986) surveyed science teachers in N. Carolina about the value and mechanics of laboratory activities as one of their methodologies. The teachers were guarded in their claims for the impact of laboratory activities in their classroom. Approximately 40% of the teachers felt that students learned a lot in the laboratory but only 60% of the students agreed with this statement. The majority of the teachers felt that students did gain something in the realm of knowledge and lab skills from laboratory activities. The majority also felt that for many topics practical work is more effective than a demonstration. However 83% of teachers used laboratory work less than 30% of their class time, and 15% of teachers used practical work less than 10% of their class time, approximately 15 minutes /week. The majority of the teachers also reported increased discipline problems during laboratory activities, and teacher strain, amount of disruption to routine, expendable laboratory supplies, length of class period and class size were all factors which affected teachers' responses.

Although teachers may feel favorably towards laboratory activities and recognize that they are an important part of their methodology in science teaching, they are unsure of exactly what role they should play. The stated role and the actual role may
not coincide. Practical considerations about the actual time and effort involved in setting up laboratory activities, safety concerns, behavior problems, budgetary considerations, accommodation, class size and teacher stress and strain are all factors which govern the amount of time spent on laboratory activities. Teachers need to be convinced about the value of practical activity in the laboratory if they are to expend the energy and initiative to make it a significant part of their class activities.

Learning in the Laboratory

The teacher is the key to effective learning in the laboratory. Shulman and Tamir (1973) observed that "the laboratory has always been the most distinctive feature of science instruction....With the advent of the new curricula, important changes have taken place in the role assigned to the laboratory...The laboratory acquired a central role not as a means of demonstration, but rather as the core of the science learning process". Studying science through laboratory oriented programs fell short of the expectations (Hofstein and Lunetta, 1982; Stake and Easley, 1978). APU (1984) showed that in England where practical work has always been given great emphasis, students failed to develop basic practical skills such as observation, estimation, designing experiments and making inferences. Woolnough and Allsop (1985) argue that the reason for this is the failure to focus a certain amount of practical work on the development of practical skills. The skills are generally used to find the answer to another problem but are seldom valued in themselves. Another suggested reason is the inadequacy of pre- and post-laboratory discussions which are essential for making sense of the laboratory experience (Friedler and Tamir, 1986; and Tamir, 1977; Woolnough and Allsop, 1985).
The practical work in certain curricula (BSCS and PSSC) was supposedly designed to be 'truly experimental in nature'. An analysis of practical work in these text books by Schwab (1962) and elaborated by Herron (1971) showed that 75% of the experimental work in these texts had the problem, procedures and answers provided, 20% had the problem and procedure provided and 5% had the problem provided. There were no examples of a totally open approach with the students setting the problem, developing procedures and arriving at a solution. Students had little opportunity to engage in original problem-solving activities.

If the stated aims and actual situation in science texts can be in opposition to each other, it is little wonder that teachers are unsure of the role of the laboratory in school science education. Although all agree that laboratory work is a unique part of school science education, they are caught between the need to ensure that students learn the content of the course according to the accepted paradigm and the desire to provide practical work which will assist students to learn the concepts, engage students in problem solving activities, generate interest and motivation, while maintaining a safe working environment where students are on task, and balancing the monetary budget, all in a room which may be inadequate for the size of the class. They truly have an unenviable task, perhaps an impossible one.

Students' Perceptions

It has often been stated that practical work should be done to 'interest and motivate students' (Woolnough and Allsop, 1985) but there is a dearth of information as to what exactly students perceive the role of practical work to be. Renner et al. (1985) reported that the majority of students expressed highly positive feelings toward
the laboratory in school physics. The students' response made it clear that they think the laboratory is important to their developing understanding of the concepts being taught. The students preferred laboratory activities to other activities because the laboratory activities help the students to remember, are less confusing and more concrete than other instructional formats and make the students think about the phenomena they are observing. The laboratory made learning an active and vivid experience, making concepts more believable and understandable. The students involved in this study attended a school where practical work was used to introduce an idea rather than to verify it and the laboratory was an important part of the methodology of the teachers involved. There had been an increase in the number of students taking senior physics during the past 10 years when this method was in place. The increase was seen to come from the student communication system which obviously supported the importance of laboratory work. The laboratory was seen as allowing students to take charge of part of their own learning.

Denny and Chennel (1986) asked students in the 11-16 year age range to write a letter to students who did not do practical work in science. Their letters showed that the over-riding function of practical work was seen to be learning about science but it was also important in reducing boredom and as a means of developing personal well-being. The element of danger that is present in some laboratory work was a reason why some children like practical work. An analysis of drawings done by the same students in the art class where they were asked to depict a science practical exercise, showed an overwhelming pre-occupation with equipment, especially the ubiquitous Bunsen burner. Forty percent of the drawings indicated feelings (excitement, boredom, surprise) and the remaining portrayed social interactions between teachers and students.
and between students. The interpersonal interactions between students were not given a high priority.

Interviews of 17 year-old English students by Watts (1988) found that they were generally dissatisfied with their previous school science courses. They stated that their course lacked coherence or continuity and many experienced less than ideal science teaching. Satisfying science education was seen to occur when teachers fostered practical work in such a way that it became a student's own genuine enquiry. Some students appreciated genuinely open-ended practical enquiries rather than enquiries which merely confirmed already known facts. Some students wanted some say in what is investigated and how the investigation is carried out. Practical work which eliminated the element of surprise, which is less 'risky' and is strictly confirmatory was described by many students. It is suggested that students may have higher expectations of science than other school subjects in terms of its potential to be engaging, exciting, active, if not sometimes exhilarating and mildly dangerous. There was a feedback loop between the way that fun and enjoyment make a subject easier to learn and how, in turn, becoming good at learning a subject makes it fun and enjoyable.

Practical work is therefore generally seen by students as being an enjoyable activity, one which relieves the boredom of a lesson as well as improving the mastery of new concepts. However the type of practical work which best achieves these aims needs to be investigated. While developing appropriate types of practical work, the experience of boys and girls in school science classes should be borne in mind as should the girls' general lack of background in science activities and their aversion to risk-taking behavior.
Girls and Practical Work

There has been considerable concern expressed by a variety of sources over the low percentage of girls engaged in science and technology activities (IEA, 1978; Science Council of Canada, 1982; GIST, 1986; Kelly, 1978). The 1980s have seen an explosion of interest among science educators in girls and science education. Originally the topic of girls and science was approached from the psychological view point. The tendency was to blame the victim, i.e. if girls don't do science there must be something wrong with their perception of science, of themselves, or of the world. The alternative approach which has been developed more recently is more sociological and structural. It locates the fault, at least partially, within science, schools and society at large (Kelly, 1987). The recognition that schools and the type of science teaching that they engage in may play a role in girls' avoidance of the physical sciences (girls are well represented in the biological sciences) requires that the methodology of school science education needs to be reviewed.

Engagement in Practical Work

Numerous investigations have shown that there are differences in the engagement of boys and girls in science classes (GIST, 1986; Kahle, Matyas and Cho, 1985; Sadker and Sadker, 1986; Science Council of Canada, 1984; Tobin, 1988). Boys dominate the co-educational science classroom. Sadker and Sadker (1985) showed that boys are spoken to more often and receive more praise, more criticism, more remediation and more acceptance responses in the science classroom. Hall (1982) revealed that primary teachers tend to praise boys for the quality of their work and girls for form and neatness. It is therefore possible that many of the gender-related
differences in achievement can be related to the different ways boys and girls relate to the teacher in the classroom.

Tobin (1988) suggests that one explanation for the gender difference in science achievement is that boys are more likely to engage in activities which facilitate science learning to a greater extent than girls. Tobin's observations in classroom situations showed that the vast majority of teachers taught using whole-class activities. The teachers tended to involve girls and boys to an equal extent when engaged in lower cognitive level interactions, but tended to involve boys to a greater extent than girls in high cognitive interactions. Boys participated in a more overt manner and were involved in responding to questions intended to stimulate thinking to a much greater extent than girls. More boys than girls stated that they liked to answer questions, and teachers elaborated more on boys' responses to questions. Target students whom the teachers asked questions of most frequently were generally boys. During practical work boys tended to be more involved in handling equipment, an observation that has been reported elsewhere (GIST, 1986; Science Council of Canada, 1984). In the Grade 11 classes where the girls had made a deliberate choice to study science the dominance of boys was less visible. The situation was not entirely the result of the boys' and teachers' behaviour. Girls expressed a desire to work in mixed groups as they perceived the boys as being better than they were in science. The students influenced the engagement patterns which were observed in classrooms.

Attainment in Practical Work

The TAPS programme in Scotland was designed to assess practical skills. Girls performed better than boys across most of the skills' areas tested with significant
differences in the grades awarded for manipulative skills and following instructions. Where an observational skill involved using a three-dimensional model, boys outperformed girls but with two dimensional models girls succeeded as well as boys (Robertson, 1987). Erickson and Erickson (1984) when studying results of the 1982 B. C. Science Assessment found an absence of sex-related differences for process skills and noted that in the NAEP survey (1977), there was a smaller male advantage in the area called process and methods than in the other content areas. Girls are equally as capable in answering process skills items as boys and their knowledge in this area may be undervalued.

Practical work is important to girls for a variety of reasons. The HMI report, Girls and Science (1980), drew attention to the "high value girls placed on practical work". There was a close correlation between a high proportion of practical work and high levels of interest among girls. HMI (1980) further commented that "Even among those girls who had dropped science it was remarkable how many commented favorably on their attitude to the laboratory work of earlier years". GIST (1986) believes that "Girl friendly science should provide visual or physical, but especially first-hand experiences which will help children understand scientific processes". Although practical work appears to be important to girls, Whyte (1984) observed that they lose out because they never really gain a proper foothold in the sciences. Boys' initial assertion of domination in the laboratory was observed to be physical, and girls were unwilling to enter into an undignified competition for resources. The fact that girls are known to be poor risk takers means that they will fail to take risks in the laboratory, either with equipment which they may perceive as being dangerous or by offering answers which may be incorrect. Girls are seldom observed engaging in off-
task behavior which involves tinkering with apparatus or playing around with the materials provided for the practical work in progress. Their off-task behavior is more likely to be in the social field.

Prior Experience and Practical Work

Farkas (1986) examined the possible role of out of school experience in contributing to sex-related differences in selected science achievement items drawn from the 1982 B.C. Science Assessment. Boys' explanations of their responses to the test items referred to considerably more informal school learning situations than girls while girls referred to more formal school learning experiences than boys. Kahle, Matyas and Cho (1985) showed that boys participated more in classroom science activities and had more extracurricular science activities, especially in the mechanical and electrical fields as well as science projects and hobbies. They suggested that if girls' interest in a science career and in science classes is to improve, girls must be encouraged to participate in more extramural science activities.

Single Sex Classrooms

If it is accepted that girls do not have the background that boys do as far as handling equipment and engaging in science type hobbies, handling and manipulating equipment in the laboratory may be very important to make up the deficit. The domination of the practical work by boys in co-educational classrooms means that girls do not get the same opportunities to handle equipment as they would in a single-sex classroom. As part of the GIST project (1986) two of the schools involved tried single sex science classes and the results were monitored. Their evaluation showed
significant improvement in the performance of girls but there was a small but statistically insignificant increase in the number of boys scoring below 50%. A further experiment in single sex classes occurred at another school involved in the GIST project where a one year group was divided into an all-boys' class, an all-girls' class and a mixed class. There was a significant increase in the number of girls electing to do physics the following year, a finding which supports the fact that more girls choose physics in all-girls' schools. The teachers involved felt that the "girls' attitudes had improved no end....they are more confident and more outgoing".

Girls' general lack of practical experience outside the science classroom combined with the domination of the science classroom by boys both during practical work and oral discussion, means that girls lose out on two fronts. It has been suggested that practical work is very important to girls and yet in co-educational settings they allow the practical work to be dominated by boys. In an all-girl science classroom, there is an improvement in attitude and an increase in the number of girls choosing physics. How much of this change is due to girls working in an environment where they have an increase in their interactions with the teacher and how much is due to girls having to do the practical work on their own and thereby gaining experience manipulating equipment has not been explored. It is most probable that both factors play an important role.

Conclusion

The exact role that practical work plays in the school science classroom appears to be imperfectly understood by those involved in school science education. Although it is thought to be important by curriculum developers, teachers and students, exactly
why this is so is not clear. Different groups have different expectations of practical work. Girls seem to regard practical work as an enjoyable aspect of the science course and recall it many years later but whether it is important to them for learning science concepts or motivates them to continue in physical sciences, is not clear. The type of practical work preferred by teachers and of most benefit to students seems to be debatable, especially as the stated aims and the actual practical work carried out do not coincide.

This study will attempt to determine what female students think about the importance of practical work in science and what type of practical work they prefer to do.
CHAPTER 111
Methodology

Introduction

This study will explore the perceptions female students have about the role of practical work in their school science education. The chosen population of students attended an Independent Girls' School and had been exposed to science education in an all female science class for at least two years. This, together with the emphasis placed on laboratory activities within the school, ensured that they had the opportunity to play an active role in the practical work. The absence of boys in the classes meant that one of the factors identified as affecting girls' achievement in science had been eliminated (GIST, 1986; Kelly, 1987; Science Council of Canada, 1984).

The students chosen were completing Grade 9 and Grade 12. The Grade 9 students were chosen because it has been reported on numerous occasions (GIST, 1986; Science Council of Canada, 1984) that it is in the early High School years that girls' interests and achievements in science, particularly the physical sciences, decline. All Grade 9 students must study a combined Science 9 course in B.C. and do not have the option to drop any of the sciences until they reach the end of their Grade 10 year. Grade 12 students, on the other hand, will have opted to study science and the students chosen will all have at least one science at the Science 12 level and one other science at the Science 11 level. The Grade 12 students have therefore chosen to do science, either because they find the subject interesting or because it is a necessary prerequisite for the career of their choice. Grade 9 students have, on the most part, only vague ideas of the careers they wish to follow and have little idea of the prerequisites required.
The Setting

The students involved are from an Independent Girls' School (Grades 1 through 12) which has a reputation for academic excellence. The school was founded in 1898, is traditional and conservative in nature. At the time of the study it had had only five principals, all female. It has a distinctly Scottish flavor, reflected both in the uniform and the large number of Scottish teachers employed by the school over the years. The Principal was Scottish, a former biology teacher at the school, and in common with three out of the six science teachers, received both her academic and teacher education at Scottish institutions. The remaining three science teachers were educated in England and Wales.

The researcher was on a one year leave of absence from the school where she is the Head of the Science Department. Her background is also Scottish. The British background of the teachers is reflected in the type of science education which the school provides. Practical work has always been emphasized and the laboratory has played a central role in science education at this school.

The researcher knew all the Grade 12 students as she had taught them and been on a residential field trip with a majority of them, at some previous time in their school career. They shared many common experiences and the students knew the researcher in a variety of capacities but especially as a person who was interested in science education, particularly the teaching of biology. She was also known as someone who had a sense of humour and was always prepared to listen to what they had to say on any topic. This was an advantage as there was already established a good rapport with the students and, as she would never teach them again, they could talk openly and express their opinions freely. An intimate knowledge of the school was an aid in
interpreting the students' responses. All students had been at the school for a minimum of two years with the average length of attendance being four years.

The researcher had never taught the Grade 9 students but was known to most of them by sight and through involvement in various activities in the school. She will not teach these students for at least another year and may never teach some of them. The relationship with these students was one based on mutual interests and trust as she was not an outsider. The majority of the Grade 9 students had been at the school for a minimum of 2 years with one student attending the school for only one year. This student had previously attended a girls' school in Hongkong and was a boarder at the school.

All students had therefore some considerable exposure to science teaching in an all girls' situation and, as five out of six science teachers are female (the senior physics teacher is male), these students are in an environment which lacks many of the factors which have been considered detrimental to girls' success in science (domination of classes by males, lack of suitable role models, etc.).

Methods of Data Collection

This study involved an in depth interview with each student lasting from 20-30 minutes. The interview method was chosen as it has been shown in numerous studies to be an appropriate method for examining the views held by students (Erickson, 1979). It allows interviewees to express themselves freely and at length on a topic. Unexpected responses to questions may be given and these can be pursued by the interviewer. The interviewer is free to explore the answers and clarify points to ensure that the response is not ambiguous, and both interviewer and interviewee share a
common understanding of the answer. The relationship with the students allowed for a natural, conversation-type of interview to be conducted. The 'natural' approach was specified by Woods (1986) as relating to people on a person-to-person basis.

The "Rapport Interview" as outlined by Massarik (1981) was deemed to be the most suitable. The relationship between the interviewer and the students was such that a there was already a mutual respect and trust partly based on a joint knowledge of the structure and functioning of the school as well as on previous shared experiences such as field trips and Science Fairs. Although the interview was focused by asking specific key questions, the interviewer attempted to be encouraging and sympathetic to the students' responses and, although not necessarily agreeing with their responses, she was non-judgmental. The interviewer generally asked a focus question and the student's response was further probed by appropriate questions. Where possible the student's answers set the pattern for the questions to follow the focus question. Although some questions were focused others were open-ended.

An initial pilot study was conducted with four Grade 9 students and four Grade 12 students. The pilot study was undertaken to test the suitability of the interview questions and to elicit any unexpected responses which might be worth probing during the study. A letter was sent to the parents or guardians of the students to inform them of the nature of the study and requesting their permission to interview their daughters (See Appendix). The students involved were chosen by the principal from volunteers to represent students who were (a) of varying ability in science and (b) adept at expressing themselves orally. The nature of the school is such that the principal is personally acquainted with all students and was deemed the best person to select the students involved. These interviews were conducted at times convenient to the student.
All interviews were conducted in the school waiting room, a comfortable room with subdued lighting and casual furniture. The atmosphere was relaxed with the interviewer and the interviewee facing each other while sitting on comfortable chairs with the audio-recorder set off to one side. There was no barrier between them.

Each interview began with a few minutes of casual conversation pertaining to the student's activities during the year. Before the interview commenced the students were informed that they could terminate the interview at any time or request that the audiorecorder be switched off or that a response be erased. They were also informed that the information received would be held in confidence, that they would not be identified, and the tapes would be erased at the end of the study. Each student was requested to be honest in her answers as that was necessary to obtain an understanding of their perceptions of practical work.

Following the pilot study the audiotapes were listened to and parts of the student's responses transcribed to ascertain the type of transcription necessary for the final study as well as to ascertain the suitability of the questions and the variety of responses that were forthcoming. The interview questions were modified to a small degree, one question was dropped and another substituted. The effect of marks on a student's choice in practical work was brought to the notice of the interviewer by the students and was subsequently dealt with when probing students' answers.

The six Grade 12 students and the six Grade 9 students chosen by the principal from the volunteers for the study were interviewed during the last week of the school year at a time that was convenient to them. All interviews took place in the same location.
The following focus questions formed the skeleton around which the interviews revolved:

1. Imagine you have been told that in your next science course there will not be any practical work (practical work is anything that involves you using equipment, specimens, apparatus). How do you think this would affect your experience in the course?

2. Is a demonstration the same as hands-on practical work?

3. What is the role of a partner in practical work?

4. Should you do the associated practical work before doing the theory or do the theory first and then the practical work?

5. If you carry out an experiment and your results are different from the textbook example (or a fellow student's), what would you do?
   
   Does it make a difference if the experiment which gives different results is in the physical sciences or in the biological sciences?

6. You are given a choice of doing two different types of experiments on the same subject. One experiment, A, is described in detail with all the equipment listed and the method clearly described. The second experiment, B, is given to you as a problem and some equipment you might use suggested. How you tackle the
experiment is up to you. Which type of experiment would you choose to do? Would it make a difference if the experiment involved the physical sciences or the biological sciences?

Would it make a difference if the exercise is being graded?

7. If you think back over your science courses to date, what stands out in your mind?

8. Do you think you are good at (competent in) science?

Analysis of Data

The interviews were audiotaped and no notes were taken during the interview. This allowed the interviewer to focus on the student and avoid interrupting either the interviewer or interviewee's train of thought. The interviewer tried to appear as being "interestedly quiet" (Woods, 1986), using sympathetic and encouraging "Uh-hu"s at appropriate times. All the audiotapes were transcribed and then checked against the master tapes for accuracy. A sample of a transcript for the main study can be found in the Appendix.

The interview data was then grouped together under the following categories:

a) Students' perceptions of the importance of practical work: this category includes all the relevant material that emerged in each interview about the importance of practical work. It was culled from the responses to a variety of questions both fixed and open.
b) Demonstration versus hands-on practical work: this category includes all the students' responses to a focus question pertaining to the efficacy of demonstrations versus the students carrying out the practical work themselves.

c) The role of a partner: this category includes all the students' responses regarding whether they prefer to work with partners, how many partners form an optimum group and the characteristics of a good partner.

d) Sequencing of theoretical concepts and practical activities: this category deals with students' preference regarding whether they prefer to have some theoretical background before they carry out the associated practical work or whether they prefer to do the practical work with no theoretical background.

e) Results different from the expected: this category includes students' reactions to, feelings about and response to obtaining results in an experiment which differ from the expected outcome.

f) Preferences in practical work: this category explores a student's preference when presented with two different types of practical work on the same subject and factors which would affect that choice.

g) Part of science course that stands out in a student's minds: this category summarises which parts or activities stand out in a student's mind when they reflect back on their science courses.

h) Competence in science: this category records whether students felt competent in science.

As many of the same focus questions were posed in both the pilot study and in the actual study, the responses of both groups are included in certain areas: perceived importance of practical work, the role of demonstrations, the sequencing of theoretical
concepts and practical activities, results different from the expected and competence in science. The role of a partner and preferences in practical work as well as the importance of grading to choices involving practical work were not probed in depth in the pilot study but were included in the main study as the students' responses in the pilot study revealed them to be of interest. The question as to what stood out in a student's mind was only asked in the study as the wording evolved from a pilot study question.

The pilot study involved four Grade 9 and four Grade 12 students while the main study involved six Grade 9 and six Grade 12 students. Generally there was a close correlation in the responses received in the pilot study and the main study. Grade 9 results are reported separately from the Grade 12 results although there is much commonality between them. Whenever possible student responses have been quoted, from both the pilot study and the main study, to exemplify some of the points raised. There has been an attempt made to quantify the data by collecting it into table form to simplify its interpretation but much is also presented qualitatively.
CHAPTER IV

Results

Introduction

This section will deal with the interpretation of the interview data. The data were grouped into categories based on the focus questions outlined in the previous chapter. The data include both the pilot study and the actual study except for two categories: the role of a partner and the effect of grading on choices in practical work. These areas were explored as a result of information obtained during the pilot study.

CATEGORY A.

Student perceptions of the importance of practical work

The responses for this category were collected by reading through the transcripts from both the pilot and the main study. All points relating to the students' views on the importance of practical work were noted and have been grouped as shown in Table 1. As students frequently gave more than one reason for practical work being important, the numbers in the table do not add up to the total of eight pilot students and twelve study students.
Table 1

**Student perceptions of the importance of Practical Work**

<table>
<thead>
<tr>
<th></th>
<th>Pilot Grade 9</th>
<th>Pilot Grade 12</th>
<th>Study Grade 9</th>
<th>Study Grade 12</th>
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<tbody>
<tr>
<td>Learning/Understanding</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Remembering</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Motivating</td>
<td>3</td>
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<tr>
<td>Experiencing</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
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</table>

Learning/Understanding

There is a widely held student perception that practical work is important for the learning and understanding of science concepts. This response was recorded in both the Grade 9 and Grade 12 group. Learning and understanding have been grouped together because the students' responses suggest that they see them as being similar or very closely linked and they tend to use them interchangeably. Further questioning revealed that students also see these categories as being very different from memorization of material. As J. a Grade 9 student in the pilot study explained:

Memorizing something you know the words but if you learn it you know what you are saying and can explain it in different words.

Other students explain it by saying:

Once you understand why it works that way it will help you remember the formulas better. You can't just memorize it. If you learn it well you
have it in your brain so you can apply it to other things. (N. Grade 9, pilot study).

Sometimes I don't understand those things before I did the experiments but after that I think I usually understand it 'cause you experience it by yourself and calculate things, you measure things and you take observations by yourself so, and you can come to the conclusion yourself too........Practical things are really important for understanding 'cause you can't understand everything just by theory and lessons and talking. (C. Grade 9).

The students see a very definite connection between learning and understanding and perceive the two as being quite different from memorizing. As Y. a Grade 12 student states:

If you just memorize it you might not understand it but if you learn you definitely have to understand it.

Other Grade 12 students stated it this way:

For chemistry and physics you just know the principle, you understand the concepts and you can do the problems without memorizing anything........Actually sometimes if you don't understand something then obviously you have to memorize it in order to write it out, right, when you are asked about it but if you really understand it then you don't need to do anything. (R.)

Memorizing is just strictly by the book, you could repeat back what you learned. But understanding it, you can take the knowledge and apply it. I think hands on experience lets you do that. (J.)

Remembering

Practical work is also seen as a definite aid to memory. Students refer to thinking back to practical work when answering test questions. The fact that doing practical work is an aid to memory may be foremost in students' minds because of the time of year when the interview took place. The Grade 12 students were preparing for
Provincial Government Examinations during the pilot study and were either in the middle of them or just finished during the main study. The Grade 9 students also had formal terminal examinations at the end of the summer term. However, when students were asked what stood out in their minds about their science courses, for five of the six grade 9s it was practical work, particularly biology. It is worth noting at this juncture that as far as Grade 9 and Grade 12 students are concerned there is only one type of biology practical exercise, the dissection. This is in spite of the fact that many other labs were done during the year (food tests, enzyme activity, etc.). This observation will be further explored later. It does, however, lend weight to the students' assertions that they remember the practical work although the theory involved may not be remembered clearly. Many students when faced with an examination or test question state that they remember back to the practical work associated with it and from that starting point they deal with the theoretical concepts. This was common to both the Grade 9 and Grade 12.

A lot of practical experience I've had, I remember it a lot better quite a long time down the road. (J. Grade 12)

But if they stopped it (practical work) in physics, there's a lot that I remember, you can easily remember the labs that you've done and figure things out from it, so it's a lot easier to understand, especially with magnetism and stuff because if you have the formulas and stuff, if you remember what you did in the labs you can figure out what it is so you can solve the problems because of it. (A. Grade 12).

I think it is easier for me to remember something if we are going to have a test on it if I have actually had the experience of doing it. ......it just stays with you more. (J. Grade 9).

Student: If you actually do the experiment you actually remember....... 

Interviewer: So if you are answering a test?
Student: Yea, you would actually think back to what you are doing in your experiment, like an idea of what it was like so you kind of remember what your results would be. (Ch. Grade 9).

If you are doing it, experiment, you know, you are concentrating a lot so that you kind of remember it for a long time 'cause it is kind of pictured in your mind and so it's, is not just letters and words, it's like a picture 'cause if you are memorizing your notes they are all words and diagrams and they get all jumbled together and you get everything all mixed up but in the experiment you wouldn't, you would be usually using different kinds of equipment so you kind of remember each lab separately. (Ch. Grade 9)

The students appear to use the experience of carrying out practical work as a vehicle for both the understanding of the concept and for remembering the details of the concept necessary to solve problems in a test situation. It suggests that the absence of practical work may make the learning and understanding of concepts more difficult and possibly affect the recall of information.

Motivating

Practical work has a strong motivational value for students. Only two students in the study had any reservations about practical work and they seemed to focus on the element of time. As Ch. in Grade 9 stated

They always seem so complicated and the teachers never explain it really fully, and accurately to us and so, ....every...., classes aren't long enough so we are always rushed, we always make mistakes so we have to start over again.

Yet the same student particularly enjoyed dissection although she did not enjoy practical work in physics, a finding that was not unusual in the Grade 9 group. Another grade 9 student in the pilot study found laboratory activities frustrating and misleading.
Labs can cause so much confusion sometimes. (N. Pilot study)

This student seemed to feel very pressured about time and considered practical work to be very time consuming when time could be spent on a more worthwhile activity. She considered demonstrations to be as effective as hands-on practical work and would have preferred to spend more time on discussion. The same student also stated that English was her favourite subject. Both students did however see labs as aiding in understanding and remembering material but they considered them to have some drawbacks.

All other students felt that not only was practical work an enjoyable experience but it had a strong motivational factor as well. It prevented boredom setting in during science class, kept them interested and they looked forward to lessons when they knew there was to be a laboratory activity. One grade 12 student stated that not only would she have done less science courses (she took three science 12 courses) but the absence of practical work

Will make it very boring and I won't be interested any more. (Y.)

The strongest statement came from a Grade 9 student who stated that

Student: It (practical work) is quite important to me in the area of sciences because it is something I look forward to in that without it I would be really bored in science and it's something to kind of keep me going through the term and it helps me learn..... Towards the end of the term it's, it's getting kind of boring and it's,... I've learned so much that I don't want to learn anymore and everyday you sit in class and you write down notes and don't actually get to see it or anything like that its not the same as being
actually able to do something rather than learn specifically by memorization or writing notes.

Interviewer: So if I told you that in Grade 10 Science next year you weren't going to do any practical work at all, what would you feel like?

Student: I'd feel like I wanted to drop science. (K.)

Practical work is obviously an enjoyable activity, one which may make science classes very different from other classes in school and one which encourages students to take further studies in science. It is worth noting that the majority of girls have a very favourable attitude towards practical work, particularly dissection.

Experiencing

The students also felt that the actual experience of doing practical work was valuable, not from the point of learning specific skills which was not mentioned by any students, but from the effect of visual learning, learning by making mistakes, and learning by doing. The students all seemed to have a knowledge of how they were best able to learn material and many referred to the importance of actually seeing something happen or experiencing the touch or feel of it. The sense of touch or feel was particularly important to the Grade 9s although it was mentioned by two of the Grade 12s.

I think back and remember touching and feeling a shell and remembering what phylum it was....(J., pilot study)
As one Grade 9 stated

Well, in biology you get to kind of touch things more, I guess, you know and mush things about here and there, and well, I guess if you dissect a fish I guess, I mean you have to be careful in all experiments and mmmmm.... Well, in physics I guess, it is just straight forward calculations but in biology you get to kind of explore the fishes stomach or something. (Ch.)

It appears that in laboratory activities involving practical tasks all the senses are engaged to a greater or lesser extent and students value this aspect of the activity.

Other aspects

Certain other facets of practical work surfaced in a few of the interviews. A concern for safety was expressed by some of the Grade 9 students and this affected their answers and choices in other areas of the study. One grade 9 student would choose a stated lab rather than an open exploration in chemistry because of the danger of it exploding in her face while another expressed concern about lighting things and getting burned. One student thought that carrying out experiments helped develop decision making skills while one Grade 9 student focused in on the atmosphere in the laboratory during practical activities. She stated that

I think it most feels better, it doesn't seem really like a school, a classroom is very serious, I think it improves the relationship between the classmates and teacher.......I think it does because you have to talk a bit and discuss a bit and in experiments and it improves the atmosphere and I'm happier. (C).
Summary

The overwhelming impression from the study is that students value practical work as an aid to learning and understanding of scientific concepts and as a memory aid. The actual manipulation of equipment, the sensory input from a variety of sources and the feel and touch of materials all appear to aid in the learning process. Their replies suggest that when they are responding in test situations they are recalling the practical work involved and using it to clarify their thoughts and respond to the question or work out the problem. Practical activity is generally thought of as being an enjoyable activity, one which is looked forward to and which encourages students to pursue sciences at the senior grade level. Although a small minority of students expressed doubts about the value of practical work, even they felt it helped them to understand the concepts better. It was generally the type of practical work that they did not enjoy rather than practical work in general, with physics practicals being singled out as being least interesting. The nature of the practical work that the students enjoy will be commented on later in this study.
**CATEGORY B**

**Table 2**

**Demonstration versus hands-on practical work**

<table>
<thead>
<tr>
<th></th>
<th>Pilot Grade 9</th>
<th>Pilot Grade 12</th>
<th>Study Grade 9</th>
<th>Study Grade 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands-on preferred</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Demonstration preferred</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No preference</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

From these results it is obvious that students prefer to have a hands-on approach to practical work rather than view demonstrations. Two of the students would have accepted a demonstration in the physical sciences but really preferred hands-on in biology. Again dissection was the practical work they had in mind. They felt that as long as they could see it in physics and chemistry it was acceptable but in dissection they liked to see and feel it for themselves. The students involved preferred biology to the physical sciences.

There was a general consensus of opinion that demonstrations were preferable to the absence of practical work but they did not have the same impact from a learning perspective as did hands-on practical work. Demonstrations by the teacher were seen
as being very similar to a regular classroom situation where the teacher taught and they watched. As students said:

Your concentration tend to go away after a while. You start to talk to you lab partner. I don't think it is as effective 'cause you look at it and you go Oh yea, I understand it and then if you try to do it yourself you find out you don't. It is much easier for you to learn it to do it yourself. (E. Pilot study. Grade 12)

It helps to understand the method of the procedure of the experiment. Other than that, it is sort of like teaching. I think it is more effective if the individual does it themselves. (K. Pilot study, Grade 12)

It is just like watching a film then if you don't get to do it. (Ca, Grade 9)

There is once again the perception that if the students actually carryout the practical work they will understand and remember it better.

I think when I see a demonstration, I won't remember it but if I did it myself I will. (N. Grade 12)

I think if you can do it yourself, if you're doing it yourself and you have to do the graph yourself, you can really see what's happening instead of if somebody else is doing it and you are just watching, you're just watching it happen and you're not finding out what's happening, so I think it's probably better to do it yourself. (A. Grade 12)

The idea that if you do it yourself and make a mistake you will learn from that mistake is prevalent while if a teacher does it he/she will seldom make a mistake and therefore a learning opportunity has been lost.

It is better if you have the chance to make mistakes and then redo it and then you'll get set into your mind what is right. (J. Grade 9)

When the teacher demonstrates it she's doing everything where, when you do it yourself, you get the chance to do it and you get to see it and if you mess up then it is your mistake and if the teacher messes up then you
don't really, I don't really understand why she has done it wrong but if I do it wrong then I really understand more about what I'm trying to do, right? (K. Grade 9)

It is like looking around. You don't actually learn. Like they always do it right, right? So you can't find out anything you can go wrong like when you do it yourself you always go wrong and then you learn from what you got wrong. (R. Grade 12)

The above statements do not mean that students see no role for demonstrations in the science laboratory. Rather they see a different role for them when compared to hands-on practical work. Demonstrations are seen as being necessary to illustrate skills and procedures the students have not yet seen or mastered, to illustrate how a complex procedure should be carried out or to be necessary from a safety point of view. Demonstrations are, however, not an adequate replacement for practical work and do not lead to the same understanding of concepts or retaining of information as hands-on practical work.
Students in Grade 9 and Grade 12 showed a different response when questioned about whether they preferred to work with a partner or by themselves. The Grade 9s had a definite preference for working with a partner while the Grade 12s generally preferred to work by themselves although the choice was dependent on other factors. One Grade 12 preferred to dissect on her own because:

Student: It is much easier, for example if you are dissecting a pig and it is really interesting, I really want to do it on my own, and then sometimes I don’t know, you just get mad at the other person if they do something wrong because they cut through the skin wrong or something.......Physics is better to do with a partner I think.
Interviewer: Now why is that?

Student: Because I don't usually know what I am doing. (Y.)

The students who expressed a preference for working on their own did so because they felt they learned more if they did everything:

I like working by myself better, I mean it depends what the lab is but, umm, especially in chemistry, the less number of people you work with, the more of the lab you have to do, so it can, you remember everything you have done. (A. Grade 12)

Well, it is more fun to work with a partner but then you learn more if you do it by yourself. (R. Grade 12)

Grade 9s showed a definite preference for working with a partner. The role of the partner was to help ensure that the procedure was carried out correctly and prevent mistakes. The fact that they were working with a partner seemed to make them feel more secure in what they were doing and less anxious about getting the expected result.

It is more interesting to work with somebody and you can ask questions and maybe sometimes you forget the instructions and something like that so if you have a partner you won't forget anything, I mean you can ask her and you won't do anything wrong and, yea, it is better because she can help you and you can help her. (C. Grade 9)

Well, you don't feel all alone and, I don't know, it's mmm, you feel more relaxed and stuff with a friend and ...

(A. Grade 9)

Well because mm...you have more fun to me and if you don't understand something then they probably will and you enjoy it more because I learn with someone else rather than just having to do everything myself and if I'm with a partner I don't feel so nervous about what I'm doing, about making a mistake because it doesn't seem as important to make a mistake when I'm doing it with a partner. (K, Grade 9)
There seems to be a definite feeling of security present when a student is working with a partner as well as the feeling that 'two heads are better than one' when trying to ensure that a practical exercise is carried out correctly. The feeling of security was expressed most strongly by the Grade 9 students who were unwilling to take the risk of doing the wrong thing. Making an error made them feel stupid or inadequate and insecure. The Grade 12 students felt comfortable working on their own unless the task was confusing or needed more than one pair of hands. They seem to have acquired a confidence in themselves that is lacking in younger students.

Students also have very definite perceptions of the characteristics of a 'good partner'. 'Good partners' are people who pay attention in class, are competent at handling equipment and following directions, do not do either all or none of the work involved in the practical. They must also have good communication skills and be easy to get along with.

Someone who doesn't try and do everything and not let you do anything and someone who listened and is willing to take part in the experiment and who doesn't get grossed out by eyeballs and that kind of thing. (K. Grade 9)

I think one with co-operation and she lets you do something 'cause I hate those people who do experiments and just do it all by themselves and they just do everything. I want to do this. I want to do that. That's not really good. (C. Grade 9)

Someone that is reliable, is careful with what it is, thinks about what she does before she does it, well, someone that you get along with well, someone that kind of reads the experiment before she does it, and someone that has a good brain, scientific brain I guess. (Ch. Grade 9)

The question of the academic ability of the partner was raised by some students. Partners were preferred to have either the same academic ability or be academically
more able. Students who were able in science and worked hard to obtain good marks preferred to work with a partner they considered to be more academically able than they were, while the less able students preferred to work with people on the same ability level. Some students feel that they learn more if they are working with someone they consider more academically able than themselves while other students prefer to work with people of the same ability level who will not get impatient with the speed they work at or the questions they ask. Partners in practical work are obviously important particularly at the Grade 9 level and students feel that they cannot work with just anyone. The partner seems to be necessary to give confidence and reduce an anxiety producing situation to a more relaxed one. Although at the Grade 12 level students either preferred to work alone or with a partner in certain situations it is worth noting that a student who was ambivalent about working with a partner stated that:

It is kind of weird but then if you know that you have to do it by yourself you kind of get scared. (R. Grade 12)

There appears to be security in numbers no matter how good you are in science or how many years you have been working in a school science laboratory. It should be noted at this point that all the students interviewed felt quite competent and comfortable in the laboratory.
From the above table it is obvious that students show a strong preference for a knowledge of the theoretical background before the associated practical work is carried out. The student in the Grade 9 pilot study who preferred to do the practical first confided in the interviewer that the vocabulary involved in science 'blows me away' and if she did the practical work first she was better able to understand the theory as she felt she could work it out for herself from her results. This may be indicative more of the student's language problems rather than a true reflection of her preferences. The Grade 12 student who is shown as having no preferences did feel ambivalent towards the problem. Although she preferred theory first in biology but not in physics, she did not feel the sequence was critical for her.
The preferences were clear cut in both Grade 9 and Grade 12 and the students' supporting reasons were very similar. There was a very strong feeling that you had to know what to look for in a lab or you focused on the wrong thing and missed important points. There was also a fear that by focusing on the wrong thing they would have a poor recall of the practical and be incapable of remembering exactly what had happened, even if they were corrected by the teacher. As one Grade 12 in the Pilot study stated:

This is something I wanted to tell you. In physics I found that if I didn't know what I was doing before I did the lab. I didn't understand what I was doing or why I was doing it or why my results turned out the way they did and so I got completely discouraged, not knowing. Like with physics I think it was really, really important to have the work before you did the lab and that is what we are doing in M.s class. .....I feel more comfortable that way. (G.)

As another Grade 12 stated:

I think you should do the theory first so you have some idea what you're doing and then you do the practical work to see what it really is.......I don't think I could do a physics lab without doing the theory first. Actually I don't think it's possible, you wouldn't know what to do unless you had some idea, some background. (N.)

The perception that practical work is to give improved understanding of the concepts in science has a not insignificant effect on the student's choice as does the idea that it helps her remember the theory.

Theory first because whenever you are doing the lab you already know what should happen or you can see it, it just helps reinforce it or you can understand it because with a lot of physics labs, a lot of it is hard to visualize anyways. (A. Grade 12)
Well, for me it would probably be better if we did the theory and then the practical work so if there is any questions I have after that they will be answered by that and just, I just easily tend to forget if I did the theory after. (J. Grade 9)

I guess I would remember it better if we did the theory work first, because I would understand it before I did the lab and so I could kind of understand the lab more fully before I did it and not just start on something new and not know about it. (Ch. Grade 9)

It appears that students have a definite preference for some knowledge of the theoretical concepts before proceeding with the associated practical work. This theoretical knowledge could come from a lesson taught by a teacher or a textbook assignment that could have been assigned for homework. Regardless of how it was obtained it was deemed necessary by the students. Many students stated that they liked to discuss the theory again after they had done the practical work to ensure that they really understood it. They appear to have a tacit knowledge of the role of practical work in the development of theoretical concepts and may be approaching experimentation in a manner similar to scientists.

CATEGORY E

Results different from the expected

The results for this category came from a focus question which asked students what they would do if they carried out an experiment and their results differed from either the textbook or fellow students. The importance of the grading of practical work to their answer was mentioned in the pilot study and this question was subsequently altered in the study to include an exploration of the role of grading of laboratory exercises.
Table 5

Results different from the expected

<table>
<thead>
<tr>
<th></th>
<th>Pilot</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade 9</td>
<td>Grade 12</td>
</tr>
<tr>
<td>Negative feelings</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Repeat procedure</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Would alter results</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Would not alter results</td>
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<td>2</td>
</tr>
</tbody>
</table>

The numbers in the pilot study do not account for all the students since the question of altering results if marks were involved was not brought up by the students until the study was underway. The results were deemed worthy of inclusion as they tend to reinforce some ideas brought forward by the study.

Obtaining results which do not correspond to those in the textbook or to those reported by fellow students resulted in feelings of stupidity, frustration, anxiety, and disappointment. These negative feelings were of a personal nature and none of the students referred to feeling negative towards science in general. They all thought that they were responsible for what they saw as their inability to follow directions correctly.
Student: I would feel stupid.

Interviewer: Stupid? Do you think if you get different results it is because you are stupid?

Student: Yes, most of the time. (R. Grade 12)

A bit down, I guess as like everyone else gets the right answer or the right result and you're the only one gets the wrong one. You would probably also feel rushed too as everyone is going on to different thing when you are trying to do it over again, you would probably feel frustrated if it happened to be you that did it wrong. (Ch. Grade 9)

The problems of grading practical work surfaced when it was suggested to students that sometimes students at University altered their results and students were asked if they would be tempted to do that. Most students stated that they would repeat the activity or ask the teacher for help. Their answer to the question, however, depended on whether or not the lab was to be graded. If the labs were not to be graded then they would not alter their marks and some students stated that they would not alter their marks under any circumstances although they may write an explanation for the anomaly beside their results.

Student: If I was under great pressure and I needed the labs I think I guess I would.

Interviewer: Would it make a difference whether the lab was being graded?

Student: Well, I think we would all tend to if we were under pressure and it was more marks, I guess we would rather than if it just wasn't for marks. (C. Grade 12)

If it wasn't being marked I think I would just leave them. (N. Grade 12)

If I really need a good mark...Right. If I know that the teacher will mark it and then go 'What did she do?' or something like that and then fail you or something then I might change it but if you are just doing it for fun, I don't know, I think I would do it again. (R. Grade 12)
The very act of grading practical work appears to have a significant impact on students' treatment of results although the Grade 9 students seemed to be less influenced by grades and less likely to alter them. One aspect of altering results was voiced by a Grade 12 student who stated categorically that she would not alter results:

No, I am usually so muddled, I wouldn't know what's happening, especially in physics. (Y.)

To successfully manipulate results and improve on the ones obtained a student must have a sound grasp of the concepts involved and therefore the ability to do this is an indication of a good understanding of the topic.

When questioned on the grading of practical work the students belief that practical work is to aid in the understanding of concepts again showed.

Yes. I do, I think, well in something like chemistry, I don't really think it matters, because a lab is just doing it yourself so you understand what you are doing, I don't think the results are too important, but in physics, if you set up the circuit wrong you would never know it if that wasn't marked, right? (N. Grade 12)

Well some people are much more accurate, well we do it...we so differently in each lab, right? If you do it, if you do this lab very well it doesn't mean that you do the other labs accurate so it doesn't mean anything at all except for practice and learning so I don't think it should be marked. (R. Grade 12)

Yea, I think so, like how you participate and what you have learned and have a test and something. (A. Grade 9)

Student: I think some labs should be and some labs shouldn't and I think that if they are graded and people get different results from someone else there shouldn't be deducted marks because that is what their experiment told them and you learn by your mistakes.
Interviewer: You said some should be and some shouldn't. Which ones should and which ones shouldn't?

Student: Well labs that are on say an exam or important to that particular work, then they should because if you did it wrong then you would want to know that you had done it wrong and so you could try and see what you had done wrong but labs that are not really going to affect it in your term or on to an exam in any great length I think they should be done for our own good. (K. Grade 9)

The very act of grading practical work in a particular way can have a significant influence on students and may be encouraging them to 'fiddle their results'. This activity seems to be at odds with the students' perceptions of practical work as a means of increasing scientific understanding of a concept, and may represent a divergent view between students and teachers as to the role of practical work. The role of evaluating practical work may need to be rethought. If, in the students' view, it is to increase understanding of the theory involved, then grading or marking should be confined to evaluating their knowledge of the theory. If it is to master the skills and processes necessary to undertake a scientific investigation, evaluating a written report may only be evaluating the ability to obtain the 'right results' by whatever means the student uses, including altering the results to fit the theory. Student responses suggest that grading the practical work takes away the fun from it.

If I know that the teacher will mark it and then go 'what did she do?' or something like that and then fail you or something that then I might change it but if you are just doing it for fun, I don't know, I think I would do it again. (R. Grade 12)
Preferences in practical work

The results in this section were obtained in response to the following focus question: 'You are given two different types of experiments on the same subject. One experiment, A, is described in detail with all the equipment listed and the method clearly described. The second experiment, B, is given to you as a problem and some equipment you might use suggested. How you tackle the experiment is up to you. Which type of experiment would you choose to do?' Where clarification was required it was given with experiment A being compared to a recipe in a cookbook. After the students answered, if they did not inquire if it was to be graded, they were asked if their choice would be the same if the experiment was to be graded. As the issue of grading arose during the pilot study, not all students in the pilot study were questioned about the effect of grading as the table of results will show.

Table 6
Preferences in practical work

<table>
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<th>Pilot study</th>
<th>Grade 9</th>
<th>Grade 12</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Lab B</td>
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<td>4</td>
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<tr>
<td>Marks</td>
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<td>2</td>
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</tbody>
</table>

As some of the students asked if the experiment was on a topic they were familiar with, they were told it was. Familiarity with the topic was an important aspect
of their choice and if the topic was new the results would have been considerably different.

Table 7

Preferences in practical work

<table>
<thead>
<tr>
<th>Study</th>
<th>Grade 9</th>
<th>Grade 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lab A</td>
<td>Lab B</td>
</tr>
<tr>
<td>No marks</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Marks</td>
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<td>2</td>
</tr>
</tbody>
</table>

Unfortunately one of the Grade 9 students was not asked the effect of marks on her choice although she had originally chosen lab B. Another student's choice would have depended on the time allocation. Although she is reported as choosing lab B if marks were involved, this was assuming there was no time limit. If there was a time limit then she would have chosen lab A. The two grade 12 students who chose lab B when marks or grading were involved stated that they did so assuming that the grading would reflect on the type of investigation that they had carried out and not on obtaining the correct result. The student who chose lab A when no grades were involved stated that she was used to having trouble with labs and felt safer doing a lab that is all set out for her.
One of the most interesting aspects of the result to this question was the wide range of reasons which governed a student's choice.

Student: Let me think. Can you turn off for a little while?......I think I would prefer the one without the instructions 'cause first it is more interesting and I think if you figure it out yourself um..you understand it well, better and yea, you learn a lot from that and you...I think, like for example the Science Fair, did the same thing so I didn't have any instructions so I did it myself and I really learned a lot from that so I think it is better.

Interviewer: Which one do you think you would learn most from?

Student: If it is for exam, I think the instructions, the one with instruction is more useful but for real life, practical life, I think the second one is better 'cause you figure it out by yourself and you understand it.

Interviewer: Which one would you enjoy more?

Student: I think the second one 'cause I would choose that and that one is more interesting.

( C. Grade 9)

The students all expressed the opinion that Lab B would be more demanding and more satisfying to do and that they would learn more from it but whether they would choose to do that lab was dependent on a number of things.

Grading of the labs obviously had a significant impact and their reasons for choosing A in that situation is that it is easier to obtain good marks where everything is set out for you. The need to obtain good marks will obviously over-ride their feelings that it would be more interesting and satisfying to do lab B. Familiarity with the material and the procedure was also important. Students did not feel they would like to do a more open-ended lab if they were unfamiliar with the material and/or procedure.
It depends what kind of lab it is. If I know something about it then I would rather think up the procedures for myself. Like be more creative or something but if I know nothing about it, then I would rather have someone tell me what to do. (R. Grade 12)

Students needed to feel secure in their knowledge of the material and the possible procedures before they would feel they could tackle a more exploratory lab. The element of danger is of considerable concern to students, particularly Grade 9 students. While biology is seen as possessing few elements of danger even if they are using sharp scalpels, chemistry is perceived as having inherent danger and this would affect their choice.

Interviewer: Given a complete open choice which would you prefer?

Student: The second one (B).

Interviewer: The second one. And would it make a difference whether the problem was in the physical sciences or biology?

Student: It would make a difference if it was in bio.

Interviewer: So you would do the second choice if it was biology?

Student: Uh-hu. Yea.

Interviewer: And if it was physical sciences?

Student: Mmmm. It depends.

Interviewer: What would it depend on?

Student: Well, I guess this has a lot to do with chemistry too. If you are mixing chemicals together and you don't want a big chemical reaction you have to make sure that, you know, umm, things are proper but I don't know, something like figuring out the acid or base, it doesn't really matter because nothing is going to explode in you face. (A. Grade 9)
When questioned most Grade 9 students would prefer to do an open type of inquiry in biology rather than in the physical sciences. Whether this is a reflection of the fact that the students show a definite preference for biology over physical sciences or is influenced by the perception that there is an element of danger in the physical sciences is unclear. It should be noted that students do not perceive physics as being a dangerous activity, simply one in which they are not particularly interested.

There are other factors which would affect their choice. Students said that if they were feeling lazy, tired or pressed for time then their choice would be A and some days they simply do not feel like working and thinking hard. There is obviously an emotional component to their choice.

When questioned, all the students except for one Grade 9 stated that they had never carried out an experiment similar to lab B. This is in spite of the fact that the school has run a large and successful Science Fair for the past five years in which almost all the students interviewed had participated at least once. They had therefore had the experience of forming their own hypotheses and developing their own experiments. Somehow this activity is not seen as part of school science but remains apart.

The emphasis given to the choice of lab B because it was not only more satisfying but also a better way of learning and becoming familiar with the material is worth noting. It provides support for the students' view of practical work as being important for understanding and learning scientific concepts. This is the dominant reason for undertaking a more open-ended laboratory activity but it is subservient to obtaining good grades, especially in the Grade 12 year. They seem to appreciate the necessity of good grades to gain entry into the career of their choice.
Table 8

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<thead>
<tr>
<th>Study</th>
<th>Grade 9</th>
<th>Grade 12</th>
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<tr>
<td>Practical work</td>
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<td>Subject matter</td>
<td>1</td>
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<td>Teacher/approach to subject</td>
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The appeal of practical work seems obvious from the results. The teacher/approach to the subject category also involved a positive attitude to practical work as both the teachers mentioned carry out laboratory activities as an integral part of their teaching. The subject matter reflected a personal choice of the students. One Grade 9 student found astronomy fascinating and a Grade 12 student had really enjoyed her Chemistry 11 course. The practical work done by students seems to make a lasting impression on them. As one student put it

Biology does because it's my favorite science. Experiments in biology and chemistry stand out actually. Most of the stuff we do in class when we take notes or tests and so on are kind of a blurr but it's the actual experiences that stick in my mind and the humorous things that happened during them. (J. Grade 12)

Other students referred to not enjoying their Biology 12 course because it lacked lab work.
I didn't really enjoy biology this year because we just wrote notes all class and I really didn't like that and I didn't like not having lab work either. (N. Grade 12)

Well, I'd just like to say that this year I don't think biology was as much fun as last year because it was just copying down of notes and I mean each class we would just be sitting down and copying down notes and ....um.. it really makes a difference to one's attitude towards a class if say there is something fun to do in class and it is a lab or an experiment to look forward to doing. (C. Grade 12)

In Biology 12, I don't think we got enough practical work. That's just a personal comment. (J. Grade 12)

For the Grade 9 students in particular, when they thought about what stood out in their minds, the practical work they remembered was dissection.

Dissection in biology science classes seems to differ from other practical work. The majority of students refer to it as an enjoyable and interesting activity, one which they look forward to and prefer to undertake by themselves. Many students stated that dissection was the only practical work they undertook in biology science classes although discussion with their teachers and a review of the Record of Work for the previous year showed this not to be the case.

The appeal of dissection seems to lie in a variety of areas. The Grade 9 Biology course includes a unit on the Salmon Resource and a unit on Human Biology which has been expanded in this school to include Family Life Education. The students undertook two dissections: a perch, a sheep's heart and viewed a rat being dissected by the teacher. Numerous other labs were done including a range of food tests, enzyme experiments, recording heart rate, etc. None of these labs was mentioned by the students. The Grade 12 Biology also devotes approximately 60% of allocated time to human biology and includes a dissection of the fetal pig.
The stated reasons for the appeal of dissection varied but seemed to have some common themes. There is the idea that it is something unique to school science, something that you won't get the chance to do again.

It is interesting and you don't have the chance, you don't always have the chance to do it 'cause you don't dissect a heart, you won't buy a heart to dissect it, but you know for the physics thing it always happens in real life, not always but sometimes but for the biology thing you can just do it at school and maybe it is the only chance in your life if you are not going to study biology later, well you know. Of course if you are going to be a doctor you are going to have many chances to dissect but not if you study business or something like that. (C. Grade 9)

Student: Well because it is the kind of thing everyone looked forward to but as soon as we got our eyeball or worm or something everyone would shy away and go Oh! Gross, this is disgusting. It was, I wouldn't consider it fun because it smelt really bad but it was a lot more interesting and different.

Interviewer: So what made it memorable besides everyone going Oh!?

Student: Well the fact that you were cutting open something that used to be alive, and the, that, that's what is inside you in some cases, you are not the same as a worm or anything but you are seeing in real life what something looks like rather than a model or something.

Interviewer: So you like dissection?

Student: I like it because you see inside but I don't like getting my hands in all the goup.

Interviewer: Do you think a video would be the same?

Student: No.

Interviewer: No?

Student: No.

Interviewer: What would be the difference?
Student: In, when you are doing it yourself then you are actually doing it and you are the one who has to cut it open but in a video it is not the same when it shows you what to do, it is not the same as doing it 'cause you won't do it the same and it will be different for everyone. (K, Grade 9).

Even although students may not enjoy the act of dissecting or the associated odors, there is the element of exploration present. They are being given the opportunity to cut open and examine the inside of a formerly living thing. They are the first person to actually explore and see the inside of it and it is recognised by the students that their animal may be different from that of other students and is unique to them. The following response from a Grade 9 student compares dissection to experiments in physics which she did not enjoy.

There is always like numbers and everything on the equipment and they are kind of all similar. Its like you get 500g weights and everyone else gets the same one but in biology you get a different sized rat or something and you get to kind of do something yourself, you are the first one to actually handle that animal and dissect it so that makes you sort of feel that you are unique, but in physics you know you are just repeating experiments with the same kind of weights and...(Ch.)

The positive feelings towards dissection were not confined to Grade 9 students but were evident in the Grade 12 sample.

I would say a good lab was one I got a lot out of, if I got the opportunity to, in a dissection, to actually get in there and get a lot out of it so ...I had a lot of time to explore my own way and explore everything I was interested in, everything I wanted to see, I would say it was a good lab. (J.)

The interest and fascination with dissection as well as the fact that students remember it for a long period of time seems to be the result of a variety of factors. It is
an experience that is unique to the school biology laboratory and one in which they can undertake individual exploration. There is always the element of surprise in that you don't know what you are going to actually see in there although you may have some knowledge of the anatomy. It is akin to opening a box in which you know there is a sweater but you don't know the kind or colour of sweater. It involves a number of senses: touch, sight and smell, all of which seem to be important. Last, but not least it is directly related to the students themselves. The fact that you are cutting up a heart that is very similar to the one inside you that is keeping you alive as long as it functions makes a strong impression on the students.

The students feelings about dissection were elicited as an incidental to the main thrust of this study and the information gained is not adequate to gain an in-depth understanding of the appeal of dissection. The comments of the students however may help to shed some light on the role of practical work in the sciences and the more favourable attitude students, especially Grade 9 students, have towards biology when compared to physics.
These results clearly indicate that the students felt competent in the lab and their answers to previous questions were not influenced by feelings of being unable to handle equipment or carry out experiments.

Summary

The results show that practical work is an important aspect of school science education. It is an activity valued by students in both Grade 9 and 12 for a variety of reasons, the most important being the enhancement of understanding and learning which it brings about. A prior theoretical knowledge is seen as being essential if the maximum amount of information is to be obtained from the experimental situation. It is viewed as being an enjoyable activity which encourages girls to continue in science. The type of practical work which students would undertake given the choice is influenced by a variety of factors,
not least of which is whether the work is to be graded and the time allowed. The poor risk taking behavior of girls is indicated by the role of partners in Grade 9 and to a lesser extent in Grade 12, and the inadequate and negative feelings about themselves which follow the obtaining of a wrong result. Biology is the preferred sciences among the students and this is particularly obvious in Grade 9.
The purpose of this study was to investigate girls' perceptions of the role of practical work in High School science education. This chapter will summarize these perceptions and discuss their implications for science education.

Discussion of major findings

This section will examine the major findings reported in Chapter IV, organising them around the major research question and the sub-questions which dealt with the type of practical work undertaken and how it was carried out.

Major Research Question

What are female High School students' perceptions of the role of practical work in their school science education?

The practical work undertaken during science classes was seen by female students to be important for a variety of reasons but one reason over-ruled all others: the understanding and learning of the material, two concepts that they saw as synonymous. A review of responses to all questions asked during the interview showed that ultimately their responses to all questions were determined by the need to understand the concepts. Choices between working with a partner or by themselves, the type of practical work they preferred and the sequencing of the theory and related practical work were determined by what the students perceived as being, for them, the best way
of learning and understanding the concept. This finding corresponds to that of Denny and Chennel (1986) and Renner, Abraham and Birnie (1985) who reported that students considered laboratory exercises to be of assistance in understanding and learning science concepts.

Practical work was viewed as being a vital part of coming to or negotiating an understanding of a concept. The students are perhaps coming to what Solomon (1988) refers to as 'the confluence between word meaning and practical perception'. Theoretical discussions, while perceived as being necessary pre-requisites for the successful completion of practical work, were not in themselves viewed as being adequate for the complete understanding of the concept. The 'hands-on' approach of practical work, the manipulating of materials, the construction of apparatus, the feel of the material being dissected, all appeared to play a role in building a working knowledge of the concept and developing a tacit understanding of how it works. This confirms the findings of Renner, Abraham and Birnie (1985) who reported that, in the physics laboratory, students found that practical work made concepts more believable and understandable, as well as making them more memorable.

The enjoyment factor cannot be ignored here. Students looked forward to a lesson with practical work. It made a break in routine, allowed them to move around and work in co-operative groups. This motivational factor cannot be underestimated, especially as it appears to attract female students to science.

The importance to the students of understanding the concept and remembering the material may be influenced by the type of educational institution these students attend. It is a school which values academic achievement and has formal examinations twice a year. These examinations concentrate on the acquisition of accepted science
content and the understanding of the concepts involved. Students and parents treat these examinations seriously and students generally work hard to achieve a good grade. Formal practical examinations are not used as part of this particular evaluation and practical work could therefore be viewed only as a means of increasing understanding to improve exam results. Many students feel pressurized to obtain good marks as their parents may be making monetary sacrifices to send them to the school. These students are expected to succeed. Their perceptions about the role of practical work in their science education may be influenced by this. This does, however, tend to support their belief that practical work helps them in the understanding of theory. If their experience in the classroom has shown them that practical work has little or no role to play in the elucidation of a concept, then they would value it less and prefer to spend time on other areas of scientific enquiry.

The presence of British Columbian Department of Education examinations in all science courses at the Grade 12 level could also influence a student's perceptions. These examinations currently account for forty percent of the student's mark for their Science 12 courses. The examinations closely follow the Curriculum Guide for each subject and their emphasis is on content. This has an effect on the type of science taught in schools, particularly in the Grade 12 year, but there may also be a 'filter-down' effect on both teachers and students. Learning accepted scientific content may therefore be important to both the students and teachers and this may affect student's perceptions of the role of practical work in science education.
First Specific Research Question

How effective are demonstrations versus hands-on practical work in meeting these students' expectations of practical work?

The students' views on the role of demonstrations in school science added credence to their views on the importance of practical work. Demonstrations were seen as being little different from a teacher talking about a laboratory exercise or viewing a video. The demonstrator, frequently the teacher, seldom made a mistake as he/she carried out the experiment. Students viewed this as a less valuable experience as they felt they learned more if they made a mistake and then had to work out what went wrong. If the teacher carried out a demonstration which didn't quite work out as planned, a not uncommon situation in a science teacher's life, the students felt frustrated as they did not understand what happened. This lead them to feeling confused and unsure of what the point of the demonstration was.

The concentration required to watch a demonstration, or rather the lack of concentration and distractions that result were also mentioned by students as leading to less understanding about and retention of the material. Although superficial comprehension of the material may occur and some students felt they had grasped the essence of the demonstrated experiment, a subsequent attempt to repeat it made them realize that they were mistaken.

This is not to say there was no role for demonstration in school science. Students felt they were valuable in illustrating skills and procedures that were
unfamiliar to them. They also felt that they may be necessary from a safety point of view.

Most research studies have shown no significant difference in achievement, attitude, critical thinking and knowledge of the processes of science between instructional methods which used the laboratory, demonstrations or discussion (Hofstein and Lunetta, 1982). The testing involved was of the pen and paper variety with few attempts at assessment which required actual performance in a real situation. There has been shown to be a low correlation between results from practical examinations and pen and paper tests and whether these are measuring the same things is debatable. Students place a high value on hands-on practical work. The skills they acquire and the tacit understanding they develop may not be evaluated by the traditional pen and paper tests.

The type of laboratory work undertaken in science classes can vary considerably. It can range from being purely confirmatory, where the results have been stated before the activity is carried out, to being an original enquiry by the student. There is a wide range of possible activities which fall between these two extremes and it may be that certain types of practical activities may be better at promoting concept development than others. As far as female students are concerned, carrying out a laboratory exercise by themselves promotes understanding and recall of concepts better than watching a demonstration.
Second Specific Research Question

What is the role of a partner in practical work?

The use of practical work as an aid to the understanding of concepts is also reflected in the importance the Grade 9 students attached to working with a partner who paid attention and knew what to do. By interacting with a partner who may have understood something they did not, and who could explain the procedure to them in a different way, the students felt their knowledge of the subject was increased. They also felt more secure about carrying out unfamiliar activities. Many expressed concern that they would be thought stupid if they got the answer or the procedure wrong. It was not so traumatic if they were working with a partner and were therefore both responsible for the mistake. There were obvious feelings of insecurity evident in the responses of the Grade 9 students. They were poor risk takers but they placed the blame for any mistakes squarely on themselves, never on the subject or the instructions or lack of instructions or the quality of the apparatus they worked with. They felt that they were stupid or dumb if they could not carry out the procedure correctly. The result was negative feelings about their own abilities but not about the subject. However, it is likely that negative personal feelings will affect how a student feels about the subject. If a science subject continually makes you feel stupid and insecure you are unlikely to keep studying it once it becomes optional.

There was a striking difference between the Grade 9 and Grade 12 students as far as the role of a partner in practical work was concerned. Grade 12 students generally preferred to work by themselves unless they needed another pair of hands to
manipulate the apparatus. Again this was because they felt they learned more if they did everything themselves. However, if it was a new situation or they felt they did not understand what they were doing, they preferred to work with a partner. The Grade 12 students appear to feel more secure and comfortable working in the laboratory but this is somewhat superficial. An unusual situation or something they know nothing about will bring on feelings of uncertainty, anxiety and fear. These students again stated they felt stupid if the experiment didn't work out or they did something wrong. They always blamed themselves, not the type of experiment, equipment used or procedure required. They also valued the teacher's opinion of them and did not want to appear stupid, thereby lowering the teacher's perception of their abilities. No student questioned the type of practical work assigned, the need for it or its function. It was an accepted part of their science class and as such seemed to be above question.

Although there was a difference between the Grade 9 and 12 students, the tendency to blame one's self if something goes wrong and the feelings of stupidity that result is common to both groups. This insecurity and tendency to self doubt could well lead to girls' allowing boys to dominate science classes, a situation which has been reported by many researchers (GIST, 1986; Kahle, Matyas and Cho, 1985; Sadker and Sadker, 1986; Science Council of Canada, 1984; Tobin, 1988).

The importance of working with a partner who meets an individual's needs is something that should be borne in mind by teachers. It may benefit students more to work with a partner they choose for themselves rather than to be paired by teachers. Teachers pair students together for a variety of reasons, a major one being discipline. Perhaps, where possible, more consideration should be given to student needs.
Third Specific Research Question

How does the sequencing of theory and practical work affect students?

The relationship between theory and practical work was manifest to students. Practical work was done to elucidate theoretical concepts. No other role for practical work was mentioned.

The students showed a strong preference for a theoretical background knowledge before any experimental work was done. To know what the important features, observations and required results of an experiment were, it was necessary to approach it with some knowledge of the theoretical concept involved. The student's viewpoint was that if there is no knowledge of theory it would be impossible to focus in on the critical points of the experiment, and they would end up confused. Later correction by a teacher would result in poor recall of the material and the whole point of the practical work would be lost. They did not feel it was possible to do an experiment if you had no theoretical background. Students viewed practical work as being necessary to further their understanding of theoretical concepts. They were using practical work to further develop their own understanding of the concept and in this way may be using practical work in the same manner as a scientist who uses an experiment to further refine her/his understanding or knowledge of a developing theory.

Students approach science with some theories of their own. These theories may be firmly held and at odds with the accepted paradigm. Without any guidelines pointing to the accepted scientific theory, they may well use their own theories to
interpret the results of laboratory activities. If this is the case, practical work is not promoting the development of an accepted scientific concept. Rather it could be reinforcing their 'personal' theories. By providing a theoretical background before an experiment is carried out, a student's attention is drawn towards the accepted paradigm and perhaps questions begin to surface in her/his mind. The actual carrying out of practical work may help to merge or shift the student's explanation of a phenomenon towards the accepted scientific explanation, especially if the experiment does not yield results which can be interpreted satisfactorily by the 'personal' theory. Both exploratory and illustrative experiments may assist in this. It is less easy to dismiss a phenomenon that is contradictory to 'personal' theory when it is happening before you and is not only in the realm of theory.

The development of skills necessary for work in the laboratory, learning to approach a problem in a scientific manner, undertaking problem solving activities, acting like a real scientist were all ignored. Students seem to attach little value to the laboratory skills themselves and viewed them as a means to an end rather than an end in themselves. This may be a reflection on how they have learned these skills or how these skills have been valued or evaluated by the teacher. They may have been acquired to carry out an experiment to elucidate theory and not valued or graded in themselves. The students' perceptions in this area may well be influenced by the teachers' failure to value these skills. This finding, however, raises serious questions about Woolnough and Allsop's (1985) suggestion that one of the three main aims for practical work should be the developing of practical skills and techniques. If students value practical skills so little, one must question making them one of the main aims of practical work,
particularly as the transferability of skills is in dispute (Miller and Driver, 1987). It may be that teachers attach a higher value to the acquisition of science skills than do students but, if this is the case, this high value is not being communicated to the students.

Students in this age range do not view themselves as scientists or even pseudo scientists, and are perhaps realistic enough to know that the required answer to the laboratory work they carry out is already known, if not by their teacher, then by a scientific expert in the field. Older students have a sound knowledge of how the world works and know the limits of their own knowledge and abilities.

Fourth Specific Research Question

What effect does obtaining results that differ from the expected have on students?

When the results obtained from a practical exercise differed from the expected, negative feelings were engendered in the majority of the students. Again the students blamed themselves, labelling themselves as stupid. Feelings of frustration, anxiety and disappointment were also reported. Whether they would change their results was determined in part by their grade level and in part by whether the lab was to be graded, and how it was graded. Grade 9 students were generally less mark conscious and felt the teacher would understand that they had done their best and this would be reflected in their mark. Grade 12 students were more likely to alter their results but again this was influenced by grading. If a lab was done 'for fun' then there would be no motive for altering results but if it was graded and the grading was based on obtaining the
correct results, then they would be tempted to tamper with results. The act of grading practical work and how this grading occurs appears to have a significant effect on students. Students like to have their labs corrected by the teacher so they know that their method and procedure are correct but whether this should be assigned a mark for inclusion in term marks is debatable. Some felt that as practical work was to elucidate theory, then if they can answer the theoretical questions, that should be sufficient. Others felt how they actually carried out the experiment in the laboratory should be evaluated, not how they wrote it up. The act of grading had a significant impact on students views in this area. Teachers therefore need to be very clear why they are evaluating laboratory activities and how this is to be carried out. If they are evaluating only the acquisition of skills, then this must be evident to the student. There are many ways of evaluating practical activity and each method will have an impact on the students.

Fifth Specific Research Question

What type of practical work do students prefer when offered a choice between a 'cookbook' approach and an inquiry approach?

When offered a choice between carrying out an experiment where the procedure is outlined (Lab A) or solving a stated problem with a few suggestions offered (Lab B), the students in both Grades 9 and 12 showed a preference for the latter. This preference was based on the assumption that they knew something about the topic in hand. This was critical to their choice. Only if they had some previous
knowledge of a topic would they consider undertaking Lab B. They needed some conceptual framework before they felt they could carry out a meaningful, problem solving, laboratory exercise. Security may have played a role in this but it is possible that they are, like scientists, using practical work to further theory development. Without some type of theoretical framework, developing an experiment to solve a problem may be impossible.

Their choice was further influenced by whether they were dealing with a physical or biological science. An open ended type of inquiry was preferred in biological sciences rather than physical sciences by the majority of Grade 9 students. Whether this reflects Grade 9 students' apathy towards physical sciences, particularly physics, or safety concerns in chemistry is unclear. It may also be a reflection of their fascination with dissection which was, in their eyes, the only practical work in biology, or their own individual preference for biology.

They saw the problem solving type of approach as being more satisfying to carry out, more demanding and one from which they would learn more. As soon as the question of grading the lab arose, however, the choice was changed in many cases. Lab A was seen as being the easier choice for obtaining good marks. Those students who would still choose Lab B did so in the expectation that the marking scheme would reflect the creativity and effort they had put into the procedure and would not be based solely on obtaining the right answer. Certain students who preferred to carry out Lab A even if no marks were involved based their choice on their perception that they generally experienced difficulty with practical work or lacked sufficient time to complete the required work.
The effect of grading and the basis of the grading therefore had a considerable effect on a student's choice. When grades are of paramount importance, as they can be in the senior school years, they will dominate all other concerns. They will lead students to choose less personally rewarding practical work and to change results to obtain the "correct" answer.

When asked if practical work should be graded, there were mixed responses. Some students felt it should not be as it was being carried out to help them understand concepts which would be examined in other ways. Others felt it should be checked to make sure they carried out the procedure correctly, particularly if the material were examinable but not necessarily graded except as satisfactory or unsatisfactory. A third group felt that the actual carrying out of the procedure should be graded, not the write up. There was no one clear view. The question of grading practical work is one which merits further consideration as it has an impact on student choices. If one looks only at student preferences, then Lab B is the preferred choice if they know something about the topic. If this problem solving or inquiry approach is to form the basis for practical work in a science course, clear guide lines on grading must be in place and must be explained to the students. The grading system must reflect the student's use of practical work to further develop their conceptual knowledge and understanding of a topic, as well as provide useful feedback on whether the student is carrying out the procedure correctly and showing creativity and originality in her/his approach.

The responses to this question also shed light on the 'Inquiry Approach' in science classes. Frequently written about in school texts, it is seldom in evidence (Schwab, 1962; Herron, 1971). Although female students would prefer to undertake more open-ended, inquiry type activities, these cannot be in areas in which they have a
poor theoretical background. Girls need to feel comfortable with the material and be assured that the grading scheme reflects all aspects of the inquiry and not just the ability to obtain the correct results. The time consuming nature of these inquiries also needs to be recognised. Students who feel pressured about time will choose a set laboratory exercise although they recognise the benefits of a more open ended approach. A variety of practical exercises which range from the set 'cookbook' type at one end of the spectrum to a completely open-ended type of inquiry activity at the other end of the spectrum may be necessary with the latter type being reserved for areas in which the student already has considerable theoretical background.

Sixth Specific Research Question

What aspects of school science courses are particular memorable and why?

For the majority of students, what stood out in their minds about their school science education was the practical work, especially dissection. The material covered, the mix of theory and practical and the personality and teaching methods of the teacher were also mentioned but it is the practical work which is the most memorable. This suggests that it has a considerable impact on students.

The practical work which proved to be most memorable, particularly at the Grade 9 level was dissection. The reasons for this are not clear although it is something that is unique to school science and is unlikely to be experienced outside an educational setting. Although students may not like the activity of dissecting, their
apathy is overcome by the fascination of seeing what the inside of a living thing looks like and relating it back to themselves. Videos were seen as being an inadequate replacement for dissecting. It was an activity that senior students preferred to carry out alone so a partner would not remove something they had not yet seen. The idea that they were the first person to explore the inside of living organism was also important. Students seem to be fascinated with the insides of living organisms. The reasons why dissection is viewed differently from other types of practical work requires further exploration.

Competency in Science

All students felt they were competent in science. Some found it a difficult subject but they all felt they were quite good at it. None of the students expressed any negative feelings about the subject. The fact that none of the students expressed doubts about their competency suggests they all felt quite comfortable carrying out practical work. Their responses to the interview questions were therefore not influenced by any feelings of incompetency.

Safety Concerns

Concern over safety surfaced during the study and is worth some consideration. This concern with safety was unexpected and its appearance is the result of the method of inquiry used. No focus questions enquired about this aspect of science education as it had not appeared to be an area of concern in surveyed literature. The "Rapport Interview" technique used with its conversation-type questioning allowed this concern
to be expressed and subsequently pursued by the interviewer. One of the strengths of the interview method of collecting data is that it allow students to express themselves freely and may raise hitherto unforeseen points.

Safety is of particular concern to Grade 9 students who appear to view chemistry in particular as being fraught with danger. Physics and biology are seen as being relatively safe subjects. The threat of explosions and things going wrong may well have an inhibitory affect on these students. As there is an increased emphasis on safety in science education in British Columbia, with prescribed texts containing a chapter devoted to safety, teachers are presented with a conundrum. They must ensure that students are thoroughly conversant with safety rules and procedures but at the same time they must not make them so anxious about safety that they are scared to experiment. For boys the element of danger can add excitement and a memorable impact to an experiment but to many girls it may lead to anxiety and even fear. Farkas (1986) reported that many girls expressed concern over the operation of a bunsen burner and some of them never learned to use them properly. Safety concerns may well make girls less likely to carry out experiments or tinker with science materials. It may play a role in the domination of a mixed sex science class by boys. If girls are physically afraid of injury in practical work, they may be more likely to play the role of note-taker. Teachers are known to use the element of danger to make a practical lesson more exciting. While this may appeal to boys, it may have the reverse effect on girls.

Grade 12 students appear to be less concerned by safety problems or perhaps have a more realistic appreciation of the actual dangers involved in school science. They have more years of experience in the school science laboratory and may have come to appreciate that, with due care, the chance of an accident occurring is minimal.
However, the treatment of safety and its emphasis in the laboratory may have an impact on both the students' perceptions of practical work and the pursuit of individual inquiry.
Conclusion

The aim of this study was to assess the role of practical work in school science education, particularly from the viewpoint of High School female students. Based on the results of the study the following general conclusions can be drawn about students' perceptions about practical work in school science:

1. Practical work is important for the understanding and learning of material. Students feel it helps them to reach a tacit understanding of concepts and is an aid in recalling theoretical concepts in examinations.

2. Demonstrations have a role to play in school science but, from a students' viewpoint, they should not be used to replace hands-on practical work. Students view them as a means of learning new techniques or methods but not as an adequate replacement of practical work.

3. Students feel that practical work can only be undertaken if there is some theoretical background already present. It is therefore necessary to have some knowledge of the theoretical concept involved before carrying out the associated experimental work. The elucidation of the concept will be assisted by the associated practical work.

4. The type of practical work preferred by students depends on a variety of things, not least of which is the grading or non-grading procedures used. Original explorations are viewed as being more valuable from a learning standpoint but students must have some prior background knowledge to be confident enough to carry them out.

5. The tyranny of the 'right result' can engender negative feelings in students. Female students who do not obtain the 'right result' in experiments will blame themselves and may label themselves as stupid.
6. Practical work, especially dissection is what stands out in students' minds when they reflect on their science education.

7. Most girls in this study felt competent in the laboratory.

8. There is a motivational aspect of practical work which should not be undervalued. To remove practical work from school science would be unthinkable to students and may lead to fewer choosing to study science.

9. Safety is of concern to girls, especially at the Grade 9 level. Their concerns over safety may inhibit them in laboratory activities.

10. Grading of practical work can have a significant impact on students. The value of grading and its basis needs to be carefully determined by teachers to ensure that they are evaluating all aspects of practical work and not just the ability to obtain the 'right answer'.

11. Female students, particularly Grade 9s, prefer the biological sciences to the physical sciences.
Recommendations for future research

On the basis of the research conducted for this limited study, it is apparent that the value of practical work as part of school science education for females in particular requires additional research. The following areas are recommended for further research:

1. There appears to be a discrepancy in teachers' and students' views on the value of practical work. Further studies need to be carried out to elicit what values teachers attach to laboratory activities and their reasons for holding these values. The area of skills development in particular is valued by teachers but students do not appear to consider it important.

2. The advantages and disadvantages of different types of practical work requires further investigation. Although students may state a preference for a more open, enquiry approach, when confronted with actually carrying this out, they may find it less desirable and may learn less about the concept than in a more structured setting.

3. The effect safety concerns have on female students in the Intermediate years needs to be investigated. Safety appears to be of concern to female students and may inhibit girls from tinkering, an activity that boys have been observed to be involved in in the laboratory. It may also be one of the influences which cause girls to prefer biology to the physical sciences in the Intermediate years.

4. The reason for the appeal of dissection requires investigation. The increased emphasis on environmental and bioethical concerns have lead to a growing demand that dissection no longer be part of school biology courses. Before this aspect of biology is removed from school science, why it is so appealing to the majority of female students should be explored.
BIBLIOGRAPHY


PARENTAL CONSENT

Female High School Students' Perceptions of the Role of Practical Work in School Science.

I consent/ I do not consent to my daughter's participation in this study. I have received the letter documenting the project, its goals, procedures and requirements for participants.
I understand my daughter has the right to refuse to participate or to withdraw at any time without in any way jeopardizing her standing in school, class or relationship with the Principal and researcher.

..................................................................................................................
(Name) Signature

Phone Number:..........................................................
TRANSCRIPT

SUBJECT: Caroline,  
Grade 9  
Length of time at school: 5 years  
I - interviewer  
S - subject

I: Imagine that you have been told that in your next science course there will be no practical work. Practical work is anything that involves you using equipment, apparatus or specimens. OK? How do you think this would affect your experience in the course?

S: Mmm. Well, I know as a fact that I look forward to practical work because it is not something that you have to study for or you have to particularly learn about, I enjoy doing it and I think that it would affect it because I wouldn't enjoy science as much and I wouldn't want to learn and I wouldn't really, if we learned about something and we didn't have a chance to do it ourselves, I wouldn't really understand what we were trying to do and in dissection and stuff I can see what's, what I'm learning about and if you didn't have any practical work, diagrams aren't the same as actually being able to do it yourself.

I: Now you have used the word learn. How could you define for yourself learning?

S: Umm.. taking in information and keeping it without forgetting.

I: OK. Now is that different from memorising something?

S: Umm.in a sense it is because when you can learn things without particularly memorising them. Well you can, when you sit down to memorise something you usually do it because you have to but when you learn
something it is almost natural you just, because when you are growing up you learn your alphabet but you don't sit down and memorise it, you learn it from practice.

I: And once you have learned something can you use it again or..?
S: Yep.
I: In new situations or old situations?
S: New situations. You can have lots of different things.
I: OK. Is it the same to have a demonstration by the teacher as to do it yourself?
S: Not, not to me because when you do it yourself, when the teacher demonstrates it she's doing everything where when you do it yourself, you get the chance to do it and you get to see it and if you mess up then it is your mistake and if the teacher messes up then you don't really, I don't really understand why she has done it wrong but if I do it wrong then I really understand more about what I'm trying to do, right?
I: OK. Now which one would you learn more from, a demonstration or doing it yourself?
S: Doing it myself.
I: OK. Do you think there is a role for demonstrations in practical work?
S: Sorry?
I: Do you think we should do demonstrations?
S: If the experiments dangerous or if it, if it requires a lot of work towards it then perhaps demonstration or just walking around, walking around while we are actually performing it and helping us.
I: OK. Do you prefer to work by yourself when doing practical work or with a partner?
S: I like working with a partner.
I: OK. Why is that?
S: Well because mm.. you have more fun to me and if you don't understand something then they probably will and you, you, I enjoy it more because I learn with someone else rather than just having to do everything myself and if I'm with a partner I don't feel so nervous about what I'm doing, about making a mistake, because it doesn't seem as important to make a mistake when I'm doing it with a partner.
I: Now is one partner good or two partners or how many?
S: Umm. I don't really mind actually, I enjoy,... I don't like working with too many people because you don't get a chance to do anything yourself. I think the limit I like to work with if we are doing practical work is three or four.
I: OK. How would you define a good partner, somebody who is a good partner?
S: Ummm..Someone who doesn't try and do everything and not let you do anything and someone who listened and is willing to take part in the experiment and who doesn't get grossed out by eyeballs and that kind of thing
I: OK. Do you think practical work is more important in one science than in another, sort of in the physical sciences or biological sciences or is it important in both?
S: I think it is important in them both but in different ways.

I: OK

S: Because in biology it is mainly dissection and you see what is inside and you see what you are trying to learn about and it is different from learning by diagrams. In the physical sciences you are learning why that thing happens in a sense because sometimes you can't see it happening but if you have an experiment that you do different things then you can actually see it happening but if you, I can't see something happening then I don't really know why it is happening, so I think it is important in both.

I: Would you like to take a, say which one it is more important in?

S: No

I: No. Important in both. OK.

Do you think you are going to learn more then if you do practical work when you are doing a topic?

S: Yes

I: A lot more or just a little or..?

S: Ummm. you probably won't actually learn anything more but if you are doing the topic anyway you'll understand it better and you'll be, when you come to memorising it or learning it for a test you'll really understand what is going on but I don't think you can learn the same, well you can't really but you under... you can learn the same without it but you can't understand it the same to me.

I: Now does it make a difference when you are doing a test on something you have done practical work with?
S: Mmmm. Yes, it does.

I: What do you think back to when you are doing your test?

S: Ummm, I usually think back to the experiment we did or when we dissected whatever it was.

I: So that helps you with the test?

S: Yea.

I: OK. I have heard some students refer to a lab as being a good lab. Is that a term you would use?

S: Yea.

I: Now what do you mean by a good lab?

S: Well, a lab that is not boring and a lab that is fun to do and you can actually see things happening and that it is not a lot of memorising formulas and weighing things on balances but it is more, I like mixing things together.

I: OK. Can you give me an example of some good labs?

S: Umm. When I remember in grade 7 when we watched things fizz up and I enjoyed doing that and I enjoyed lighting the splint and putting it in, I think it was oxygen and it popped and I enjoyed that kind of thing. This year in physical sciences we weighed ice and water and found that really boring.

I: So you don't like using balances

S: No

I: You like things that are going to happen and be spectacular?

S: Yea.

I: OK. Should you do the practical work before you do the theory behind it or should you do the theory first and then the practical work?
S: Mmm. Theory and then practical work

I: Why is that?

S: Well because if the teacher just says this is the experiment we are going to do, just go ahead and do it and then teaches you what you were doing afterwards I don't get the same, well I wouldn't get the same level of understanding if you learnt all about it and then were able to see it happen, we would understand what was happening rather than just seeing something happen and not really understanding it and then understanding and you would I think, if you did the lab afterwards you would get more out of it.

I: OK If you carry out an experiment and your results are different from what is in the text book or what your other classmates have got, what would you do?

S: I'd keep them the same and I'd write the correct results next to it because that is what I got, that's just what I got, it doesn't matter what was in the book.

I: Now does it bother you if everyone else has got one thing and you have got another?

S: Not, really.

I: Not really?

S: Because I could be the only one that got it right and everyone else has got it wrong.

I: That's true. I know that university students are sometimes tempted to fiddle their results a little bit. Would that ever cross your mind in grade 9?
S: Mmm..well not really because I don't think it is at the same level as universtiy and I don't think labs and results are as important as they are in a university level.

I: Would it make a difference if the lab was being graded?

S: Mmmm. Well it would depend if it would be graded and if I got different results from everyone else if I got it wrong then I would probably would try to, try to make mine the same as everyone elses but if it wasn't being, if I wouldn't be losing marks for what my experiment turned out to be then I wouldn't change them.

I: OK. Do you think labs should be graded?

S: Umm. I think some labs should and some labs shouldn't and I think that if they are graded people get different results from someone else there shouldn't be deducted marks because that is what their experiment told them and you learn by your mistakes.

I: You said some should and some shouldn't. Which ones should and which ones shouldn't?

S: Umm. Well labs that are on say an exam or important to that particular work, then they should because if you did it wrong then you would want to know that you had done it wrong and so you could try and see what you had done wrong but labs that are not really going to affect it in your term or on to an exam in any great length I think they should be done for our own good.

I: OK. Would it make a difference to you if the lab you got a different result in was in the physical sciences or in the biological sciences?
S: No. Actually it might make a little bit more difference if it was in physical sciences because biology is more, physics is more...I'm not sure how you can put this. It is not really more important but it is a lot more stressed. People learn physics more than they learn biology.

I: So you feel there is more emphasis on physics?

S: Yes.

I: Do you think that is a good thing or a bad thing?

S: Well, I don't like physics so I think it is a bad thing.

I: What was it about physics that you don't like, Caroline?

S: Well, a lot of the things you do are so abstract and it is memorising things and you can't, a lot of things you can't really see happen whereas in biology. I really like animals and so I have a desire to learn about them and in physics I don't really care about chemistry and that kind of thing, it is just boring to me but in biology I enjoy learning about it.

I: OK. Now you are given the choice of doing two different types of experiments on the same subject, OK?

S: OK

I: One experiment, experiment A, is given in detail with all the equipment listed, and the way to do it and results that are needed, OK? The second choice you have, B, you are given a problem, on the same topic. Some equipment is suggested that you might use but how you do it is up to you? Which of those two labs would you like to do best?

S: Lab B

I: Why is that?
S: Because you would be able to experiment more and you would be given more freedom and you would have to work out what things you are going to need and why, because if someone became a scientist they wouldn't be given a specific lab and all the equipment they would have to work it out for themselves and I think you would be more gratified if you got the right answer without having everything listed than having everything done for you?

I: So you think it would be more fulfilling?

S: Yea.

I: OK. Which would be more difficult, more demanding?

S: Lab B

I: OK. Can you see any role for the first type of lab?

S: Mmmm yes, if it is dangerous or if we are not at the right level to be able to figure out that kind of lab then I think that would be better or if you were doing it in class and you don't have the time to experiment or the materials are expensive or if you waste something.

I: So you think Lab B would take longer?

S: Yes.

I: And if the labs were being graded, would it make any difference?

S: Yes, I would choose labA if they were being graded.

I: Why is that?

S: Because you would have more of a chance of getting it right and it would be easier to do.

I: OK. Anything that might affect your choice?
S: The teacher.

I: How would that affect your choice?

S: Mmm. Well, if the teacher was going to grade it and if the teacher was a hard marker or an easier marker or if the teacher enjoyed letting you experiment around and that kind of thing.

I: Anything else?

S: Not really.

I: OK. If you think back on the science courses you have done, Caroline, what stands out in your mind about them?

S: Dissection.

I: Why is that?

S: Well because it is the kind of thing everyone looked forward to but as soon as we got our eyeball or worm or something everyone would shy away and so Oh! Gross, this is disgusting. It was, I wouldn't consider it fun because it smelt really bad but it was a lot more interesting and different.

I: So what made it memorable besides everyone going Oh?

S: Well the fact that you were cutting open something that used to be alive, and the, that's what is inside you in some cases, you are not the same as a worm or anything but you are seeing in real life what something looks like rather than a model or something.

I: So you like dissection?

S: I like it because you see inside but I don't like getting my hands in all the goup.

I: Do you think a video would be the same then?
S: No.
I: No?
S: No.
I: What would be the difference?
S: In , when you are doing it your self then you are actually doing it and you are the one who has to cut it open but in a video it is not the same when it shows you what to do it is not the same as doing it 'cause you won't do it the same and it will be different for everyone.
I: So which one would you learn more from, Caroline?
S: From doing it yourself.
I: OK. Anything else you would like to tell me about practical work?
S: No, not really, we have covered everything.
I: OK. How important is it to you then?
S: It is quite important to me in the area of sciences because it is something I look forward to in that without it I would be really bored in science and it's something to kind of keep me going through the term and it helps me learn.
I: What do you mean 'keep you going through the term.'?
S: Well towards the end of the term its, its getting kind of boring and its, I've learned so much that I don't want to learn anymore and everyday you sit in class and you write down notes and don't actually get to see it or anything like that it's not the same as being actually able to do something rather than learn specifically by memorisation or writing notes.
I: So if I told you that in Grade 10 science next year you weren't going to do any practical work at all, what would you feel like?
S: I'd feel like I wanted to drop science.

I: You would, would you?

S: Yea.

I: Do you feel when you work in the science lab, you feel quite competent in there?

S: Yes.

I: Nothing about doing practical work that puts you off?

S: Occasionally in physics when you have to light things up and just, the scare of getting burnt or something like that.

I: So the safety worries you does it?

S: Yea.

I: Anything else?

S: No

I: OK. Thank you very much indeed.