Science and Mathematics Education Centre

Practicals in Science Education: A Study of the Theoretical Bases, Rationale, and Implementation of Practicals in Junior Secondary Science Education

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ABSTRACT

This study explores the issues involved in the theoretical bases, rationale and implementation of practical work in junior secondary science programs. The part that practical work has played in science education, both internationally and in Australia, is reviewed. Links are made between statements made by science educators more than 200 years ago to those made by modern day researchers into science teaching and learning. The study draws together the research traditions of the philosophy of science, science curriculum development, learning environments, and educational psychology. The researcher has carried out a multi-stage field study using both qualitative and quantitative methods to achieve the objectives of the study. Developments in the philosophy of science as they impinge on science education are reviewed. Science practicals are defined for the purposes of this study and a new Theoretical Model for Science Practicals is proposed. The model enables the description and statement of purpose of eight types of science practicals. The target population of the study is Australian science teachers and students. The model provides a theoretical basis for the development of the survey instrument, *Science Practicals Inventory* (SPI), to investigate students' perceptions of the use of practicals in science learning. The eight types of practicals described in the model were used as the scales for the SPI. Qualitative data collected during separate group interviews of science teachers and students supported the development of the SPI together with quantitative data from three pilot studies. The SPI was validated using samples of high school students from Tasmania and Western Australia. Using statistical procedures involving factor analyses, alpha reliability, discriminant validity, and ANOVA, a valid, reliable, efficient, eight scale, 50 item instrument has been developed. Analysis of the quantitative and qualitative data in this study enabled issues involved in the theoretical bases, rationale and implementation of practical work in junior secondary science programs to be clarified and better understood. The results of this study include implications for science curricula and recommendations for further research and are generalizable to science teachers and students in Australia. The SPI is available for further application in action research, science program evaluation, science teacher professional learning and science program renewal.

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This study has been a personal journey taken after a long career in science education and secondary school administration. I acknowledge the encouragement and assistance that I have received from my science teacher colleagues in Tasmania and Western Australia, many of whom have allowed me into their science classes to collect research data. I am particularly grateful to those science teachers who took part in the group interviews which were an important part of the development of the research instrument. I thank the school principals who approved my access to their schools and the students, in Tasmania and Western Australia, who completed the research questionnaires and took part in the student group interviews. The study was carried out with the general approval of Alison Jacob, Deputy Secretary (Education Strategies), Department of Education, Tasmania.

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PREFACE

The great difficulty which has been found in attempts to instruct children in science has, we apprehend, arisen from the theoretical manner in which preceptors have proceeded. The knowledge that cannot be immediately applied is quickly forgotten and nothing but disgust connected with useless labour remains in the pupil's mind. ...(Pupil's) senses should be exercised in experiments and these experiments should be simple, distinct and applicable to some object in which the pupils are immediately interested. We are not solicitous about the quantity of knowledge that is obtained at any given age, but we are extremely anxious that the desire to learn should continuously increase. ...Until children have acquired some knowledge of effects, they cannot inquire into causes. Observation must precede reasoning; and as judgement is nothing more than a perception of the results of comparison, we should never urge our pupils to judge until they have acquired some portion of experience, (pp. 226, 329, 424).

Edgeworth, R. L., & Edgeworth, M. (1811). *Essays on practical education (3rd ed.)*. London: Johnson.

CHAPTER 1

Introduction to the Thesis

1.1 INTRODUCTION

I consider myself very fortunate to have been a secondary science student during the 1950s, which was a time of rapid and important science development. Watson and Crick had worked out the double helix structure of DNA. The electron microscope uncovered the secrets of the cell and together with developments in organic chemistry; foundations were laid for the new approach of modern biology. New plastic materials and synthetic fibres were developed. Nuclear physicists developed peaceful uses for atomic energy. New telescopes extended the boundaries of astronomy. The launching of the Russian Sputnik began the exploration of space and led to the allocation of large resources to science and science education. The development of small scale science equipment and extra resources meant that we were able to have our own sets of equipment to support our science learning in the newly built science laboratories. I found science education interesting, exciting and fun. The interest, sense of excitement and fun that I had as a school boy has sustained me and has been reinforced throughout a satisfying 40 year career as a science teacher. That interest, excitement and sense of wonder has been maintained and expanded by the continuing scientific discoveries and adventures into the 21st century.

As I approached retirement I became concerned that most secondary students today do not seem to develop the same level of interest and get the high levels of excitement and fun from their science learning as I and my school friends. For many years now there have been statements of concern at the declining numbers of students choosing pre-tertiary science courses which has led to reduced science courses at universities (Moodie, 2005). The Australian newspaper reported that safety concerns, fear of litigation paperwork, and difficulty obtaining specimens for dissection meant that students were denied some of the practical aspects of science lessons. Teachers are concerned that science lessons are less fun and that students can be left under prepared for tertiary study (Hutchinson, 2003). A research report for the Department of Education, Training and Youth Affairs found that many science students in Australian high schools experience disappointment because their science learning is neither relevant nor engaging and does not connect with their interests and experiences. Traditional chalk-and-talk teaching, copying notes and *cookbook* practical lessons offer little challenge or excitement to students. The declining numbers of students who take science courses in the post compulsory years of schooling reflect the student disenchantment with science (e.g. Fensham, 2005; Goodrum, Hackling, & Rennie, 2001)

Examination of the science education literature suggests that there are problems with the practicals in junior secondary science programs. There have been developments in the philosophical view of the nature of science, as well as the nature of science education, and the way children make meaning of their world. There has been a change of emphasis within science programs with time. Therefore, this study is timely in that it focuses on the design and implementation of practicals in junior science programs. The study involves the development, validation and use of an instrument to determine students’ perceptions of the practicals in science programs. Quantitative and qualitative data enables an in-depth exploration of issues with science students and science teachers. The research methods draw on the theory and procedures of cognitive learning theory, studies of the interpersonal behaviour of teachers in the classroom, and studies of school learning environments. Implications for the school science program are identified and recommendations for the development of curriculum guidelines are proposed.

1.2 BACKGROUND TO THE STUDY

This study arises directly from the task that faces junior secondary science teachers as they develop science programs in schools. In *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b) it is asserted that science education has a role in achieving all of the *Common and Agreed National Goals for Schooling in Australia* (Curriculum Corporation, 1994a). At different times different purposes for science education are favoured. Roberts (1982) identified seven curriculum emphases, each of which conveys a different message about the nature of science. Different interest groups favour different emphases. Emphases, and thus the content of science programs, change as different groups become influential. Although stated in different terms at different times, some understanding of *the nature of science* and the *scientific method* has been a central and enduring feature of school science education (Jenkins, 1996). Novak (1988) recognised that the science laboratory has always been regarded as the place where students should learn the process of doing science. Most scientists and science educators agree that practical work in the form of a laboratory practical is an essential part of science curricula.

For the purpose of this study, the definition of a practical follows that of Hodson (1988) and Kirschner (1991). A practical is a didactic method of learning and practising all the activities involved in science. Experiments are considered a subset of laboratory work. Laboratory work is a subset of practicals, which is, in turn, a subset of the didactics of science education. This definition includes investigations and task-orientated problem solving.

While there is apparent agreement on the need for practicals there is no consensus on either the pedagogical basis for practicals or the relative importance of the educational objectives of the practical work. Much has been written over a long period about the aims and objectives and implementation of practical work in science education (Boud, Dunn, Kennedy, & Thorley, 1980; Hodson, 1988, 1996; Kerr, 1964; Lynch & Ndyetabura, 1983; Tamir, 1976; Woolnough, 1976). However, the available literature does not offer very much help in deciding on the objectives of practical work. In his review of practical objectives Swain (1974) concluded that there is no real consensus among science educators as to the objectives of practical work in science education. Since 1974, there have been at least seven other studies that have tended to confirm Swain's conclusion, for example, Gunning & Johnstone (1976), Woolnough (1976), Ogborn (1977), Gould (1978), Lynch & Ndyetabura (1983). As well as a lack of consensus about the objectives of practical work the literature contains many references to its lack of educational value, for example, Kreitler & Kreitler (1974), Tamir (1976), Moreira (1980).

Hodson (1991) in his review of *The Student Laboratory and the Science Curriculum*, edited by Hegarty-Hazel (1990) reported that the collection of essays by prominent science educators concludes that despite its massive share of resources, laboratory work provides little of real educational value. These ideas are not new. The Prime Minister's Committee on Natural Sciences in Education in Great Britain reported in 1918 that in many schools more time is spent in laboratory work than the results obtained can justify. Cunningham (1946) found that summaries of research on the value of laboratory work for learning science did not favour laboratory over lecture demonstration. The 1960s and 1970s was a period of major science curriculum development that made practical work in laboratories more important. Stake and Easley (1978) reported a lack of effectiveness of laboratory instruction. Other studies showed that most students in laboratories gained little understanding of either the key science concepts or the process of science (Novak, 1988).

According to Hodson (1988) most curriculum reform in science education since the 1960s has moved away from teaching science as a body of knowledge towards an increasing emphasis on the processes and procedures of science. Out of this change of emphasis have come commitments by science educators to teach scientific knowledge through methods of discovery or inquiry. Schwab (1962) in his essay *The teaching of science as enquiry*, proposed a science curriculum emphasising scientific enquiry as both content and method. A misunderstanding of Ausubel’s (1963) work on meaningful and rote learning led to confusion between the teaching and learning processes, and the methods and processes of scientific enquiry often referred to as the *scientific method* (Hodson, 1996; Kirschner, 1991; Novak, 1978). Many large science curriculum projects, developed during the 1960s and the 1970s, emphasised learning by inquiry and discovery with outdated ideas of the nature of scientific enquiry. Australia was not isolated from these trends. During the 1970s the *Australian Science Education Project* (ASEP) was developed. The processes of scientific inquiry were also given prominence in the move towards a national curriculum

In 1989 the Australian Education Council ratified a formal declaration of 10 national goals for schooling. The importance of science education is acknowledged in Goal 6 of the *Common and Agreed National Goals For Schooling In Australia*, and the specific goals for science specified in *A Statement on Science for Australian Schools* include, for example:

> Uphold attitudes and values such as openness to new ideas, intellectual honesty, commitment to scientific reasoning and to striving for objectivity, respect for evidence and for the tenacious pursuit of evidence to confirm or challenge current interpretations.
>
> Use the skills of scientific investigation, reflection and analysis to generate or refine knowledge, find solutions and pose more questions. (Curriculum Corporation, 1994b, p. 5)

However, there has been growing awareness that such methods, which rely on induction, create a distorted and inadequate view of scientific inquiry. Hodson (1990) summarised this: "…such views have long been abandoned by philosophers of science. It is high time that science teachers abandoned them, too!" (p. 37)

By the time this statement was made, researchers were questioning the practice of teaching science as inquiry. The work of Osborne and Freyberg (1985) questioned the separation of science learning from the context of that learning. Considerable attention has been paid to the part that the development of skills and processes play in science curricula. To what extent do junior science programs, through the use of practicals, emphasise the processes of science?

Millar and Driver (1987) have reviewed the extensive body of literature that raises doubts that processes exist, independent of content, and questions the existence of a unique and definitive scientific method. Their work has led to another change of emphasis in science education: from the processes of science to how students learn science. Many writers now support a constructivist view of learning, recognising that students and teachers (in fact, everyone) construct their own meanings from their experiences. "All learning involves the construction of meaning, whether the learning is discovered or received by direct transmission" (Fensham, Gunstone, & White, 1994, p. 6). Constructed meaning depends on existing meaning or conceptual framework. The teachers' role is to promote conceptual development and change.

Constructive approaches to learning are as old as human thought, going back at least as far as Greek and Roman times. Novak (1988) identified David Ausubel's (1963) *the Psychology of Meaningful Verbal Learning* and his (1968) *Educational Psychology: A Cognitive View* as the first attempt to present a theory of learning that dealt with the role of meaning. There is a growing consensus that cognitive psychology offers principles of learning that have significance for science education (Novak, 1988). *A Statement on Science for Australian Schools,* under the heading "Principles for effective learning experiences in science" includes, for example:

- *Taking account of students' views*. Learning starts from and values the beliefs, concepts and skills of students.
- *Recognising that students construct their own understandings*. Learning activities should encourage students to clarify, evaluate and reconsider their own understanding of the biological and physical world.
- *Learning in practice*. Science learning occurs in many ways – talking, listening, reading, drawing, making, enacting, experimenting, modelling, handling animals, rocks and tools, and using equipment. Practical investigations are especially important as they enable students to work back and forth between theoretical ideas and direct experience. (Curriculum Corporation, 1994b, pp. 5-6)

Goodrum, Hackling, and Rennie (2001) assert that learners need practical experiences of genuine scientific investigation that promote conceptual development and the construction of meaning. To what extent do junior secondary science programs, through the use of practicals, promote conceptual development and the construction of meaning?

1.3 RATIONALE FOR THE STUDY

There are inconsistencies in the theoretical bases, rationale, and implementation of practicals in junior secondary science programs. While there is apparent agreement between most scientists and science educators that practicals are an essential part of science education, there is a lack of clarity and consensus as to the pedagogical basis for practicals in science programs. How have schools addressed the 'Working Scientifically' strand as defined in *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b) and the *Profiles of the Common and Agreed National Goals For Schooling in Australia (Curriculum Corporation, 1994a)*? How are science teachers providing practical experiences of genuine scientific investigation that promote conceptual development and the construction of meaning? An important outcome of this study is the development of an instrument that teachers will be able to use as part of the evaluation of science learning programs. The instrument will assist the provision of science teacher professional learning and the renewal of science practical programs.

1.4 RESEARCH QUESTIONS AND INTENTIONS

The main aim of the study is to explore, clarify, and improve understanding of the issues involved in the theoretical bases, rationale and implementation of practicals in junior secondary science programs. The research questions central to this study are:

1. What are the theoretical bases and rationale for practicals in science programs?
2. What are the requirements for practicals as specified in published curriculum documents developed from *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b) ?
3. What are teacher perceptions of practicals and their educational value in their science programs?
4. What are student perceptions of practicals and their educational value in their science programs?
5. What are the implications of this study for science curricula?

1.5 SIGNIFICANCE OF THE STUDY

The study is of significance to science educators as there are many references in the literature to the need for clarification of the issues involving practicals in science learning, (e.g., Hodson, 1991, 1996; Layton, 1991; Watts & Gilbert, 1989). Large science education projects and the provision of science education for all, for the development of scientific literacy, stress the importance of practicals. Practicals require a large allocation of resources in terms of time, equipment, laboratories and specialised science educators. At a time of great pressure on resources of all kinds, it is important that there is clarity and consensus about the theoretical basis, rationale and implementation of practicals in junior secondary science.

The study involves the development and validation of an instrument to determine student and teacher perceptions of their science programs. This instrument will be useful to science educators who wish to evaluate their science programs.

The study provides information about student and teacher perceptions of their science programs and how they are achieving the goals of the curriculum documents: *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b) and the *Profiles of the Common and Agreed National Goals For Schooling in Australia* (Curriculum Corporation, 1994a).

This study indicates ways in which science programs can be improved.

1.6 METHODOLOGY

A field research study consisting of several stages was completed. The Theoretical Model of Science Practicals was developed from the literature (Ausubel, 1963; Elton, 1987; Novak, 1978). The main research instrument, The Science Practicals Inventory (SPI) was developed from the Theoretical Model of Science Practicals, a series of pilots, and group interviews of science teachers and junior high school students. The development and administration of the questionnaires followed the processes and strategies of research on learning environments. The instrument was used with science students in Tasmania and Western Australia. The response data was analysed to determine the reliability and validity of the questionnaire. Qualitative data were obtained from open-ended questions, answered by students, and group interviews of science teachers and students. Further analysis of quantitative and qualitative data enabled recommendations to be made for the improvement of science programs.

1.7 OVERVIEW OF THE THESIS

The thesis consists of seven chapters, references and several appendices.

CHAPTER 1, *Introduction to the Thesis,* outlines the intentions and ramifications of the study.

CHAPTER 2, *Practical Work in Science Education - A swinging Pendulum,* explores the context of practical work in science learning. A historical review of the role of practical work in science education is presented. Issues that impinge on the rationale for practical work in science education programs are discussed, such as the philosophy of science, knowledge of how children interpret their world, and science curriculum development. Also the need for a new definition of practical work in science learning is established.

CHAPTER 3, *Practicals for Scientific Literacy,* discusses the theoretical basis for practical work in science learning. The term ‘practical’ is introduced and defined. A theoretical model for the different types of practicals is developed by drawing on the research traditions of science curriculum development and educational psychology.

CHAPTER 4, *Collecting Perceptions of the Use of Practicals in Science Programs,* restates the research questions and describes the research design of the study. A new instrument for the evaluation of science practical programs, the Science Practicals Inventory (SPI), is presented. The chapter concludes with a statement of the assumptions and limitations of the study.

CHAPTER 5, *Analysis of the Data,* outlines students’ perceptions of science practicals from the analysis of qualitative data, followed by the validation of the SPI from the analysis of quantitative data. The SPI, is presented as a valid, reliable and efficient instrument for investigating student perceptions of the use of science practicals in Australia.

CHAPTER 6, *Applications for the Science Practicals Inventory*, discusses examples of possible applications of the SPI in the areas of science program evaluation, science teacher professional learning and science program renewal.

CHAPTER 7, *Summary and Conclusions*, reviews the study and reports the major findings of this study with reference to the research questions and intentions presented. Implications and limitations of the study as well as recommendations for further research conclude the study.

The thesis is completed with the references followed by several appendices consisting of letters of intent, participant approval forms, group interview field text and SPI charts.

CHAPTER 2

Practical Work in Science Education: A Swinging Pendulum

2.1 INTRODUCTION

In the previous chapter I gave an outline of the study. I recognised that the emphases of science education courses may change with time and that the importance of practical work within these courses may also change. In this chapter, I explore the context of practical work in science learning. The philosophy of science is discussed as it impinges on science education. I present a historical review of the role of practical work in science education, drawing on the work of Solomon (1980), Kirschner (1991), Gabel (1994) and Fensham (1995), among others. I discuss issues that impinge on the rationale for the use of practical work in current science education programs. The rationale for science education for all students is reviewed.

For more than 200 years practical work has been an important part of science research. During that time practical work has become established as an important part of science education. The term *practical work* is used in the literature with United Kingdom affiliations and corresponds to the term *laboratory work* as found in United States literature. In Australia both terms are in common usage.

Student laboratory work has been defined by Hegarty-Hazel (1990) as a form of practical work taking place in a purposely assigned environment where students engage in planned learning experiences, and interact with materials to observe and understand phenomena. This definition implies that there are other forms of practical work that can occur outside the laboratory. The rationale for practical work in science education is reviewed and I establish the need for a new definition of practical work in science education.

2.2 PHILOSOPHY OF SCIENCE: A BASIS FOR SCIENCE EDUCATION

At this point it is necessary to explain terms that have emerged from the philosophy of science that have affected science education. It is not my intention to review the philosophy of science but to clarify the rationale for change of emphasis of science education programs described in this chapter.

Logical positivism emerged as a dominant philosophy of science during the 1920s. Developed by the Vienna Circle, a group of scientists and philosophers, logical positivism accepted as its central doctrine Wittgenstein's Verification Theory of Meaning (Brown, 1977; Passmore, 1967). The verification theory holds that statements or propositions are meaningful only if they can be empirically verified. This was an attempt to distinguish between scientific and thus meaningful statements, and metaphysical or meaningless statements and to assert that science was securely based on the objective observation of reality (P. F. Anderson, 1983) The objectivity of positivist science was questioned by many thinkers. This led to the development of a moderate view of positivism known as logical empiricism (Carnap, 1936, 1937). Logical empiricism became the dominant view in the philosophy of science for about 20 years (Suppe, 1974). Logical empiricism softened the concept of verification to the idea of "gradually increasing confirmation" (Carnap, 1953 p.48), by arguing that statements could never be verified as established truth but could be confirmed by the accumulation of successful empirical tests. Logical empiricism still had the problems of relying on induction, which is, making inferences from an unspecified number of instances; and the continuing insistence that observations are objective or value and knowledge free.

Popper (1972) developed *falsification* as an alternative science method designed to overcome these criticisms of logical empiricism. Popper accepted that "observation always presupposes the existence of some system of expectations" (Popper, 1972 p. 344). In Popper's view the scientific process begins when observations clash with existing theories or preconceptions, that is, when a problem is identified. To solve the problem a hypothesis is deduced from the theory and tested empirically. The aim of the tests is to show that the hypothesis is not supported by the observations. If the hypothesis deduced from the theory is not supported by the observations, the theory can be rejected. Theories that survive falsification can be considered supported and tentatively accepted (P. F. Anderson, 1983). Popper overcame the objections to logical empiricism by replacing induction with deduction and denying reliance on objectivity. The progress of science using the method of falsification is achieved by solving problems. Popper’s method of falsification is not without problems. Realistic test situations depend on much more than the hypothesis tested. Errors in background assumptions, flaws in the equipment and the effects of unknown processes, render any rejection arising from such tests unreliable and the status of the method of falsification dubious (Cook & Campbell, 1979).

Writers at the time noted that scientific practice is often controlled by a conceptual framework, worldview or paradigm, that is highly resistant to change and that the established framework is rarely overturned by a single anomaly (Kuhn, 1962). Kuhn considered that science progresses through paradigm shifts, not necessarily in any particular direction and almost certainly not towards the truth. Kuhn identified two distinct phases, *normal science* and *revolutionary science*. When science is in a normal phase the current paradigm dominates all scientific research and theory. Revolutionary science occurs at times when the dominant paradigm is discredited and a new one is set up in its place.

Like Kuhn, Laudan (1977) saw science operating within a conceptual framework that he calls a research tradition. A major function of the research tradition is to provide a set of guidelines for the further development of the tradition. These views led to the development of *critical relativism,* a multifaceted philosophy of science with the objective to solve problems and answer questions. One of its major assertions is that there is no single scientific method. Knowledge claims are viewed as contingent upon the particular paradigm or research tradition of its practitioners. Critical relativism rejects the positivist idea that there is a single knowable reality to be discovered by using the scientific method (Olson, 1981).

The reasoned search for truth returned to the philosophy of science when it turned towards scientific realism during the 1970s (Suppe, 1977). Scientific realism contends that the aim of science is to improve our perceptual processes, separate illusion from reality, and generate the most accurate possible description and understanding of the world. Scientific realism proposes that:

1. The world exists independently of its being perceived.
2. The job of science is to develop genuine knowledge about the world even though such knowledge will never be known with certainty.
3. Knowledge claims must be evaluated and tested to determine the extent to which they do or do not represent or correspond to the real world. (Malhotra, 1994)

A similar view of the nature of science is important for K-12 students, having an appropriate level of generality and also relevant to their daily lives. Scientific knowledge is:

- tentative (subject to change),
- empirically-based (based on and/or derived from observations of the natural world),
- subjective,
- necessarily involves human inference, imagination and creativity,
- is socially and culturally embedded (Lederman, 1998, p. 4)

This new view of science, in continuous review and upheaval rather than the steady progress of the logical positivist scientific world, suggested that a change of approach to science education was needed. If children were to be educated for an increasingly changing world it was more important that children were armed with processes for the discovery of new knowledge rather than well-learned theories and facts that might be superseded within a short time.

2.3 PRACTICAL WORK IN SCIENCE EDUCATION: A HISTORICAL REVIEW

The origins of modern practical work in science can be traced back to the 17th century (Jeans, 1947). The first *Science Society* was founded in Florence in 1657, under the patronage of the Grand Duke Ferdinand di Medici and his brother Leopold, as a forum for consultation and discussion between scientists with a goal to promote experimental learning in sciences. The foundation, by Charles II, of the *Royal Society for the Improvement of Natural Knowledge* as the science society of Great Britain occurred in 1662. In France Louis XIV founded the *Academie des Sciences* in 1666. In 1700 the Elector Frederick of Prussia founded the Berlin Academy, the corresponding organisation in Germany. A similar association, the Dublin Society, established the first recorded chemical laboratory in 1796. The Royal Institution of Great Britain was established in 1799, dedicated to scientific research and scientific education. The activities and interests of these scientific societies flowed through to education. The development of practical science education is described in the next section.

2.3.1 Developments in the old world: Europe and Britain

Early in the 19th century the use of the laboratory had become an accepted requirement for science education. An example of the arguments put forward for practical work, allowing students to exercise their minds by conducting simple experiments in areas of student interest, is provided by the following quotation from Edgeworth and Edgeworth (1811) in Lazarowitz and Tamir (1994) p. 94:

> The great difficulty, which has been found in attempts to instruct children in science, has, we apprehend, arisen from the theoretical manner in which preceptors have proceeded. The knowledge that cannot be immediately applied is quickly forgotten and nothing but disgust connected with useless labour remains in the pupil's mind. ...(Pupil's)

> senses should be exercised in experiments and these experiments should be simple, distinct and applicable to some object in which the pupils are immediately interested. We are not solicitous about the quantity of knowledge that is obtained at any given age, but we are extremely anxious that the desire to learn should continuously increase. ...Until children have acquired some knowledge of effects, they cannot inquire into causes. Observation must precede reasoning; and as judgement is nothing more than a perception of the results of comparison, we should never urge our pupils to judge until they have acquired some portion of experience. (pp. 226, 329, 424)

This quotation indicated concern as early as 1811 about programs dominated by theory and knowledge that were not relevant to the interests and lives of students. There was also an early indication of the link between understanding and experience. However, with science education still in its infancy, practical work was mainly used to confirm taught theory and not designed as child-centred research. Although school laboratories that were equipped for genuine experiments became more common, experiments performed in science lessons were usually used to support the science theory lessons. If the expected experimental results were not obtained, it was unimportant, as the correct answers could be found in the textbooks (Solomon, 1980). Between 1867 and 1897 the number of students enrolled in some kind of science education program in Great Britain increased from 10,000 to 160,000. As the number of students increased so did the complaints from examiners that there was too much emphasis on bookwork and too little on practical work (Kerr, 1964).

Towards the end of the 19th century the heuristic education movement led by Henry Armstrong, Professor of Chemistry at the London Institution and the Central Technical College (later City and Guilds College), set out to change the didactic approach to science education to one of discovery, with science being a matter for the laboratory and workshop rather than the classroom. Armstrong argued that the heuristic method developed pupil initiative and taught self-reliance, good judgment and manipulative skill through personal contact with apparatus and materials. Armstrong’s position was consistent with the ideas of Baden Powell in Scouting for boys and also with the naturalist movement in education, supported by the ideas of Froebel and Pestalozzi that emphasised the development of children. It was argued that to develop as individuals, children needed freedom to be able to exercise their own capacity for discovery. Armstrong was in favour of students being able to do original work, and thus restore excitement and originality to science education (Solomon, 1980). Armstrong considered that experimentation was very different from demonstration and that experimentation should lead to the understanding of theory. By 1896 the heuristic method of science education, with the *discovery approach* was widely adopted in school science syllabuses throughout the United Kingdom.

2.3.2 Developments in the new world: The United States of America

Similar developments of practical work in science education took place in the United States. Chemistry laboratories were established first at the Boston Girls High School and Normal School to begin laboratory instruction in 1865. The school principal in 1871 described the performing of experiments as "education in patience, watchfulness and exercise of forethought that will prove invaluable through life, in the discharge of domestic, social and professional duties" (Kapuscinski, 1981 p. 194). By 1880 laboratory equipment could be found in high schools and "…the laboratory in many cases almost entirely superseded the textbook …" (Fay, 1931 p. 1550). Physics lagged behind chemistry in the use of laboratories for educational purposes (Cajori, 1929). By 1871 there were five physics laboratories in operation or being established using the first laboratory manual entitled *Elements of Practical Manipulation* (Pickering, 1871). Pickering wrote, in his preface to the manual, that teaching students to think for themselves was the greatest advantage of a course in practical manipulation. This should be encouraged by allowing students to follow their own ideas and, as far as possible, devise and construct the apparatus needed. He warned that the advantages of this teaching technique would be lost if the work was limited to what had already been described. In 1886 Hall, at Harvard University, introduced a course of study in physics that included laboratory work. Students applying for admission were required to have completed not less than 40 experiments in the subjects of mechanics, sound, light, heat and electricity, which had actually been performed by the students at secondary school. This was the first time that a university had imposed such a requirement (Fay, 1931). Hall considered laboratory work essential for students as it provided training in observation, provided detailed information about theories learned from textbooks, trained students to use their brain power to develop their mental abilities, and aroused student interest (Moyer, 1976).

2.3.3 The pendulum swings

At the end of the 19th century the task of education was to develop the *mental faculties* of students that were seen as separate and distinct elements of the intellect. Armstrong and other reforming educationalists justified their new courses by reference to these faculties: the will, the imagination, the power of reasoning and the memory. In 1896 the Oxford and Cambridge Examination Board approved a school science syllabus that had been designed by Armstrong (Solomon, 1980). In 1898 Armstrong published an account of his methods entitled *Heuristic Method of Teaching or the Art of Making Children Discover Things for Themselves* in which he argued enthusiastically for the value of experimental work as a training ground for the mind.

During the First World War, the effectiveness of Armstrong's approach to science teaching began to be questioned when it was observed that the lack of basic scientific knowledge was endangering soldiers' lives (Solomon, 1980). In 1918 the Thomson Committee, reporting on Natural Sciences as taught in schools, questioned the value of time spent on laboratory work. The report stated that in many schools more time is spent in laboratory work than the results obtained can justify. While recognising that it was an essential part of science teaching, the report noted that sometimes the performance of laboratory exercises had been considered too much of an end in itself and that the value of a real experiment was lost when it became a dull routine (Kerr, 1964).

During the early 20th century there was a rapid development in physics, chemistry and biology. Public examinations included options requiring factual knowledge relevant to university work. Armstrong's heuristic method did not prepare students adequately for such examinations, and by 1925 he was ready to admit that it was going out of fashion (Solomon, 1980). These developments together with the economic considerations of the Great Depression resulted in much more use of demonstration as a teaching approach to science education, as it was cheaper and easier to organise. This development was supported by research that proved learning of facts could be achieved just as well through demonstration as through laboratories (Hurd, 1961).

The rationale for and use of practical work remained stable through the Second World War. The use of practical work in science education was justified as experimentation being *learning by doing* and usually confirmed the theory presented in the textbook. Experimentation was considered essential to adequate science education. However, in some areas verification experiments were considered by some educators to be unacceptable and not consistent with the scientific method. Experiments should provide practice in identifying worthwhile problems to be investigated. During their solution of these problems students would learn the meaning and use of controls, and practice analysing and interpreting data while testing a specific hypothesis (Blosser, 1980).

Two major developments that impinged on science education at this time resulted in an increase in general science courses. Concern about early specialisation resulting in an apparently educated population in which many had not studied any science subject, resulted in a call for all students to study some science during their secondary education. The increase of the school leaving age in the UK, as part of the 1944 Education Act, resulted in many more students in secondary schools, many of whom were not aiming for university science training. General science courses were introduced particularly in the secondary modern and technical schools (Solomon, 1980).

2.3.4 Developments in the antipodes: Australia

In Australia education was traditionally the responsibility of the Australian state governments. The teaching of science followed the British system in which science subjects were taught separately with physics and chemistry receiving more emphasis than biology and geology (Owen, 1977). The general science movement originated in Britain before the Second World War and eventually reached Australia. As a result, Victoria and Tasmania introduced general science courses in 1945. This was followed by the other Australian states shortly afterwards. There was considerable variation in content and emphasis between the science courses in the different Australian states. Leading science teachers from the various states of Australia were communicating and began meeting once a year. These meetings led to the formation of the Australian Science Teachers' Association.

By 1954 science teachers from all Australian states met under the banner of the Australian Science Teachers' Association. The first issue of the *Australian Science Teachers' Journal* (A.S.T.J.), published in May 1955, gave an insight into the issues confronting science education at the time. Earlier publications of the proceedings of meetings of science teachers from various states reported on the shortage of science teachers and resources for teaching science. Reports of displays of equipment and experiments indicated that the practical work supported the content of the science textbooks that were mainly from Britain (Close, Baddams, & Wannan, 1954; Heading, 1954).

Another theme of the conferences and journals was the importance of developing an interest and enthusiasm for science in students, so that they would wish to go on with their science training in order to satisfy society's increasing need for scientists and technicians in an increasingly science-based and technological world. As well as having science teachers who were genuinely interested in the subject, they also had to be able to arouse and maintain the students' enthusiasm (Simes, 1955). Simes identified two other principal requirements:

> (1) There should be different courses to suit the level of interest and ability of the students.
>
> (2) There should be individual practical work. Descriptions of reactions and demonstrations must be avoided; the pupils must have the excitement of carrying out the experiments for themselves. In passing they will learn a few techniques and maybe unlearn some bad ones...An overriding consideration for such practical work by the pupils is a very low pupil-teacher ratio, and this will have to be obtained. (p. 9)

In the same first issue of the A.S.T.J., McLean (1955) asked the question “What is wrong?” Being faced with ever-increasing demand for people with scientific training by industry, commerce and professional groups, something had gone wrong with the source of supply. “The universities, comparatively poor in science graduate output, feel that the schools are not supplying enough scientifically enthusiastic students to them” (p. 14). The A.S.T.J. provided an opportunity to promote the scientific method as a teaching objective. The scientific method was credited with building modern science. It had unique qualities that distinguished it from other methods of knowledge acquisition and had persisted since the time of Francis Bacon (1561-1626). It was argued that the “distilled essence” (Doherty, 1955, p. 12) of the scientific method could be taught to school children so that they could understand it and apply it to other fields as well as science. Enthusiasm for the scientific method could be seen in Australia, as it had been discussed at a meeting of some of the State Associations; sections of textbooks published at the time had been devoted to its description; and in some States the science syllabus listed the scientific method among the objectives of the course.

The scientific method was described as a series of steps as follows:

1. Observing and defining the problem.
2. Gathering reliable data relevant to the problem.

3. Consideration of various hypotheses and the selection of the most satisfactory hypothesis to explain the data.
4. Planning and execution of experiments or observations to test the selected hypothesis.
5. Drawing a conclusion about the support or otherwise of the tested hypothesis.
6. Publication of the procedure in such a way as to allow anyone who so desires to repeat and test any step. (Doherty, 1955, p. 13)

While Doherty argued strongly in favour of the scientific method as a teaching objective he recognised that in Australia, enthusiasm for practicals seemed to be confined to only a few and despite official approval the majority of science teachers paid only lip service to it. He also recognised that the scientific method had its critics, such as Conant, who considered that the scientific method was incomplete as it led to the verification of isolated facts rather than the development of broad conceptual themes (Conant, 1947, 1951, 1952). However, the great success of operational research indicates that the steps of the scientific method outlined above, can be used successfully to answer questions or solve problems from other areas, to test limited working hypotheses (Eddison, 1953).

Smith (1955), a leading science teacher at this time, addressing the fifth Conference of the Australian Science Teachers' Association, recognised the importance of practical work in the teaching of science as something on which all science teachers agreed. "But the relative importance of teaching by demonstration, or by an extensive course of laboratory work, is a question on which there is some difference of opinion". Smith reported that most teachers were coming to the view that "the value of the work usually done in the laboratory by the students is extremely doubtful" (p. 20). He considered that the experiments took a long time to perform, the students were already familiar with the principles or results which the experiments were designed to discover, and the experiments were so elementary that they gave little or no training in practical techniques useful in everyday life. If the teacher performed the experiments at the demonstration bench with the help of various members of the class he could perform them in a fraction of the time that the class would take. A series of questions and answers would eventually reveal the principle that the experiment was design to discover. Smith also argued that whether performed by the teacher or the students, experiments should not be to verify a principle already known to the class. The purpose of the experiment should be broadened, for example, “an experiment to determine the relationship between the variables which control the volume of a gas” rather than “an experiment to verify Boyle’s Law” (p. 20). The results of the investigation could be followed up in subsequent lessons. The value of the class demonstration in linking the theory and the practice of science was recognised at this time. It was considered that the class demonstration could be followed by a problem to be studied in the laboratory. The term *problem* was used rather than *experiment* because “I feel that too much of our practical work… is concerned merely with verifying or illustrating some law rather than with application of principles” (Saul, 1955 p. 12). The design of experiments to take the form of investigations, or problems, with the student “given as little help as he can get by with” was advocated by Reimann (1955, p. 15). As much as possible should be left to the student to devise.

> Investigations which yield runs, or a series of values of the relevant quantities, are …more interesting, and give more information about physical processes, than do those yielding only a single result, in the form of a precision determination of some quantity. (p. 15)

Reimann, the Research Professor of Physics at the University of Queensland, goes on to argue that it is better to investigate the variables that control the period of a simple pendulum, and after appropriate graphing, determine the value of *g*, the gravitational constant, than to set the problem of the determination of *g* by using only one pendulum following the recipe in the text book (Reimann, 1955). He provided us with a concise rationale for practical work in science education, as well as a picture of the result if science teachers didn’t give more challenges and responsibility to their students.

> Laboratory exercises properly carried out not only consolidate knowledge, but provide an elementary training in research methods,

> fostering an imaginative approach, critical thinking, ingenuity and self-reliance. They are also of value in developing manipulative skill. However, in order to fulfill all these functions as effectively as possible, it is obviously necessary that considerable thought should be devoted to their presentation; otherwise the student may easily fail to derive any particular benefit from their performance.
>
> Thus how often is the student in the laboratory placed almost entirely on the receiving end, being provided with a detailed sheet of instructions, which he merely has to follow assiduously to get at the end of it all, the "right" result and a good mark! From such a performance he derives little or no benefit; on the contrary, his usual harvest is just plain boredom, and at the completion of the experiment, he is, more often than not, incapable of giving an intelligent account of what he has just done. (Reimann 1955, p. 15)

The scientific method was still advocated by leading science teachers. But it was recognised that much of the science teaching at this time did not provide students with opportunities to apply the scientific method in their science learning (Stanhope, 1955). Textbooks published in Australia to meet the need for Australian science teaching resources gave prominence to the scientific method. *Modern Science 1*(Barrell, 1965), described the scientific method in its first chapter but included defined practical activities, for example, 'Activities', p. 68, and instructions for experiments, for example, 'Experiments', p. 70, that supported the theoretical science described in the chapters. These 'Activities' and 'Experiments' did not give students experience or practice in the open procedures of the scientific method as described. *Science for Secondary Schools 1* (Heading, Provis, Scott, Smith & Smith, 1966) described "deliberate investigations" including the following steps:

1. Observation that raises a question.
2. The mind offers a possible explanation (hypothesis).

3. This possible explanation is tested to see whether it is correct, the hypothesis is further tested. (p. 15)

The above procedure was described as "the way of thinking that scientists use called the scientific method". The book included "Things to do" at the end of most chapters, and "…things you can explore for yourself." (p. 18). These were instructions for closed activities that support the science theory work. In the preface of the book *Science for Secondary Schools 3*, under the heading 'ABOUT THIS BOOK', teachers were informed that:

> As in the earlier books the approach is experimental and inductive where possible. Sufficient detail of the experimental procedure has been included to facilitate the conduct of experiments in the laboratory. Moreover, topics are developed in such a way that previous knowledge can usually be brought to bear on each new problem investigated. The features of the book are in keeping with the frequently stated aim that school science should introduce the student to the methods of science as well as its content. (Heading, Provis, Scott, Smith, & Smith, 1968)

By 1967 all states had adopted courses in general science at the junior secondary level. However, the emphasis of the different courses varied between the Australian states. The New South Wales Syllabus in Science for Forms II-IV (1963) emphasised major concepts that integrated the sciences. The South Australian Science Syllabus (1966) emphasised, for example, the scientific method, experimentation, science rather than individual disciplines, and the needs of pupils. In Western Australia, Queensland and Tasmania a topic approach to science courses was adopted with suggested course content listed under separate headings of, for example, Astronomy, Biology, Chemistry, Geology and Physics (see Western Australia, Science A and Science B for Secondary Schools (1962); Schools Board of Tasmania, Manual (1966); Queensland Syllabus in Science A and B (1967). Attempts were made to cater for different student abilities by offering different courses of study following a common science in Grades 7 and 8. These syllabuses had hardly reached the printers before dissatisfaction was being expressed by leading science educators.

2.3.5 Developments through international cooperation: 'The Sputnik Shock'

New developments in different areas of thought impinged on science education, for example, the work of Popper (1935; 1959) and Kuhn (1962) produced new philosophies of science. Concern about *two cultures* in society, as a result of early specialisation in secondary education, led to calls for science education for all students. New understanding of childhood learning and thinking, and the work of Jean Piaget (1952), led to calls for more child-centered science education. The successful launching of the Russian *Sputnik I* in 1957 was seen in America as a large affront to national pride and stimulated a major review of science education. There was an increase in cooperative efforts between scientists and specialists in science education to improve science teaching worldwide.

Following the British 1944 Education Act and its associated extension of the school leaving age to 15, there was a large increase in the number of students in schools. Consideration needed to be given to education so that it was appropriate for the full range of student abilities and interests in science. Also, at this time, concern was being expressed about early specialisation into *the sciences* or *the arts*. The Nuffield Foundation adopted the slogan "Science for All" as it provided generous funds to support school science and the development and implementation of new science education courses (Solomon, 1980).

At the same time, a new understanding of children's learning and thinking about the natural world developed from the studies of Piaget (1952; 1964). By watching, questioning, testing and analysing the responses of groups of children of different ages he was able to describe the staged conceptual development of children. He described the stages through which the unstructured observation of a curious toddler developed and grew towards the sophisticated formal reasoning processes required by secondary science education. Piaget's ideas had a major influence on the development of science education resources around the world, for example; the *Australian Science Education Project* (1974). *ASEP* developed a large number of units for teachers to select from to form a course of study for their students. Each *ASEP* unit was developed to match a particular Piagetian stage. Units were prepared for three stages: concrete operational (Stage1), formal operational (Stage 3), and the transitional phase between these two stages (Stage 2). A set of Piagetian principles formed a strong basis for *ASEP* philosophy:

1. New ideas and knowledge should be presented at a level consistent with the child's development of thinking and language.
2. A major source of learning is the activity of the child.
3. Classroom practices should be tailored to the needs of the individual children and should present moderately novel situations.
4. Children learn by social interaction.
5. Children should have considerable control over their own learning. (Ginsburg & Opper, 1969, pp. 236-7)

These principles, as a set, provided a strong endorsement for activity-based science learning with a strong emphasis on practical work. The project designed its materials to encourage inquiry in a broad sense. Inquiry in its various forms was seen as engaging in the processes of science. *ASEP* defined this as requiring students to identify problems, observe, measure, classify, order, infer, predict or form hypotheses, search for and discover meaningful patterns, design and perform experiments, interpret and analyse data, and verify the validity of conclusions reached. The approach was that of an inductive process in which students learn by discovery, and receive guidance according to their individual needs at each development stage. *ASEP* was developed towards the end of a large movement of science curriculum reform, begun in Britain and America, that spread around the world over about 20 years, ending in the mid 1970s (Welch, 1979). Similar trends were evident in America.

Dissatisfaction with existing science courses being felt in the United States of America was given impetus and direction by the United States Government following the launching of Sputnik I in 1957. Fox observed that:

> About the time of Sputnik, specialists in various disciplines concerned with the upgrading of the rational capacity to cope with rapidly changing technological demands placed on our society looked at our educational programs and were appalled at the lack of correspondence between the current state of knowledge in their fields and what was being taught in schools. (Fox, 1972, p.139)

Using expert resources from the scientific and larger education community, new courses and support materials were developed with the major aim of updating the content and placing an emphasis on the processes of science and experimentation as an integral part of science education programs (Owen, 1977). Initial courses were designed to meet the needs of senior science students. The most famous of these were *Physical Science Study Curriculum (PSSC),* set up in 1956, the *Biological Science Curriculum Study (BSCS)* and the *Chemical Education Material Study (CHEM Study)* established in 1959. A second round of courses was aimed at students who would not study science at college, for example, *Harvard Project Physics, Science - A Process Approach* and *Elementary Science Study,* 1960-1975. These courses consisted of independent units of study for use with a wide range of students. At about the same time, partly in response to the need for students to be better prepared for inquiry-based studies in the senior school, several curriculum projects were commenced to provide more appropriate courses for use at the junior high school level, for example, *Introductory Physical Science (IPS)*, the *Earth Science Curriculum Project (ESCP)*, and the *Intermediate Science Curriculum Study (ISCS),* in 1967-1968. The Nuffield Foundation in Britain was strongly influenced by trends in America. The Nuffield Foundation set up the *Nuffield Science Teaching Project* in 1962 that prepared activity-based materials for all levels of schooling. The *Science 5-13 Project* and the *Schools Council Integrated Science Project (SCISP)* which ran from 1968-1984, followed the initial project. *Nuffield Combined Science*, released in Britain in 1970, was widely adopted, forming the science course for the first two years of secondary science programs in one school in three. School organisation factors, for example, mixed-ability classes and a trend towards student-paced learning, contributed to the popularity of *Nuffield Combined Science (Booth, 1975)*. Its adoption also reflected the trend away from specialisation in junior secondary science education. Mixed-ability groupings and integration of the science disciplines have been strong trends in science curriculum development in Australia (Oates, Gunstone, Northfield, & Fensham, 1980).

Dissatisfaction with science curricula in Australia can be traced back to a statement made by Yaxley in his presidential address to the annual conference of the Australian Science Teachers' Association, CONASTA, in 1963:

> Many of us are dissatisfied with actual science courses recommended because they emphasise factual knowledge and do not adequately represent the true meaning, scope and structure of science as a discipline and as part of our culture. (Yaxley, 1963)

Cohen (1964) provided a theoretical basis for changing science courses in Australia. He developed a science curriculum model for the development of science curricula in Australia. Using methodology utilised by researchers into comparative education, the Australian Science Curriculum Model was developed by Cohen with a suggested mechanism for its implementation. The curriculum model evolved from 70 recommendations obtained from reviews of science education and the related areas of education, science and psychology. These recommendations were in areas that included objectives of science education; procedures from some National Science Foundation sponsored curricula; science elements unique to the Australian culture; and the findings of science education research. The Australian Science Curriculum Model represented a major stage in the broadening of science curricula in Australia, see Figure 2.1.

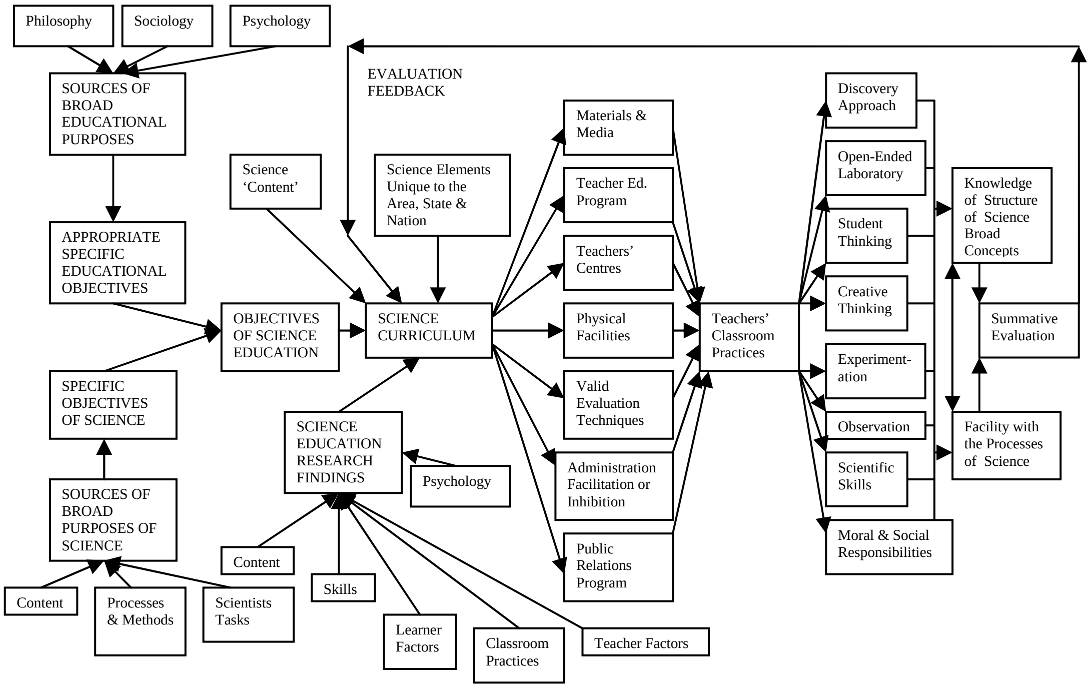

Figure 2.1. The Australian Science Curriculum Model (Cohen 1964).

The Australian Science Curriculum Model consisted of two broad phases: development and implementation. In the implementation phase of the model the element *Teacher's Classroom Practices* flows through to eight components:

Discovery Approach
Open Ended Laboratory
Student Thinking
Creative Thinking
Experimentation
Observation
Scientific Skills
Moral and Social Responsibilities

These *Teacher Classroom Practices* were linked together and flowed through to the major elements of the model: *Knowledge of the Structure of Science- Broad Concepts* and *Facility with the Processes of Science,* which were interacting with each other. The model indicated the importance of practical work in *Student Thinking* and *Creative Thinking,* leading to the development of *Knowledge of the*

Structure of Science- Broad Concepts and *Facility with the Processes of Science*. However, it does not recognise the importance of interests of students and their prior knowledge to learning. It indicated, like others referred to earlier in this chapter, a lack of precision in the use of common terms in the area of science practical work, for example, is there a difference between *Experimentation* and *Open Ended Laboratory?* Is *Observation* separate from *Scientific Skills,* or is it one of the skills usually included under this heading? Is it here that we see the lack of distinction between the research traditions of science as practised by scientists and that of educational psychology as it relates to science education? This lack of clarity between learning science and doing science, together with high priority placed on unbiased inductivist-empiricism, led many educators to advocate the *discovery method* as the way to teach science (Allen, Barker, & Ramsden, 1986; Anthony, 1973; Cawthron & Rowell, 1978; Obioma, 1986). The inclusion of the *discovery approach* in the Australian Science Curriculum Model is significant, as discovery learning was becoming increasingly important in the new movements in America and Britain.

In America, the major support for discovery learning came from the writings of Schwab (1962), who recognised *stable inquiry* and *fluid inquiry*, similar to Kuhn's ideas of normal and revolutionary science. He considered that the rapid growth of scientific knowledge had shortened the duration of stable inquiry so that it had ceased to be an appropriate guide for science teaching, and neither, as represented in the science textbooks, was it a useful source of technical innovation. Fluid inquiry, on the other hand, showed the uncertainty of scientific knowledge, and by placing experimentation ahead of classroom instruction, introduced students to the processes of knowledge creation. He strongly opposed the "rhetoric of conclusions" found in student science textbooks that should have been replaced by open materials, which led students to the identification of problems for investigation. He argued that laboratory manuals should not be volumes that "tell the student what to do and what to expect" and should be "replaced by permissive and open materials which point to areas in which problems can be found" (Schwab, 1962 p. 55). School textbooks were discarded as the main resource for teaching science. Experimentation was given priority, in which the students enquired into problems set by the teacher, or more rarely, they were given open-ended investigations where the students, as the result of contact with materials, identified problems and proposed hypotheses to be tested by experiment. The insecure assumptions supporting the discovery approach to science learning were compounded by a misinterpretation of Ausubel's work on *meaningful* and *rote* learning (Hodson, 1996; Kirschner, 1991; Novak, 1978). Rote learning was wrongly linked with transmission/reception methods and meaningful learning with discovery methods. Ausubel's ideas will be discussed further in Chapter 3 of this study.

The first swing away from the traditional textbook course in secondary science in Australia was in 1966 with the establishment of the *Junior Secondary Science Project (JSSP)* by the Science Standing Committee of the Victorian Universities and Schools Examination Board and the Australian Council for Educational Research. The aims of the project were summarised in a progress report in 1967:

> They were to provide an opportunity for students to proceed at individual rates; to include laboratory experiences as an integral part of the learning sequence; to be flexible in structure to facilitate modification by the teacher or the project; and to provide a guide to the teacher. (Australian Council for Educational Research, 1967, p. 71)

Interest shown by other states in the JSSP materials led to the development of the national science curriculum project, the *Australian Science Education Project (ASEP)*. The Curriculum Development Centre (CDC) was established by the Australian Government in 1973 and became a major influence in science curriculum development in Australia. Its activities included major projects, for example, the continuing distribution of *ASEP*, the *Agricultural Science Materials Project*, the *Physical Science Project* and the *Agricultural and Environmental Science Project.* The provision of a vast array of student-centered teaching materials that enabled students to *do science* provided clear guidelines of what was expected of the students. However, teachers were less clear about their role in the discovery/process approach to science learning. In Australia, the *Science Teaching Project*, a CDC professional learning project aimed at science teachers, was an attempt to meet the need for teacher support. In England, the role of the teacher can be summarised as the task of “radiating enthusiasm and encouragement, adapting the course as he went along” (Solomon, 1980, p. 26). In America, the teacher was to “rally to the national call, to read widely in the philosophy and history of science, and to carry out the behests of the educationalists” (p. 26).

The major effort to improve secondary science education during the 1950s through to the 1970s fell short of expectations. This was because there was a reliance on the obsolete epistemology behind the emphasis on inquiry and investigation in the discovery methods used in many of the projects (Novak, 1988).The philosophy of science has generally not been used in a systematic and deliberate manner with laboratory practices being based on dubious or discarded philosophies of science (Layton, 1990, p.37). Discovery learning relied on inductivism and thus presented a distorted and inadequate view of science methodology. Although science skills, such as, observing, and collecting and recording data accurately, are important in themselves, if discovery is to improve meaning and understanding it requires a prior conceptual framework (Hodson, 1988). Skill development and the importance of a student’s prior knowledge became the focus of attention in science education during the 1980s.

Fensham brought us to the 1980s as follows:

> ‘Head science’ with its emphasis on big ideas and the structure of knowledge; ‘heart science’ with its more random pleasure orientated approach without rigor or structure have both failed in their turn to have significant impact on the majority of students. The intentions have been good and noble - so what can we do in the 1980s to achieve the scientific literacy that we desire? (Fensham, 1981, p. 53)

Fensham’s recommendation for the 1980s, what he called “hands science”, emphasised meaningful practical skills that would bridge the gap between theoretical science and technology (p. 54). The steps of skill acquisition, moving from the *Primitive Skill* to the *Developed Skill* are summarised in Figure 2.2.

Primitive Skill	→	Demonstration and Practice	→	Improved Skill	→	Knowledge x,y,z on which Skill is based	→	Developed Skill

Figure 2.2. Instruction sequence for “hands science” courses (Fensham, 1981, p. 57).

Considerable attention has been paid to the part that the development of skills and processes play in science curricula. Practical work in science learning has been a rich source for educational researchers. The focus of many studies has been to clarify the objectives of practical work in science learning. The focus of many studies has been to clarify the objectives of practical work in science learning. The use of objectives of various types and levels has not resolved the confusion that has been described earlier in this chapter. The use of long checklists of objectives in assessment of student learning presented teachers with a logistical impossibility when trying to assess the learning of the large number of students normally taught by individual teachers. There is no consensus among science educators as to the objectives of science practical work (Swain, 1974). Kerr (1964) in a study of the nature and purpose of practical work in secondary school science surveyed science teachers who were asked to rank 10 statements from published reports on methods of science teaching. Since that study was published there have been at least seven other studies published in which teachers were asked to rank the importance of similar objectives of science practical work (Beatty & Woolnough, 1982; 1980; Gould, 1978; Gunning & Johnstone, 1976; Lynch & Ndyetabura, 1983; Ogborn, 1977; Woolnough, 1976). Table 2.1 presents the rankings of 10 different objectives in six of the studies identified. Objectives from the two studies not included (Gunning & Johnston, 1976; Ogborn, 1977) were not considered comparable to the objectives in Kerr (1964). As an example of the lack of consensus consider the objective: *To arouse and maintain interest in the subject*. Lynch and Ndyetabura (1983); Boud, Dunn, Kennedy, and Thorley (1980) and Kerr (1964) report this objective to be rated as relatively unimportant, while Beatty, Gould and Woolnough (1982) report higher ratings of importance for this objective. *To develop manipulative skills* received ratings of importance between 2 or 6.

Although ratings of importance for the objective: *To give training in problem solving* were in the middle they ranged from 4 to 8. The objective that specifically mentioned *scientific methods of thought*, although in the top half of the relative importance range was rated between 1 and 4.

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Although ratings of importance for the objective: *To give training in problem solving* were in the middle they ranged from 4 to 8. The objective that specifically mentioned *scientific methods of thought*, although in the top half of the relative importance range was rated between 1 and 4.

As the research has taken place during a period of 20 years a possible explanation for different rankings of the individual objectives is the change in thinking among educators about the nature, content and didactics of science curricula over the same period. If the changes in ranking of objectives since Kerr’s study were attributable to changes in thinking about science curricula, one would expect to see a steady increase in the support for practical work to develop scientific skills, and a reduced emphasis on practical work as an aid to understanding and learning theoretical or factual material. Such trends are not evident and after reviewing the results of all of these studies, Kirschner (1991) agreed with Swain’s conclusion that there is no consensus among science educators as to the objectives of science practical work

The focus of many studies has been to clarify the objectives of practical work in science learning. The use of objectives of various types and levels has not resolved the confusion that has been described earlier in this chapter. The use of long checklists of objectives in assessment of student learning presented teachers with a logistical impossibility when trying to assess the learning of the large number of students normally taught by individual teachers. There is no consensus among science educators as to the objectives of science practical work (Swain, 1974). Kerr (1964) in a study of the nature and purpose of practical work in secondary school science surveyed science teachers who were asked to rank 10 statements from published reports on methods of science teaching. Since that study was published there have been at least seven other studies published in which teachers were asked to rank the importance of similar objectives of science practical work (Beatty & Woolnough, 1982; 1980; Gould, 1978; Gunning & Johnstone, 1976; Lynch & Ndyetabura, 1983; Ogborn, 1977; Woolnough, 1976). Table 2.1 presents the rankings of 10 different objectives in six of the studies identified. Objectives from the two studies not included (Gunning & Johnston, 1976; Ogborn, 1977) were not considered comparable to the objectives in Kerr (1964). As an example of the lack of consensus consider the objective: *To arouse and maintain interest in the subject*. Lynch and Ndyetabura (1983); Boud, Dunn, Kennedy, and Thorley (1980) and Kerr (1964) report this objective to be rated as relatively unimportant, while Beatty, Gould and Woolnough (1982) report higher ratings of importance for this objective. *To develop manipulative skills* received ratings of importance between 2 or 6.

Table 2.1
A Comparison of the Rankings of Objectives for Practical Work in Science in Six Studies

Objective	Kerr (1964)	Wool-nough (1976)	Gould (1978)	Boud (1980)	Beatty* (1982)	Lynch (1983)
To encourage accurate observation and careful recording	1	1	2	3	1	6
To elucidate theoretical work to aid comprehension	2	6	8.5	8	8	4
To be an integral part of the process of finding facts by investigation of facts and arriving at principles	3	8	8.5	4	7	3
To promote simple, common sense, scientific methods of thought	4	3	2	1	3	1
To develop manipulative skills	5	5	6	2	5	5
To verify facts and principles already taught	6	10	10	- +	9	-
To make biological, chemical and physical phenomena more real through actual experience	7	2	3	5	4	2
To give training in problem solving	8	7	4	7	6	-
To fit the requirements of practical examination regulations	9	9	7	-	10	10
To arouse and maintain interest in the subject	10	4	5	9	2	8
N	701	655	214	307	238	257

* Beatty studied final year primary school students.
+ A dash (-) means that an objective was not included in the study. (Kirschner, 1991, p. 64)

Although ratings of importance for the objective: *To give training in problem solving* were in the middle they ranged from 4 to 8. The objective that specifically mentioned *scientific methods of thought*, although in the top half of the relative importance range was rated between 1 and 4.

In a thorough review of objectives in science programs (Kirschner, 1991) distinguished between *general learning objectives* and *end terms*.

General learning objectives have been formulated on expected learning results and each one has been subdivided into a list of *specific learning objectives* that specify the expected learning behaviour of the students. For the achievement of the general and specific learning objectives the completion of the practical work was an end in itself. The common assumption that students gain understanding of the processes of science simply by doing practical work is not supported by the research of Gott and Duggan (1995). There is a need to formally teach the procedural concepts of evidence to achieve the process objectives and the nature of evidence. For a fuller discussion of procedural concepts see Gott and Duggan (1995).

Kirschner recognised that the organisation of objectives was made more difficult because "the stated objectives are either so detailed that they can only be used in specific laboratories in specific disciplines or are so general that they include almost anything any one can think of, for instance, imparting information, training basic processes and building up adequate motivation" (p. 27). Not withstanding these reservations, Kirschner went on to catalogue more than 100 different specific objectives that were divided into six general objectives as follows:

A -To solve problems (including the formulation of hypotheses).
B -To use knowledge and skills in unfamiliar situations.
C -To design simple experiments to test hypotheses.
D -To use laboratory skills to perform (simple) experiments.
E -To interpret experimental data.
F -To describe the experiment clearly.

Achievement of end terms required the completion of practical work and other learning tasks and was a means to an end. Statements that defined specific end-terms of a program were grouped under the following two general end-terms:

I -To obtain good scientific attitudes.
II -To understand the scientific method.

Examples of the 38 specific end terms include;

I *To obtain good scientific attitudes.*

-formulate a problem so that it can be researched,

-survey the literature relevant to some problem at hand.

Other classifications of specific objectives have been proposed, for example, the Oxford Certificate of Educational Achievement Criteria divides the science process into:

1. -Planning: producing testable ideas, designing investigations.
2. -Performing: manipulating, observing, data gathering.
3. -Interpreting: data handling, drawing conclusions, applying concepts.
4. -Communicating: reporting, receiving information. (Josephy, 1986)

Also:

1. -Planning and design
2. -Performance
3. -Analysis, interpretation and explanation
4. -Application
5. -Communication (Tamir & Amir, 1987)

It seems that the categories of specific objectives are not absolutes. The particular classifications used are a matter of perception and definition by particular authors for specific purposes. There is no agreement as to the educational goals or the best way to assess the achievement of goals for practical science (Trumper, 2003). I suggest that one reason for the uncertainty, that exists in the area of the organisation of objectives for science education, may be the different levels of goal statements that are possible in curriculum theory, and the tendency to judge the appropriateness of scientific literacy as a goal for science education by the present state of science learning rather than the successful achievement of the preferred science learning. Different levels of goal statements include, for example, goals, aims, general objectives, specific objectives and end terms.

Not withstanding the disappointing impact of the discovery approach to science learning, the objectives referred to above indicate a strong commitment to the scientific method and scientific inquiry as an important part of science education at the time. However, the changes in the philosophy of science, the move away from an inductivist science method, and the ideas of Kuhn (1962) that emphasised the importance of the dominant paradigm or existing conceptual framework of scientific researchers, discussed earlier in this chapter, had begun to influence researchers into science learning.

Following the work of Millar and Driver (1987), Osborne and Freyberg (1985) and Piaget (1964), science curriculum developers recognised the importance of prior knowledge and existing beliefs in the learner's conceptual development and achievement of understanding. As part of the documents produced in the move towards a national curriculum *A Statement on Science for Australian Schools,* under the heading 'Strand 1 – Working Scientifically,' recognised the importance of prior knowledge as follows:

> Working scientifically is a challenging interaction between existing beliefs, the goal of better understanding, and the processes and methods of exploring, generating, testing and relating ideas. It involves a number of attitudes: valuing ideas and seeking explanations; respecting evidence and logical reasoning; open-mindedness, critical-mindedness; scepticism about evidence and arguments; honesty and openness to new ideas; creativity and lateral thinking… accepting the provisional nature of knowledge.
>
> Working scientifically is something students do in their everyday lives as a way of extending their understandings, making decisions and achieving practical outcomes. (Curriculum Corporation, 1994b, p. 15)

A constructivist view of reality is consistent with the scientific realist view of the real world discussed earlier in this chapter. However, these ideas are not new. Von Glasserfield noted that:

> From the beginning of the 5th century B.C. the sceptics have shown that it is logically impossible to establish 'the truth' of any particular piece of knowledge. The necessary comparison of the piece of knowledge with 'reality' cannot be made, because the only rational access to that

> reality is through yet another act of knowing, (von Glasserfield, 1992, p. 5)

Constructed meaning builds on the learner’s existing understanding or conceptual framework. Knowledge is constructed by individual learners but is socially moderated.

> Science does not exist as a body of knowledge separate from knowers. On the contrary, science is viewed as a set of socially negotiated understandings of the events and phenomena that comprise the experienced universe. (Tobin & Tippins, 1993, p. 4)

Learning is now considered to be a personal construction by the learner, with the learner central to and involved in the process of learning. Learners construct their own knowledge and understandings based on their prior knowledge and experience and the socio-cultural context in which they find themselves (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Goodrum et al., 2001; Solomon, 1993). The learner’s prior knowledge and experiences are important determinants of their new knowledge and understanding (R. J. Osborne & Wittrock, 1983). For every person trying to understand the world in which they live, learning is a dynamic process through which learners assimilate and accommodate new ideas, arising from new experiences, into their existing conceptual framework. This requires a restructuring of the learner’s existing conceptual framework. The new knowledge and understanding are not only personal but are tested in the social context within which the learner operates. Research suggests that learners are reluctant to give up their own ideas and will only do so if they can see that the more scientifically valid ideas will work better for them (Hewson & Thorley, 1989; Posner, Strike, Hewson, & Gertzog, 1982). Constructivism has implications for teaching. The role of the teacher is to promote conceptual development, and change and mediate the learning of students in the new constructivist educational climate in which the emphasis has changed from the processes of science to the nature of the learner and the achievement of meaning and understanding (Tobin & Tippins, 1993). The search for understanding and wisdom is part of the human condition and the study of science as a *way of knowing* and a *way of doing* is identified as a means by which students can reach deeper understandings of the world. Science education is essential for all students and the achievement of scientific literacy is increasingly being adopted as the primary goal of science education (Bybee, 1997; Goodrum et al., 2001). The next section explores what is meant by the term *scientific literacy* as the main goal for science education and how this compares with what is happening in science classrooms today.

2.4 SCIENTIFIC LITERACY: A RATIONALE FOR SCIENCE EDUCATION

The adoption of *scientific literacy* as the rationale, or main goal for science education, considered essential for all students, was reported by Bybee (1997). Goodrum, Hackling and Rennie (2001) listed the following examples of this development: Collins (1995) described the National Science Education Standards (National Science Council, 1996) as significant in the move towards achieving scientific literacy for Americans; and Millar and Osborne (1998) recommended that the purpose of science curricula for primary and secondary students is to develop scientific literacy. Curriculum developments in America and Britain continue to influence Australian science education. Although each Australian state was able to go their own way with regard to the adoption and continued development of the National Curriculum documents after the July 1993 meeting of the Australian Education Council, the "common heritage" of the National Statement and Profile was evident in the science curriculum documents of the States and Territories (Goodrum et al., 2001). The rationales for learning science emphasise the relevance and importance of science for all students; as a part of everyday life. Everybody requires an understanding and appreciation of the concepts and processes of science if they are to meet the challenges of being an active citizen in modern life. The rationales describe a view of science that

> fosters students' curiosity about their world, develops their intrinsic interest in things around them and their willingness to be questioning, and to explore explanations for their ideas. These kinds of statements adhere closely to the idea of scientific literacy and....

> it seems fair to say that the rationale for teaching science includes a commitment to scientific literacy. (Goodrum et al., 2001, p. 31)

The following description of the science learning area on the Tasmanian Education Department's Discovery Website is quoted as an example of the adoption of scientific literacy as the main purpose of science curricula in Australia:

> SCIENCE
> The Science learning area is concerned with the development of all students as scientifically literate members of their community able to contribute to debate on issues and to make informed decisions. Scientific Literacy is essential to understanding our world.
> Science is the dynamic discipline through which people investigate the living, material, physical, and technological components of their environment and makes sense of them. It consists of a set of big ideas, current theories, accepted scientific methodology and conventions. It is always open to new ideas and creativity.
> (Office of Leadership and Learning Education Department Tasmania, 2003)

The notable feature of this description of the science learning area, apart from its commitment to scientific literacy and the achievement of understanding, is its openness to new ideas and creativity. It recognises science as being dynamic, as well as the value in investigation to make sense of our world, while also recognising that it does have conventions and accepted methodologies. The conceptual content knowledge and the processes, skills and attitudes of science are considered to be interdependent, linked to each other and to the context rather than separated parts of the science education program (Hennessy, 1993; Woolnough, 1994). *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b) required schools to present students with a broad range of science concepts organised in contexts which are interesting and relevant to their daily lives. The big ideas, current theories or concepts of science, are represented by the four conceptual strands of the national statement (Curriculum Corporation, 1994b): Earth and Beyond, Energy and Change, Life and Living, and Natural and Processed Materials. The processes, skills and attitudes of science are described as essential learnings for all students within the *Working Scientifically Strand* of the national statement. The contexts will often cut across the traditional subject boundaries of science. The processes of science may still be applied through practical work within the contexts. An example of this approach is the Tasmanian Essential Learnings Curriculum Project, developed as part of the curriculum consultation with the Tasmanian community. The five strands of the Essential Learnings Framework are: Thinking, Communicating, Personal Futures, Social Responsibility and World Futures. The emphases of current science curriculum documents from all States of Australia were summarised by Goodrum, Hackling and Rennie (2001) as: "On the whole, the current science syllabuses and curriculum frameworks provide an appropriate modern and progressive vision of the intended science curriculum" (p. 152). The science curriculum documents may be consistent with the goal of scientific literacy but research has revealed a gap between the intended or preferred curriculum and the actual implemented curriculum. At the secondary level science "is traditional, discipline-based and dominated by content, which does not relate to, nor does it prepare them for their future life" (p. 152). For most lower secondary students, the science taught lacks relevance to their needs and interests, and fails to develop key aspects of scientific literacy. Also:

> For many secondary students, the teaching- learning process is teacher directed and lessons are of two main types: practical activities where students follow the directions of the teacher to complete an experiment; and the chalk-and-talk lesson in which learning is centred on teacher explanation, copying notes and working from an expository text….
>
> Current emphases on working scientifically and open investigations (e.g. Curriculum Council, 1998; Hackling, 1998; NSW Board of Studies, 1998) that engage students in planning and conducting investigations so that they are both minds-on and hands-on and learning skills at the heart of scientific literacy, have not penetrated the traditional implemented curriculum of many schools. (Goodrum et al., 2001, p. 155)

Much of the practical work in secondary science consists of traditional closed laboratory exercises. Goodrum et al (2001) acknowledge that some schools have “enthusiastically adopted more student-centred and investigative approaches to practical work” (p. 155). Goodrum et al (2001) found that, while the curriculum statements produced for teachers by the Australian States and Territories generally emphasise the development of student scientific literacy, the actual science programs offered to students didn’t match the guidelines in the curriculum documents:

> For many secondary students the science they are taught is neither relevant nor interesting. Traditional chalk-and-talk teaching, copying notes and cookbook practical lessons offer little challenge or excitement to students. Disenchantment with science is reflected in the decline in science subjects taken by students in upper secondary school (see Section 2.7 and 6.4). In primary schools, the problem is not what is taught but whether it is taught at all. Where science is taught on a regular basis, it is generally taught in a student-centred, activity-based manner that results in a high level of student satisfaction. When students move to the secondary schools many experience disappointment, and it is here that students’ interests wane markedly. Science at school is engaging and challenging when it connects with students’ contemporary interests and experiences, but often this is not the case. (p. 166)

Although the preferred science curriculum, as reflected in the documents, is consistent with a goal of scientific literacy, the actual science curriculum delivered in most secondary science classrooms in Australia is not.

The OECD Programme for International Student Assessment (OECD/PISA) is a significant international program of which Australia is a member. The OCED/PISA plans to monitor literacy in reading, mathematics and science of 15 year-old students. It aims to develop research-based levels of achievement in scientific literacy. As a necessary part of this process OECD/PISA has defined scientific literacy as follows:

> Scientific literacy is the capacity to use scientific knowledge to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. (OECD/Programme for International Student Assessment, 2003, p. 133)

The OECD/PISA definition is consistent with others quoted earlier and represents international agreement about the nature and importance of scientific literacy as a goal for science education. In order to make the achievement of the goal measurable the goal of scientific literacy has been expanded in three aspects to provide an assessment framework for OECD/PISA's version of scientific literacy. These aspects are stated concisely in OECD/PISA (1999):

> (i) *Scientific processes* that involve knowledge of science. The five processes selected are: recognising scientifically investigable questions; identifying evidence needed in a scientific investigation; drawing or evaluating conclusions; communicating valid conclusions; and demonstrating understanding of scientific concepts. (p. 62)
>
> (ii) *Scientific concepts,* the understanding of which will be assessed by application in the content areas. Thirteen major scientific themes were chosen on the basis of: relevance to and usefulness in everyday situations; enduring relevance to life throughout the next decade and beyond; relevance to situations identified as being those in which scientific literacy should be demonstrated; and the requirement that concepts are to be combined with scientific processes. (p. 63)
>
> (iii) S*ituations*, or *contexts* or *settings* in which the assessment tasks will be represented. The situations are grouped into three clusters concerning Science in Life and Health, Science in Earth and Environment, and Science in Technology. (p. 65)

The above definition and assessment framework were developed for the pencil and paper testing OECD/PISA program and do not include skills of investigation design and data collection. It is appropriate to include these skills in any approach to scientific literacy which focuses on practical work in school science.

From the point of view of this study a further notable omission from the scientific processes is *problem solving*. In his discussion of the objectives of science education Kirschner (1991) listed "-to solve problems (including the formulation of hypotheses)" as the first category of general objectives (page 27). The omission is more surprising as "Science in Technology" has been included in the OECD/PISA aspect of situations, or contexts or settings (p.65). As technology has problem solving aspects and relates to the everyday life of students, a case can be made to include problem solving in scientific processes on the grounds of relevance to the achievement of scientific literacy. This anomaly has been resolved by the development of a theoretical framework for a separate, cross-disciplinary domain of *Problem Solving* (OECD/Programme for International Student Assessment, 2003, pp. 154-192). The distinction between science and technology is not clear from the viewpoint of lower secondary students. The association between science and technology provides a useful basis for planning the practical work in *Science for All* (Fensham, 1990). Fensham went on to suggest that there is no other subject area in the school curriculum that could, or is willing to include it, and that technology is an integral part of *Science for All*. The importance of the link between science and technology has been stressed by Jenkins (1992) who argued that science has changed in the latter part of the 20^{th} century. Science knowledge is becoming more commercialised and industrialised and more integrated with technology, as it has been applied through a range of technologies, such as, medicine, transport, communication, employment, design and manufacturing. Jenkins considered that school science should be delivered through these contexts rather than be concerned with the grammar and syntax of the scientific disciplines.

The field of scientific and technological literacy has been reviewed by Layton, Jenkins, and Donnellt, (1994). They proposed three agreed contributing elements to scientific and technological literacy:

(i) A core of facts, concepts and skills, the selection of which might show some dependence on culture.

(ii) Some experience and understanding of what it means to work as a scientist or technologist, for example: how scientific knowledge is generated, replicated and validated; the confidence that can be properly placed in it; and how a technological artefact or system comes to be designed, manufactured and used.

(iii) An understanding of science and technology as cultural enterprises, including the values and assumptions that they accommodate and the mechanisms by which they are controlled and managed. (pp. iii-iv)

Like other researchers Layton, Jenkins, and Donnellt consider that scientific and technological literacy consists of three main elements. The first element includes the more traditional science content that has been dominating science courses around the world. This has not led to the development of scientific literacy. On the contrary, there has been declining student interest and a rejection of science. The value of scientific literacy, as a goal for science education, has been questioned by several researchers, such as, Atkin and Helms (1993); Fensham (2003); and Shamos (1995).

Atkin and Helms (1993) concluded that if scientific literacy is analogous to language or cultural literacy, citizens did not need to know science in the sense that one needs to know their mother tongue. Nor is the ability to use scientific knowledge in the way one uses language essential for adequate functioning and responsible citizenship. Fensham (2003) noted that there are too many leading citizens in all societies who not only have weak scientific knowledge, but also acknowledge it without embarrassment. This view strikes at the rationale for ‘science education for all’ that arises from concern over ‘the two cultures’ and the ability of all persons to make appropriate functional decisions in an ever-increasing scientific world. Surely the leading citizens referred to above would be able to function much more effectively, with fewer problems arising from their science-based decisions, if they had high levels of scientific literacy.

Shamos (1995), in his book entitled *The Myth of Scientific Literacy,* argued that universal scientific literacy was an unachievable goal and could result in a huge waste of resources. This view was supported by the opinion that most students leave science classes with neither an intellectual grasp nor a pragmatic appreciation of science. This seems to me to be dismissing scientific literacy as a goal for science education before it has been implemented and evaluated.

Fensham (2003) noted that the critics of scientific literacy went on to suggest priorities for science education in the compulsory years of schooling. Atkin and Helms (1993) suggested that science should be concerned with science as a human activity, its social and intellectual history. Schamos (1995) emphasised science as an ongoing cultural enterprise, and as an awareness of the impact of technology on one's health and safety, and the environment. These priorities matched proposals by Millar (1996) for a science curriculum for public understanding of science. Millar went on to support scientific literacy and science education for all during the compulsory years of schooling, while recognising the need for science education for students who wish to make a career in science and follow the science expert roles needed by society (Millar & Osborne, 1998). The different priorities for science education proposed by the critics of scientific literacy are similar to the curriculum emphases proposed by Roberts (1982), which required some selection of content for particular science programs that are designed to be interesting and relevant to particular students.

This study was conducted with the view that scientific literacy is an appropriate rationale for science education. Goodrum, et al (2001) recognised that learners and contexts differ and there can be no one best approach to the teaching of science. Effective science teaching requires varied approaches, designed to make different aspects of science accessible to the variety of individual students within each group of learners. Practical work in science education needs a much more open definition than that provided by Hegarty-Hazel (1990). The definition of practical work in science education must be based on an appropriate view of science, and it must be consistent with the modern view of how children learn and support the development of scientific literacy as the main goal of science education.

2.5 SUMMARY AND CONCLUSION

Practical work has been an important part of science education for more than 200 years. The value of practical work has been questioned at various times as the emphasis of science education has changed. Towards the end of the 19th century concern about the emphasis on the knowledge content of science courses, to the detriment of experience and understanding the processes of science, resulted in the introduction of Armstrong's heuristic method. The emphasis of science education changed from one of didactics to one of discovery. The aim was to develop pupil initiative, self-reliance, good judgment and manipulative skill through personal contact with apparatus and materials. The development of the child became the focus of education. After World War I, as university science courses developed, the emphasis of school science education moved towards science knowledge required to qualify for university entrance. After the Second World War increased numbers of students and an increasingly science-based world produced a cry for science education for all. This required appropriate courses to be developed. Together with changes in the philosophical view of science and increasing knowledge of how children learn, led to a worldwide movement of science curriculum change. The teaching resources adopted a child-centred discovery approach to science learning in the United States of America, Britain and Australia. These developments, with their unsystematic, enjoyable approach, without rigour or structure, failed to have significant impact on the majority of students. The reason for this disappointing result was identified as a reliance on obsolete epistemology behind the emphasis on inquiry and investigations in the discovery approach used by many of the projects. Discovery learning relied on inductivism thus presenting a distorted and inadequate view of science methodology.

The disappointing result of these major science curriculum projects was followed by a move towards a national curriculum in Britain and Australia. *A Statement on Science for Australian Schools*, recognising the importance of students' prior knowledge, required schools to present students with a broad range of science concepts organised in contexts that are interesting and relevant to their daily lives. The processes of science were described as essential learning for all students under the heading 'Strand 1 – Working Scientifically'. All curriculum documents produced by the States and Territories were consistent with the rationale for science education being *scientific literacy* as defined by Hackling, Goodrum, and Rennie (2001) and quoted by Rennie (2003):

> Scientifically literate people are interested in and understand the world around them; engage in the discourses of and about science; are skeptical and questioning of the claims made by others about scientific matters; are able to identify questions, investigate and draw evidence-based conclusions; and make informed decisions about the environment and their own heath and well being. (p. 35)

In terms of the previous discussion of general objectives and end terms, scientific literacy could be regarded as an end term. However, recent researchers in the area of teaching for meaning and understanding have introduced a new set of terms in their theoretical framework, for example, over-arching goals, understanding performances and through lines (Blythe & Associates, 1998; Perkins & Blythe, 1994). I suggest that scientific literacy should be regarded as an over-arching goal at the highest level of goal statements. The extent of achievement of the goal could be demonstrated by performances of understanding by the students.

Scientific literacy is an appropriate over-arching goal for science education. It emphasises both the knowledge and the processes of science. Levels of achievement can be demonstrated by performance outcomes. The scientific knowledge content of science programs can be presented within contexts that are of interest and relevance to the daily lives of students. The contexts will often cut across the traditional subject boundaries of science. The processes of science may still be applied through practical work within the contexts. The goal of scientific literacy was presented as an ideal or preferred rationale for science education within a report commissioned by the Australian Government (Goodrum, et al, 2001). The report found that there was a large gap between the ideal and the actual science curriculum in most Australian secondary schools. Although the emphasis pendulum has swung several times during the last 200 years, is the situation in science classrooms, for most students, very different from that described by Edgeworth and Edgeworth in 1811? The evidence suggests that it is not. The mismatch between the preferred and the actual science curriculum offered to most secondary students highlights the need for more research into the implementation of science curricula in general, and practical science programs in particular. There is a need for support for science teachers as they try to close the gap between the preferred and actual science programs in Australian secondary schools, and as they renew their science programs to make scientific literacy the main purpose of their efforts. There is a need for a theoretical framework for practical work in science learning in order to improve the professional learning of science teachers and to support science program renewal. In Chapter 3 I will clarify what is meant by the term *practical work* for the purposes of this study.

CHAPTER 3

Practicals for Scientific Literacy

3.1 INTRODUCTION

In this chapter, I explore what is meant by practical work for science learning. More specifically, practical work that is appropriate for science learning with the main goal of scientific literacy for all. The need for a more inclusive definition of practical work for science learning than that proposed by Hegarty-Hazel (1990) was established in Chapter 2. The term *practical* is introduced and described as it relates to the promotion of scientific literacy. It is not my intention to define further what is meant by the term *scientific literacy,* as practical work in science education is the main focus of this study. The theoretical basis for practical work for science learning is discussed. A theoretical model is developed by drawing from the research traditions of science, curriculum development and educational psychology. The proposed theoretical model enables different types of practicals to be identified and described. This chapter concludes with concise descriptions of eight types of practicals that will be used later in this study.

3.2 PRACTICALS: A THEORETICAL REVIEW

It is generally agreed by scientists that practical work is an essential part of scientific research. Science educators and science students agree that practical work is an essential part of science education. Practical work in science is not the same as practical work in science education. The practical work in scientific research is determined by the research design to investigate a particular research question. Practical work in science education is designed to promote science learning and is determined by the particular goals and aims of the science education program. The dual purpose of practical work to support scientific literacy and to induct students into professional science is problematic. Indeed, the aims associated with the different purposes may be conflicting and confusing for many students (Hegarty-Hazel, 1990). This study, exploring the role of practical work that promotes scientific literacy for all in the compulsory years of secondary schooling, is not concerned with the induction of students into professional science. This may occur for interested students at a higher level of education.

3.2.1 Practicals defined

Practical work and the concepts of science, which relate to a broad range of contexts of learning for scientific literacy, are interdependent. This requires a broader view of practical work than that which supports the traditional science concepts of the science programs limited to the school science laboratory: as defined by Hegarty-Hazel (1990), or as experienced by most secondary students in Australia as described by Goodrum, Hackling, and Rennie (2001). Hegarty-Hazel considered student laboratory work to be a form of practical work, which took place in a purposely-assigned environment where students planned learning experiences, and interacted with materials to observe and understand phenomena. By locating practical work in the laboratory, other types of practical work, such as field trips, were deliberately excluded. Also the limitation of the practical work to experiences, planned by students, excluded many strategies, tactics and techniques that have been described by Garrett and Roberts(1982). The *laboratory* used as a method of instruction in science education, has been defined as "contrived learning experiences in which students interact with materials to observe phenomena in a laboratory classroom within a school" (Hofstein & Lunetta, 1982, p. 2). Hodson (1988) considered that the terms *practical work*, *laboratory work* and *experiments* have been used to cover up confusion that failed to recognise that "not all practical work is carried out in a laboratory, and not all laboratory work comprises experiments" (p. 53). He presented *experiments* as part of laboratory work. Laboratory work that he referred to as "laboratory benchwork" (p. 54) was presented as a subset of *practicals* that are considered a subset of all the instructional methods or didactics of science education. (see Figure 3.1)

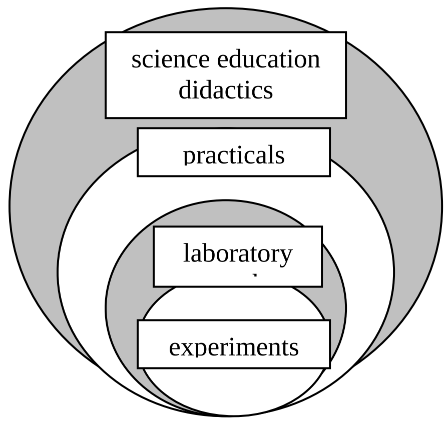

Figure 3.1. The interrelationship between experiments, laboratory work, practicals and didactics of science education (Hodson, 1988, p. 54; Kirschner, 1991, p. 61).

Practical work for science learning needs to be more than laboratory work. A broad view of practicals similar to that of Hodson (1988, p. 54) and Kirschner (1991, p. 16) is considered appropriate for the purposes of this study. A *practical* is defined as a didactic method for learning and practising all the processes and skills involved in the development of scientific literacy.

3.2.2 Practicals and science curricula

The adoption of the development of scientific literacy for all as the main purpose or goal of science education for the compulsory years of schooling provides us with a useful guideline for further exploration of what is meant by practical work and the different types of practicals in science education. Although I recognise that science practicals and science program content are interdependent in science learning, this study is not concerned with the facts or concepts of science, or the variety of contexts through which they may be delivered. This study is concerned with the practicals that promote the development of scientific literacy.

A common feature of all the definitions of scientific literacy, or descriptions of what a scientifically literate person is able to do, is the importance of understanding the world and the ability to discuss and make adequate evidence-based decisions about technology, the environment and the personal well-being of individuals and others. In some descriptions of the elements of scientific literacy the term *understanding* occurs more than once. In giving the promotion of understanding such high priority it is necessary now to explore what is meant by understanding and how it fits within what Blythe (1998) referred to as "the teaching for understanding framework" (p.17). Blythe considers that knowledge, skills and understanding are basic elements of education and that students emerge from learning experiences with knowledge, well developed skills and understanding of the meaning, significance and use of what they have studied. Knowledge is information that can be recalled, and skills are routine performances that can be repeated as required. Understanding is considered by Blythe to be more than knowledge or skills. It is the ability to think and act flexibly with what one knows. Blythe's views suggest that knowledge, skills and understanding form a hierarchy, the highest level of which is the achievement of understanding. This view leaves many unresolved questions, such as: does learning knowledge involve understanding? And, does the acquisition and development of a skill involve or require a level of understanding? It seems that Blythe has an epistemological view of knowledge acquisition. Epistemology is the philosophy of knowledge, its origin, nature, methods and limits. In epistemology the knower (the subject) develops a linear dualistic relationship with the known (the object). It is relevant to this study to explore the concepts of knowledge, skills and understanding.

The Oxford English Dictionary lists the range of uses for and different meanings of the term *knowledge*. Meanings that are considered relevant to this study are as follows: "Senses derived from the verb KNOW, in its later uses"; ".The fact of knowing a thing, state, etc., or (in a general sense) a person; acquaintance; familiarity gained by experience"; and "Acquaintance with a branch of learning, or the like; theoretical or practical understanding *of* an art, science, etc.; skill *in* or *to do* something (*obs.).*" (J. A. H. Murray, Bradley, Craigie, & Onions, 1989). These meanings suggest that skills are within the concept of knowledge. In a literature review Kirschner (1991, p. 40) found that knowledge is referred to in a variety of ways. Science knowledge is more than a collection of facts or information that can be recalled on demand. Gardner (1975) described different aspects of a specific knowledge domain as consisting of the 'substantive structure' and the 'syntactical structure'. The substantive structure of science is the network of related theories, laws and concepts (factual knowledge or declarative knowledge) that researchers use to solve problems within the discipline. Kirschner summarised knowledge as "essentially the content and facts, concepts, principles and theories of a discipline" (1991, p. 40).

Skills are referred to in a greater variety of ways than knowledge (Kirschner, 1991, p. 41), In summary, skills indicate a knowledge and ability to do something rather than knowing something. Complex skills can be broken down into a succession of simpler activities which are themselves simpler skills or sub-skills (White & Mayer, 1980). The syntactical structure of science consists of the pathways of inquiry, the processes by which new knowledge is generated and verified. In the context of this study, the syntactical structure of science means the thinking and reasoning skills used within the science discipline. Bloom et al (1956) distinguish between skills and abilities. *Intellectual skills* emphasise methods of operating in or coping with new problem situations. *Intellectual abilities* refer to the way specific information is brought to bear on a new problem. Although this distinction "may be made in achievement testing it is difficult to classify educational objectives…as abilities or skills" (Bloom et al., 1956, p. 39). As the distinction is not included in Bloom's taxonomy, syntactical knowledge is not further subdivided in this study. Science educators have a responsibility to teach students the substantive structure of science as well as the syntactical structure of science. Skills are included in the knowledge domain of science. Skills are not independent of substantive knowledge. Major skills needed for an achievement and development-orientated society such as ours, are skills required for the creation of new knowledge (Hurd, 1969). An important, if not the most important, concern of education is to develop skills that provide students with access to knowledge. The rationale for science practicals is thus to involve the learner in the use of logical processes and procedures to uncover the implications of scientific theories and laws; to give experience in asking good questions of the world; and to provide practice in recognising patterns, regularities, similarities, differences and commonalities among observations and other data. In general, the purpose is to assist the students to make sense of the data, assimilate the data, and accommodate their interpretations into their own conceptual framework. The skills needed are more intellectual than manipulatory. Kirschner (1991) describes knowledge as static, something that is acquired or possessed. Also a skill is dynamic, something that is improved and quickens through use. If a simplistic phrase, which describes the basic elements of education is needed it should recognise knowledge, skills and contexts each with a relationship with understanding.

The field of hermeneutics explores human understanding in general. Hermeneutics is the study of the "process of interpretation, the communication of meaning through a text, linguistic competence in conversation and so forth" (Gallagher, 1992, p. 6). Gallagher reports that the conceptualisation of hermeneutics has moved on beyond its concern with written text and spoken word to a more universal conception that deals with non-textual phenomena such as social processes, human existence and life itself. Philosophers, from Plato and the ancient Greeks, to Dewey and Gadamer of modern times, have recognised the importance of *Eros* to human beings. Eros is the desire for humans to have "a reflective awareness of the wholeness and integration of meaning in their lives" (Alexander, 1997, p. 333). It is fundamental to the human condition that individuals have a desire to interpret and make meaning of their lives and the world in which they live. The acquisition of knowledge involves the interpretation of language. It therefore follows that the acquisition of knowledge involves the development of understanding and the construction of meaning, and is within the field of hermeneutics. If educational experience is hermeneutical then we should be able to use hermeneutical principles to assist us through the processes of interpretation to the achievement of understandings and the development of meaning. The *hermeneutical circle* is a central principle found in almost all works on hermeneutics. The changing conceptualisation of hermeneutics can be seen in the three models of the hermeneutical circle that have been described by Gallagher (1992).

For the traditional model of the hermeneutical cycle Gallagher refers to Schleiermacher (1977) and Dilthey (1972). The concept can be traced back to Romantic hermeneutics sourced from Protestant biblical hermeneutics (Gadamer, 1999). Schleiermacher considered that the meaning of a part is only understood within the context of the whole; but the whole is only accessible through understanding the parts. "Understanding therefore requires a circular movement from parts to whole and from whole to parts" (Gallagher, 1992, p. 59). Dilthey had a similar view; increasing movements lead to enlargement of the circle and increasing understanding of the context and the parts. Both Schleiermacher and Dilthey describe the hermeneutical circle in terms of text and its objective historical context.

A second conception of the hermeneutical circle is that developed by Husserl (1973), who follows the phenomenological tradition. Experience is discussed in terms of the *horizon structure* of experience, which is akin to the hermeneutical circle and that the experience occurs within, and is interpreted from, a context that provides a degree of pre-knowledge of the experience, and that each experience has its own horizon and never comes to be known in isolation (Gallagher, 1992). Gadamer (1984) criticizes Husserl for not recognising the prime importance of interpretation. Heidegger (1982) developed this concept of pre-knowledge so that the focus of hermeneutics shifted from the objective whole and its parts, to the conditions of interpretation and the development of understanding and the creation of meaning. The process of interpretation is the process of revising the pre-knowledge as more information is gathered. The revised meanings continue to be projected until the meaning becomes clear. The hermeneutic circle does not disappear by the achievement of perfect understanding. The achievement of absolute knowledge or absolute truth is not achievable by human beings. Gadamer considers that “human understanding involves a constant temporal process of revision; it is always finite, temporal, circular; and incomplete interpretation because of the existential temporal structure of human existence” (Gadamer. in Gallager, 1992, p. 62) Prior knowledge is continually being modified by the interpretation of experience as it promotes understanding. These ideas are important for science education as they are akin to the views of Millar and Driver (1987), and Osborne and Freyberg (1985), which recognise the importance of the student’s prior learning in the achievement of any new learning. Also the conception of the hermeneutical circle as a spiral that is never closed by complete understanding is consistent with a constructivist view of reality and the scientific realist view of the real world discussed in Chapter 2. However, there is a third view of the hermeneutic circle that is relevant to this study.

A third conception of the hermeneutical circle proposed by Hirsch (1976) is based on the concept of *corrigible schema* which draws on the ideas of Piaget (1952; 1971), Anderson and Pearson (1984) and others. The concept of schema (also referred to as *schemata* in the literature) comes from rationalist epistemology and Gestalt Psychology and suggests that the knowledge we have does not exist as disconnected pieces of information but is organised into patterns or schema. Schema can organise or assimilate new information and the schema can change themselves, or accommodate the new information as new knowledge. Text and other information is meaningless without the learner having an interpretive frame work "to breathe meaning into it" (Anderson, 1977, p. 423). The learner or interpreter unconsciously selects and adjusts appropriate schema that which are context sensitive and adjustable. Hirsch's conception of the hermeneutical circle does not contradict the ideas of Heidegger or Gadamer discussed in the previous paragraph. There is no fundamental difference between Heidegger's concept of fore-structure (referred to in this study as prior knowledge) and Hirsch's concept of corrigible schemata. The constant adjustment of prior knowledge by interpretation of experience develops new understandings and new meanings. Prior knowledge may be reinforced by interpretation of experience or it may be compelled to undergo revision which in turn conditions our understanding (Buck, 1981).

For the purpose of this study, learning that promotes understanding is said to be meaningful. Science practicals provide students with a wide range of interpretive experiences, which prompt revision of prior knowledge, promoting student understanding of their world and constructing meaning for their lives. Science practicals have an important place in science education programs that promote scientific literacy for all. I will now consider the role of science practical work in teaching for understanding and the development of scientific literacy.

3.2.3 Rationales for Practicals

A common rationale for the inclusion of practicals in traditional science curricula is that they enable illustration, confirmation, acquisition or discovery of the substantive structure of science (Woolnough, 1983). Kirchner (1991) recognised four commonly held motives for implementing practicals in science programs:

1. Practicals serve or are subservient to scientific knowledge.
2. Practicals provide 'hands-on' experiences that promote the learning and practice of manipulative laboratory skills.
3. Empirical work in practicals enables the learner through experiences of natural phenomena to develop insight and understanding of the experiences and the laws of nature.

4. Practicals that rely upon discovery offer the best, if not the only way to achieve meaningful learning in science.

These motives are based on the idea (now outdated) that the process of learning science should be the induction of the learner into the world of research scientists (Bruner, 1960). They perpetuate the confusion, already discussed in Chapter 2, between doing science and learning science. Each of the above motives for implementing practicals in science programs will now be considered.

3.2.3.1 Practicals serve or are subservient to scientific knowledge

The practicals are used to illustrate, verify or confirm substantive scientific knowledge, concepts or theories that may have been taught earlier in separate theory lessons. Fensham (1990) considered that science teachers tried to bring about the induction of students, whatever the level of schooling, into the knowledge, behaviours and ways of thinking of scientists. The role of secondary schooling was the promotion of conceptual science, that is, "those building blocks of more or less current scientific generalisation and explanation of phenomena" and that just enough of "the factual properties of the phenomena were to be included to provide a minimal logical basis for the introduction of the concepts" (Fensham, 1990, p. 295). Fensham described these secondary science courses as being so deliberately an introduction to the conceptual logic of science that none of them included the guided discovery role of laboratory work. Science was considered to involve abstract and complex subject matter, which students found difficult to understand. Practicals were considered to provide students with concrete experiences and opportunities to manipulate ideas, which helped make the abstract more concrete and helped simplify the complex (Tamir, 1976). There are three concerns with the notion that practicals serve or are subservient to scientific theory:

1. Theory and practical work are interdependent.
2. The very nature of theoretical science is abstract.
3. A subservient role of practical work has led to misrepresentation of the nature of science.

The first concern is with the subservient position assigned to practicals in the educational process. Theory and practical work are interdependent. Experiments assist theory building and theory, in turn, determines the types of experiments that can be performed (Hodson, 1988). Many educators do not recognise the interactive relationship of practical work and theory. Thus practical work in traditional science courses is usually subservient to theory, it is poorly related to course objectives, and it consists of exercises for manipulative skill development rather than exercises in systematic inquiry, leading to greater understanding and the development of meaning.

The second concern is with the provision of concrete science experiences to make science concepts and theories less abstract. Science deals with theoretical concepts and their interrelationships. The very nature of theoretical science is abstract. Theoretical concepts and their conceptual frameworks have to be considered and manipulated in the abstract. It is essential that "these concepts are separated from their concrete reality if the maturing scientific mind is to gain mastery of them. We mislead and restrict the thinking of students when we give the appearance of relating everything to a laboratory experience" (Woolnough & Allsop, 1985, p. 39).

Thirdly, the use of practicals to illustrate and verify the theories and concepts of science has led to the provision of foolproof recipes for laboratory experiments that have misrepresented the nature of science. Science courses often involve students working through a series of foolproof *experiments'* where the expected results are the same for everyone in the class if the instructions are followed correctly. The goals of the practicals become getting the right answer rather than learning the structure of the discipline being studied (Wellington, 1981). Students are often unable to explain what they did or why they did it, even immediately after the practical (Moreira, 1980; Tamir, 1976) The logical solution to teaching abstract concepts to students, who are only able to think in concrete terms, is not to attempt it. If teachers continue to try to teach formal concepts to concrete thinkers the effect is to reinforce or introduce misunderstandings into the minds of students, which will be hard to correct later (Woolnough & Allsop, 1985). Science taught in this way is misrepresented as a body of knowledge that is certain, and can lead to student boredom and apathy towards science learning and science in general (Goodrum et al., 2001; Read, 1969; Reimann, 1955; Thomas, 1972).

3.2.3.2 Practicals provide 'hands-on' experiences that promote the learning and practice of manipulative laboratory skills

It is widely recognised that skill acquisition and development can be achieved in science practical work. I have already described Fensham's (1981) proposal for 'Hands Science' for the 1980s in Chapter 2. Fitts and Posner (1967) dealing primarily with the learning of motor skills, defined three phases in the acquisition of complex skills; the *cognitive phase*, the *associative phase* and the *autonomy phase*. The cognitive phase involves the learner trying to understand the task that he may be able to perform. Some knowledge of the substantive structure of a domain (science) is a prerequisite for learning a skill. Beginners learn to observe and understand what a task involves and how a task is carried out. Prior knowledge determines what is seen. The second phase, the associative phase, is characterised by practice and feedback during which new patterns of skill components are tried out and inappropriate actions are eliminated. Gradually the skill is refined and its performance becomes more polished and easier to apply. In the final phase, the autonomy phase, the skill is applied with increasing speed, coordination and control. The component sub-skills of complex processes become increasingly automatic and performed as a smooth uninterrupted process. Woolnough (1983) considers that practicals are best suited for the development of specific skills through exercises. Sere (2002) in describing the conclusions from a comprehensive European study, *Labwork in Science Education,* stated that there are many potential objectives to be aimed for in science practical work. "To do" and to "learn to do" must be taken as seriously as "to understand" and to learn concepts (p. 638). She goes on to argue that students must be taught the processes of science and that many of the traditional conceptual objectives of laboratory work must be put aside to make time for the achievement of new ones. It is clear from this discussion that practicals have an important role in the acquisition of manipulative laboratory skills as part of the syntactical knowledge of science for the achievement of scientific literacy by all students.

3.2.3.3 Empirical work in practicals enables the learner through experiences of natural phenomena, to develop insight and understanding of the experiences and the laws of nature

The third motive for science practicals arises from the view that students will gain understanding from the interpretation of practical work with natural phenomena. The suggestion is that students start with no understanding of a theory, principle or concept; they then collect data from experiences and from their interpretation of the data, an understanding of the experienced phenomena develops. Kirschner (1991) has identified four basic problems with this motive:

1. Observations and experiences are not neutral objective events.
2. Much of the content of traditional school science courses is not accessible to students.
3. The practical work distracts students from the subject being studied.
4. The amount of practical work required to produce sufficient experience is too great.

Firstly, Wellington (1981) referred to his problem with this motive for practicals as his objection to the empiricist view of discovery learning. Observations and experiences are not neutral, objective events and do not produce knowledge and conceptual frameworks, but are determined by them. In order to develop understanding learners need to have prior knowledge, a schema, perceptions, or a conceptual framework in their minds to make sense of what they see. Without an appropriate conceptual framework, meaningful observation and the interpretation of these observations cannot take place. Without knowing what to look for, the likelihood of students seeing what is intended is small and that their interpretation will be as planned is even smaller. It is theoretical understanding that gives purpose and form to their experiences, interpretation and the development of understanding (Hodson, 1990). The importance of prior knowledge in the development of understanding of new phenomena, the construction of new conceptual frameworks and the ability to solve problems has been recognised by many authors, such as, Hewson (1980) and Suchman (1966). Research into the problem of students' pre-existing misconceptions of scientific concepts is extensive, for example, Berg and Bower (1991), Driver Asoko, Leach, Mortimer, and Scott (1994), Gilbert and Watts (1983), Osborne and Freyberg (1985), Shuell (1987). Learners with misconceptions of scientific principles appear to have little difficulty interpreting new observations in terms of their misconceptions. This leads to understandings of an alternative science that are the result of accurately recorded observations and other data, and the result of logically derived interpretations, but are based on unconventional science principles.

The second problem relates to the abstract nature of the theoretical concepts of science and their relationships. Much of the content of traditional secondary science courses are not accessible to students who have not reached the formal stage of thinking (Hodson, 1988). Students can be misled and their thinking restricted if attempts are made to relate all scientific theory to laboratory experience (Woolnough & Allsop, 1985).

The third problem is simply that the activity and problems of the practical work can clutter and distract students' attention away from the underlying concept that they should be studying. As well as getting lost in the details, most students do not have the conceptual development or formal thinking required to infer the patterns present in the data. Substantive knowledge is therefore better taught through lectures, workgroups, tutorials, and written assignments rather than through practicals (Woolnough & Allsop, 1985).

Finally, the fourth problem, which is separate from the other three problems, is that the amount of experimentation and empirical work necessary to make sufficient interpretive experiences to develop understanding and meaning requires so much time, energy and resources that implementation is impossible. Multiple exposures to demonstrations of a concept are required for adequate understanding to develop (Kreitler & Kreitler, 1974). It follows that if the interpretation of practical work is the primary means of concept formation it is an ineffective and inefficient way of achieving understanding of concepts.

3.2.3.4 Practicals that rely upon discovery offer the best, if not the only, way to achieve meaningful learning in science

The discovery approach to science learning has been discussed earlier in Chapter 2. The rationale for discovery learning assumes that the attainment of scientific attitudes, the encouragement of interest in science, the acquisition of scientific skills, the learning of scientific knowledge, and understanding the nature of science, can all be achieved through applying the methodology of science that is inductive in its approach. This rationale makes no distinction between the strategies and methods of a practicing professional scientist and those of a novice science student (Hodson, 1988). A scientist is a person committed to investigation, accumulating knowledge and possessing a large amount of knowledge, as well as an ability to make predictions about natural phenomena. A student, on the other hand, is still learning about science and does not possess the knowledge, wealth of experience or high level of sophistication of the researcher. Ausubel (1964) expressed concern about the failure to distinguish between the scientist and the student. He described scientists as being engaged in a search for new, general or applied principles in science, and students learning the basic subject matter of science and the way in which scientists practice. Discovery approaches to science learning deliberately avoid giving the students any prior understanding of the practical work and its content. I have argued earlier in this chapter that prior knowledge is important in any interpretive experience. If students are to discover scientifically, they must first learn the content or substantive knowledge as well as how to discover or the syntactical knowledge of science. Scientific inquiry is a systematic, imaginative and creative process, which is considered part of the syntactical knowledge of science. Scientific inquiry is effective after a researcher has acquired a critical part of the substantive knowledge of science through more formal learning processes. It does not equate with the open-ended discovery methods of science learning (Kyle, 1980). Discovery learning for the substantive knowledge of science has been characterised by Hodson (1986) as epistemologically weak and pedagogically inappropriate. The origin of the wide spread adoption of discovery learning is at least partly due to the misinterpretation of Ausubel’s ideas on the psychology of meaningful verbal learning. Supporters of the view that discovery in a laboratory is the only way to achieve meaningful learning equate reception learning with rote learning and discovery learning with meaningful learning (Novak, 1978; Summers, 1982). This idea is shown as a one-dimensional continuum in Figure 3.2.

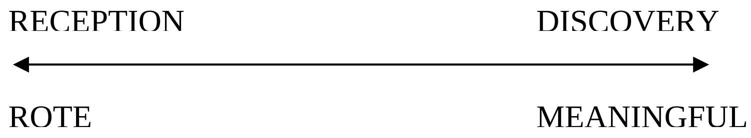

Figure 3.2. A one-dimensional misrepresentation of the ideas of Ausubel (Summers, 1982, p. 363).

Ausubel was very clear in his distinction between reception and discovery learning as one continuum, and rote and meaningful learning as another. He argued very clearly against the one-dimensional continuum advocated by the supporters of the discovery approach to meaningful science learning (Figure 3.2). I think it is important to note Ausubel's actual words on this point:

> The distinction between rote and meaningful learning is frequently confused with the reception-discovery distinction…This confusion is partly responsible for the widespread but unwarranted twin beliefs that reception learning is invariably rote and that discovery learning is inherently and necessarily meaningful…. Actually each distinction constitutes an entirely independent dimension of learning. Hence a much more defensible proposition is that *both* expository *and* problem-solving technics can be either rote *or* meaningful depending on the conditions under which learning occurs. (Ausubel, 1963, p. 18)

It is clear that Ausubel considered that verbal reception learning can be genuinely meaningful and that the criticisms of the method of expository verbal instruction are not inherent in the method but are the result of misapplications or bad teaching. He also considered that the above criteria for meaningfulness apply to problem-solving and laboratory methods. If the criteria are not met then discovery approach learning will result in rote learning. Reception learning may be rote or meaningful and discovery learning may also be rote or meaningful. The discovery approach to meaningful learning in science is theoretically unsound. Also, empirical research studies indicate that students who have been exposed to the discovery approach to science learning in laboratories do not perform any better, and sometimes do worse, than students who have not had laboratory experience (Flansburg, 1972; Garrett &

Roberts, 1982; Hodson, 1990; Hofstein & Lunetta, 1982; Shulman & Tamir, 1973; Tamir, 1976). In comparative studies, there are often no significant differences of conceptual development, substantive knowledge, or understanding of methodology, the syntactical knowledge of science. Again, I think it is appropriate to leave the last words to Ausubel.

> One basic lesson that some modern proponents of the discovery method have drawn from this educational disaster is that problem-solving *per se* is not conducive to meaningful discovery. Problem-solving can be just as deadening, just as formalistic, just as mechanical, just as passive, and just as rote as the worst form of verbal exposition. The type of learning outcome that emerges is largely a function of the structure, the substance, the organisation, and the spirit of the problem-solving experience one provides. However, an equally important lesson which these proponents of the discovery method refuse to draw is that, because of the educational logistics involved, even the best program of problem solving experience is no substitute for the minimally necessary amount of appropriate didactic exposition…(Ausubel, 1963, p. 142)

Ausubel referred to the discovery approach to science learning, introduced during the 1960s and 1970s, as an educational disaster. Hodson (1996) reports discovery learning, as characterised by the *Nuffield Physics Course (Nuffield Physics, 1967)*, as purporting to be student-driven inquiry but degenerating to a powerful form of teacher direction and control (p. 119). Although Ausubel argued strongly against discovery learning, as proposed by Bruner (1960) and Schwab (1962), he did support learning by discovery under certain circumstances. He considered that it had a place in the repertoire of accepted pedagogic techniques available to teachers for "certain designated purposes and for carefully specified learning situations, its rationale is clear and defensible" (Ausubel, 1963, p. 139). The discovery method is useful in the early, unsophisticated stages of learning any abstract subject matter, particularly prior to adolescence.

The view of science indicated by the rationales for practical work in science learning discussed in this chapter has not kept pace with the developments in the historical, philosophical and sociological understandings of the nature of science. The significant changes that have taken place in the academic view of the nature of science discussed earlier in this study seem to have had little impact on school science. Millar (1989) has referred to this as the persistence of a commonsense view of science. The rationales for practicals are generally theoretically flawed, and are consistent with the description of traditional science used by Goodrum, Hackling, and Rennie (2001) and have not responded to the view of science as a sociological, creative and institutionalised activity. Philosophical, sociological and historical approaches to understanding the nature of science have, with minor exceptions, maintained their conceptual and institutional independence (Jenkins, 1996). The teaching of the scientific method has been an important curriculum component for more than a century, being justified as an example of rationality that was transferable to everyday life through the development of scientific literacy in all students. This view of science that has "explicitly or implicitly provided coherence and security for generations of [science] teachers is now an antique" (Ravetz, 1989, p. 20). A view of science allied with rationality and empiricism in everyday contexts tends to support a positivistic science method, which is attractively simplistic but cannot be theoretically sustainable and "ultimately points to the quagmire of epistemological relativism" (Jenkins, 1996, p. 147). Such a view of science gives undue status to the instrumental scientific method at the expense of a more hermeneutical approach to science. A modern view of science, which gives due recognition to science being one of the great achievements of the human race, needs to be more hermeneutical in approach and understanding of the nature of science. I have already argued that science practicals provide rich experiences and new opportunities for students to interpret their experiences, to develop understandings, and to construct meanings. Such opportunities are provided by scientific inquiry. Inquiry approaches to science learning are recommended to science program developers, such as: the American Association for the Advancement of Science (AAAS) (1995); the Curriculum Corporation (1994b); the Curriculum Council (1998); and the National Research Council (1996). Although there are national and international curriculum recommendations towards inquiry, science teaching and learning is generally inconsistent with inquiry science (Goodrum et al., 2001). Another indication of the trend towards inquiry in science education programs is the Four Stage Model for the shift towards inquiry in the professional development of teachers (Moscovici, 1998).

3.2.3.5 The Four Stage Model for the shift towards inquiry science

Moscovici (1998) has proposed the Four Stage Model for the shift towards inquiry science. This model suggests four stages through which science teachers may develop during their teaching careers: textbook science; activity mania; imposed inquiries; and personal inquiries.

Teachers in the first stage, *textbook science*, rely on the textbook as their main (and often the only) science teaching resource. The science lessons consist of reading the text followed by answering questions at the end of the chapter, sometimes followed by multiple choice tests supplied by the textbook editor.

Teachers within the second stage, *activitymania*, keep students busy with disconnected and short hands-on activities, which often remain at the level of fun and do not lead to scientific inquiries. The activities are self-contained, do not lend themselves to inquiries as they usually ‘work’ and all students observe/record the expected results and reach the same expected conclusions.

Teachers in the third stage of the model, *imposing personal inquiries*, use a pedagogy that imposes the problem, the solution, the results and the explanation on the students.

In the fourth stage of the model, *personal inquiries*, teachers encourage and support students to raise their own researchable questions, devise ways to answer them, experiment and collect data, organise and interpret data and develop understandings of science didactic and syntactic knowledge as recommended by the National Research Council (1996).

The Four Stage Model (Moscovici, 1998) may be useful as a guide to the professional development of science teachers. But it focuses on what teachers do rather than describing the range of different science practicals available to the competent science teachers. Science teachers use a range of approaches to learning and would not operate in only one stage. There is a need for a theoretical model that draws on hermeneutic traditions, which will provide a basis for reviewing new rationales for science practicals.

The remainder of this chapter is devoted to the development of a theoretical framework for science practicals, drawing on the ideas of Ausubel (1963). I think it is appropriate to go back to the ideas of Ausubel. As I have explained earlier, it was a misinterpretation of Ausubel's ideas that led to the discovery learning approach to science education, which most writers agree failed to produce the science curriculum renewal that was hoped for in the 1960s and 1970s.

3.3 PRACTICALS – A THEORETICAL MODEL

Ausubel (1963) aims to present a comprehensive theory of how humans learn and retain subject matter in classroom and similar learning environments. The theory focuses on reception learning and retention of meaningful material, that is, material that contributes to understanding and the development of meaning. Reception learning refers to the presentation of the content of the learning task rather than being independently discovered by the learner. The learner is required to meaningfully comprehend the content such that it is available or functionally reproducible for future use. This is described by Blythe & Associates (1998) as "performances of understanding" (p. 21). Meaningful verbal learning is the principal means of increasing the learner's knowledge inside and outside the classroom. Discovery learning, including inquiry and problem-solving "is not a practical means of transmitting subject matter content" (Ausubel, 1963, p. 1). Ausubel discusses two completely independent dimensions to distinguish the different types of verbal learning: the reception–discovery learning dimension and the rote--meaningful learning dimension, as shown in Figure 3.3.

Figure 3.3. The dimensions of the learning process after Ausubel (1963).

Novak (1978) and Elton (1987) both propose differentiation between two separate orthogonal learning parameters, the rote-meaningful dimension and the reception-discovery dimension. Ausubel's ideas are represented in two dimensional maps of learning in Figure 3.4 and Figure 3.5.

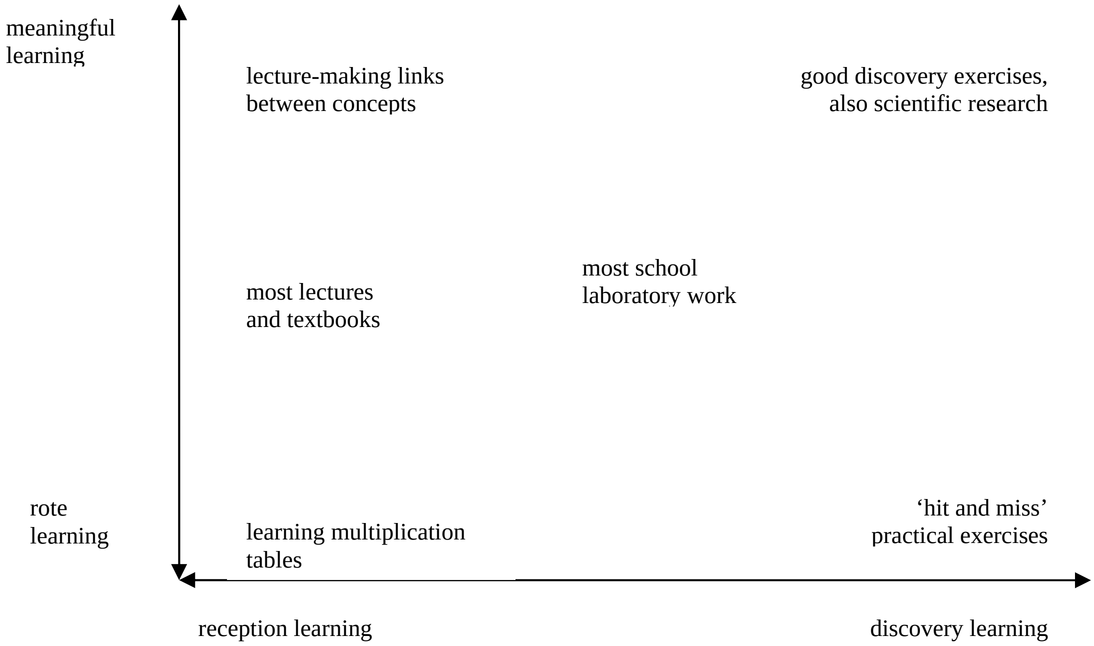

Figure 3.4. The map of learning, after Ausubel (Head, 1982, p. 638).

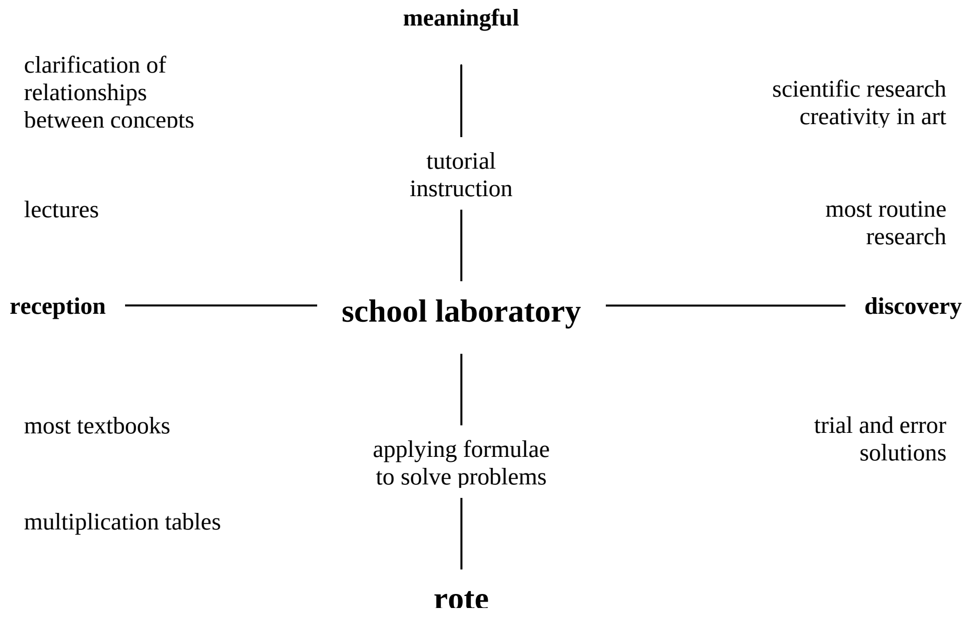

Figure 3.5. The map of learning, after Ausubel (Elton, 1987, p. 117).

For the purposes of this study the Theoretical Model for Science Practicals was developed by changing the scope and limitation of the map of learning after Ausubel, developed by Elton (1987), as shown in Figure 3.5. The model was evolved from the theoretical framework provided by Ausubel (1963). The model encompasses science practicals as defined earlier in this Chapter. It does not include some of the components of the map proposed by Elton, as they do not come within the definition of practicals, that is, lectures, textbooks, multiplication tables, tutorial instruction or applying formulae to solve problems. Furthermore, this model does not limit science practicals to the school laboratory. The taxonomy is based on the instructional purpose served by each type of practical. Eight types of science practicals have been identified from the literature and from the theoretical model shown in Figure 3.6.

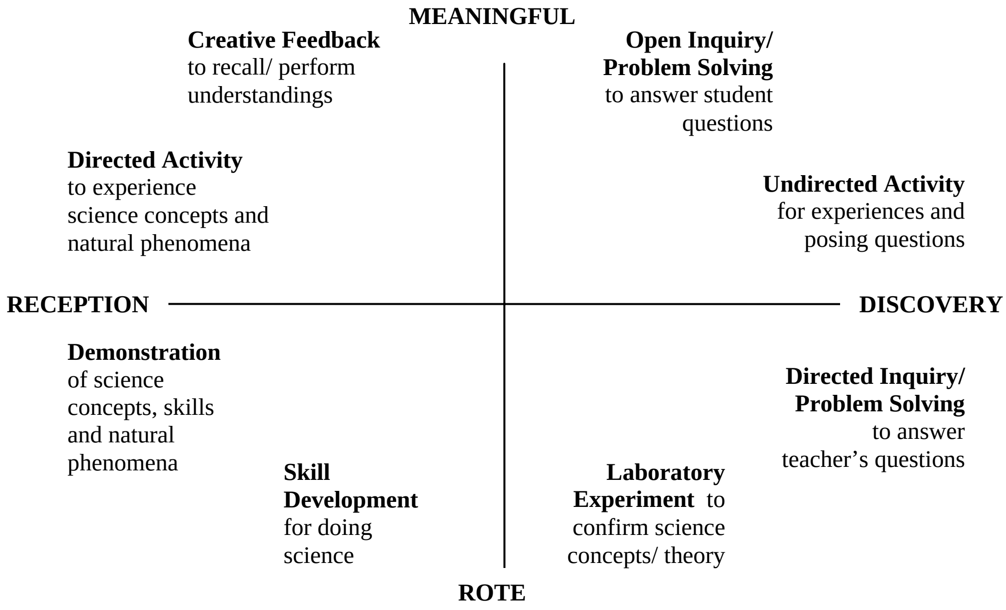

Figure 3.6. The Theoretical Model for Science Practicals, after Ausubel (1963), Novak (1978) and Elton (1987).

Each type of practical can be located on the theoretical model by the two terms that define each quadrant. The first mentioned term is adjacent to the octant that contains the practicals being considered, and is the dominant dimension, for example, the practicals located in the RECEPTION/ROTE octant are grouped as practicals type, *Demonstration*, while the practicals located in the MEANINGFUL/RECEPTION octant are grouped as practicals type, *Creative Feedback.* Each type of practical will now be considered.

3.3.1 Directed Activity: for experiencing scientific and natural phenomena

Practicals located in the RECEPTION/MEANINGFUL octant of the theoretical model, are grouped as practicals type, *Directed Activity*. Directed Activity is concerned with reception learning that may be either meaningful or rote. Directed Activity aims to present the learner with content that is to be learned through simple practical activities. Directed Activity requires directed action by the learner. To achieve meaningful learning he or she is required to follow the teacher's instructions that may be delivered directly or indirectly by use of a worksheet or text book. The learner is required to record observations and/or record results and describe what is learned from the activity. He or she is required to assimilate and accommodate the material presented to develop understanding and meaning as described in section 3.2.2. There are abundant printed teaching resources available in the form of worksheets organised as units of study or textbooks, which have adopted an active learning approach. Materials produced by the Australian Science Education Project are typical of the resources available. Although the project ended in 1974 many of the materials are still used in schools today and many of the activities, or similar, have been reprinted by various publishers of science education resources. The impact of ASEP has been more systematically evaluated and researched than other comparable courses. The research suggests that student achievement of unit objectives is enhanced if the teacher interacts with the students, actively consolidating and integrating experiences, data and ideas in a meaningful way, thus promoting interpretation of the experiences and understanding of the concepts involved (Edwards & Power, 1990). Teachers have an important role in the development of students' understandings and their construction of the meaning of scientific concepts (Driver et al., 1994).

The use of practicals to allow students to gain experience of phenomena has been characterised as "getting the feel for the phenomena" (Woolnough, 1983, p. 62) "It is the obtaining of an implicit or tacit, feeling or awareness of what is happening or what is supposed to happen as opposed to the explicit knowledge of how something works or why…. Familiarisation of the world around us cannot be achieved in any other way" (Kirschner, 1991, p. 59).

For the purposes of this study**,** Directed Activity is described as teacher directed activity in which the learner is required to do activity, following teacher instructions and answer questions provided by the teacher, to support science theory or experience scientific phenomena.

3.3.2 Demonstration: for presenting science concepts, skills and natural phenomena

Practicals located in the RECEPTION/ROTE octant of the theoretical model, are grouped as practicals type, *Demonstration.* Demonstration is concerned with reception learning. Reception learning may be either meaningful or rote. Demonstration aims to present the learner with content that is to be learned in its final form. Demonstration does not require independent discovery by the learner. To achieve meaningful learning he or she is required to assimilate and accommodate the material presented “so that it is available and reproducible at some future date” (Ausubel, 1963, p. 16). The high value placed by teachers on demonstration as a teaching method has been discussed in Chapter 2. In experimental seminars (Conway, Mendoza, & Read, 1963) students watch an experiment performed by an expert, or students perform an experiment cooperatively. In this way they may gain experience and knowledge about how experiments are performed. Collective demonstration or experimentation is followed by group discussion led, and if necessary stimulated, by an *expert*, usually the teacher. Much research effort has been directed towards the identification of student misconceptions or alternative conceptions of scientific phenomena. Teaching strategies have been developed to identify and challenge student misconceptions or alternative conceptions. It is believed that if students’ understanding of the basic concepts is consistent with the accepted views of scientists, then they have a better chance of achieving appropriate understanding and meaning from the rest of the course of study. There is a developing consensus in the science education community that traditional teaching is a relatively ineffective way to change misconceptions. Interactive methods, on the other hand, can result in significant increases in understanding. Teaching that uses interactive methods can achieve significant increase in understanding (Hake, 1998). One such method involves the use of Interactive Lecture Demonstrations (ILDs) that are designed for use in a traditional teaching context, in a class room or lecture theatre (Thornton, 1997). Students are asked to predict the results of simple demonstrations. Predictions are discussed and disagreements are resolved by discussion among themselves. The demonstrations are presented only after this has been done. The results are discussed together with any incorrect predictions. The development of ILDs has been for students in higher education. ILDs have been trialed in Australia with success, although with less improvements in understanding than in the American studies (Johnston & Millar, 2000). There is a need for research into the development of appropriate interactive strategies, which use questions, predictions and discussions as part of demonstration, in secondary school science teaching for meaningful received learning of the substantive knowledge of science.

For the purposes of this study, Demonstration is described as a type of science practicals in which the teacher or other expert presents science phenomena to support science theory, and directs student attention and the discussion of results. The more students are actively involved in the presentation or performance of the demonstration the closer the practical comes to Directed Activity

3.3.3 Skill Development: for doing science

Practicals located in the ROTE/RECEPTION octant of the theoretical model, are grouped as practicals type, *Skill Development*. Skill Development is an essential part of understanding science (Gagne, 1963). Gagne (1965) identified eleven skills or processes of science arranged in a hierarchy of basic skills including: observing, measuring, inferring, classifying, collecting data and recording data; and higher level integrated processes including: interpreting data, controlling variables, defining operationally, and formulating hypotheses. In *Science - A Process Approach* (American Association for the Advancement of Science, 1967) the basic skills are considered essential for understanding and using the integrated processes. Cain and Evans (1990) identified a similar list of process-inquiry skills including: observing, classifying, measuring, using special relationships, communicating, predicting, inferring, defining operationally, formulating hypotheses, interpreting data, controlling variables, and experimenting. All of these skills are basic to science learning. Basic skills underpin understanding of the process concepts of science (Gott and Duggan, 1995, p. 67). Skills are not content free. Skills and content are interdependent. Basic skills can be developed using specific content, for example, measuring temperature or classifying plants. OECD/PISA (2003) have developed and elaborated three scientific processes within the scientific literacy domain: (1) describing, explaining and predicting scientific phenomena; (2) understanding scientific investigation; and (3) interpreting scientific evidence and conclusions. Higher skills or integrated processes may be developed using other types of practicals, such as, laboratory experiments, directed inquiry/problem solving or open inquiry/problem solving. Which practicals are used will depend on which skills are to be developed. Skill acquisition and development may be successfully achieved by supporting students through the phases of skill acquisition discussed earlier in this study.

For the purposes of this study, Skill Development is described as the acquisition and development of basic scientific skills, in order to do science, these include manipulative skills, such as, the correct and safe use of apparatus, like the microscope, heating equipment and glassware; and science process skills, such as, observation, measurement and hypothesising.

3.3.4 Laboratory Experiment: for confirming science concepts

Practicals located in the ROTE/DISCOVERY octant of the theoretical model, are grouped as practicals type, *Laboratory Experiment*. Laboratory Experiment, also referred to in the literature as academic, formal, structured, and convergent or *cookbook* laboratories, have been a major part of traditional science education for more than 100 years. Their functions are to verify laws, principles, concepts and facts taught in theory lessons or by using textbooks. Laboratory Experiment is generally a closed type of practical with all the decisions being taken by the teacher who presents students with a recipe to be followed in order to get the correct result (Hackling, Goodrum & Rennie, 2001). The science education culture is a rich source of many hundreds of traditional laboratory experiments, which are testament to the inventive skill of previous generations of science educators. Textbooks, science education journals and the published proceedings of science teachers' conferences are rich sources of laboratory experiments. Descriptions of the experiments usually contain: AIM, a concise statement of the purpose of the experiment; APPARATUS, a list of the equipment required and a diagram showing how it is set up; METHOD, a detailed description of the procedure to be followed, data to be collected and ways of minimising errors; RESULT, detailed procedures for recording the data and applying science concept and theoretical formulae to achieve the aim of the experiment; and CONCLUSION, instructions for stating concisely what had been learned from the experiment. Students are usually required to present a detailed report of the experiment in a so-called scientific language using the past, impersonal tense. Many have very elegant and sophisticated designs and have achieved the status of classic experiments that have been repeated in many parts of the world over many years.

They have been part of the education of many practising scientists and are well known and often viewed with fondness and affection throughout the science education community. Unfortunately their complexity and sophistication of design have spoilt the simplicity, purity and creativity of scientific investigation and have given a completely false picture of the nature of science. Laboratory experiments lead to contrived confirmation or rediscovery of known propositions. Ausubel (1963) considered rediscovery to be a waste of valuable time exemplifying principles that a competent teacher could present verbally and demonstrate visually in a few minutes. Laboratory experiments that are highly structured and teacher directed offer little opportunity for students to construct their own knowledge or learn the syntactical structure of science (Gabel, 1994). Typically, laboratory experiments do not account for students' prior knowledge nor do they force students to confront their current scientific ideas (Saunders, 1992).

For the purposes of this study, Laboratory Experiment is described as experimental procedure to confirm science theory, where students follow set instructions: for the aim of the experiment, to set up apparatus, to collect data, to recognise and correct for errors, to apply theory to achieve the result, to draw conclusions, and to write an experiment report following specific guidelines.

3.3.5 Undirected Activity: for experiences and posing student questions

Practicals located in the DISCOVERY/MEANINGFUL octant of the theoretical model, are grouped as practicals type, *Undirected Activity*. Undirected Activity comes from within, and is initiated by the interests of the students. This type of practical includes a range of activities, such as, play, trial and error, tinkering, informal inquiry and simple problem solving. Play may start with random activities but this study is concerned with more serious play that affects science learning. Plato recognised the importance of play (*paidia*) in education (*paideia*). Jaeger (1943) noted: "Plato is anxious to include the play-element in his *paideia*: the guard's children are to learn their lessons through play, which means that *paidia* helps *paideia*" (p. 317). The idea that play is an important means to learning, is an accepted principle of educational theory and can be traced back through educational philosophers, like Froebel, Pestalozzi, Rousseau and Comenius, and Aristotle and

Plato (S. Millar, 1968). In the process of play, students learn about "the nature of materials and begin to form concepts of weight, size, texture, softness, hardness, plasticity, impermeability, transparency and so on" (Blackie, 1971, p. 225). Ausubel (1963) recognises the importance of concrete experiences in development of understanding and meaning of such concepts, particularly for younger students. During play children also begin to learn about the possibilities of their own mental powers. Piaget (1970) notes that "the child when it plays is developing its perceptions, its intelligence, its impulses toward experiment,…" (p. 155). All educational experience, including play, "involves venturing into the unknown, going beyond ourselves and experiencing the unfamiliar". Aristotle's view that all learning comes about from previously existing knowledge is merely a restatement of Plato's theory of recollection. Gallager (1992) considers that Plato's theory of recollection is a statement of the hermeneutical cycle. Recollection is the projection of meaning, based on past experience, to support the interpretation and the development of understanding of the new experience. "It is the creation of a context, by recollecting into a unity the experiences relevant to unlocking the meaning of the unfamiliar" (p. 69). In interpretation, familiar parts are brought forward to illuminate the new experience and promote new understanding. Students may direct activities that may stimulate questions leading to further activity and experience. The interpretation of these may lead to greater understanding and meaning as the questions are answered. New questions to be investigated may also be raised. Prior learning conditions the learning process. If students bring to the learning scientific ideas that are not consistent with those accepted by the science community, learning by unlearning might be required. Prior understandings must be confronted and discrepancies resolved. Gallagher agrees with Dewey that in some cases, learning involves problem-solving. He goes on to state that problem-solving involves a projection of meaning that "as it succeeds or fails, [it] informs and reforms the fore structure [prior knowledge] of one's approach" (Gallagher, 1992, p. 71). Dewey describes problem solving as:

> The first stage of contact with any new material, at whatever age of maturity, must inevitably be of the trial and error sort. An individual must actually try, in play, or work, to do something with the material…and then note the interaction of his energy and that of the

> material employed. This is what happens when a child at first begins to build with blocks, and it is equally what happens when a scientific man in his laboratory begins to experiment with unfamiliar objects." (Dewey, 1916, pp. 180-181)

Informal student directed activity is important for learners of all ages as they experience new material. Any experienced science teacher, who has tried to introduce, for example, magnetism and magnets to secondary students, knows that they cannot move forward with a systematic treatment of the topic until the students have worked through an informal activity period akin to play. Learning in this type of practical activity involves a form of corrective feedback that is part of a process of trial and error, involving a circular movement between the student and the unfamiliar and problematic situation. The importance of these intuitive methods in science learning is recognised by Parsons (1995). She investigated one method by which some students acquired prior learning: by exploring the nature of student tinkering within the context of physical science, electricity. The study resulted in the elaboration of a theoretical framework for tinkering and expanded our understanding of *students' science*.

The role of the teacher in Undirected Activity is important and interactive, encouraging students to challenge their prior understandings in the light of new experiences. New questions may be posed and new problems defined. Simple questions and problems may be answered and resolved by the operation of the learning cycle. Unanswered questions and unresolved complex problems may be identified for more systematic study by open inquiry/problem solving.

For the purposes of this study, Undirected Activities are described as informal hands-on activities, which increase student experience of science phenomena, including, for example, play, trial and error, and tinkering. They may challenge the students' prior knowledge and lead to the posing of questions and the identification of problems.

3.3.6 Open Inquiry / Problem Solving, for answering student questions

Practicals located in the MEANINGFUL/DISCOVERY octant of the theoretical model, are grouped as practicals type, *Open Inquiry/Problem Solving*. Open Inquiry/Problem Solving is the active search for understanding to answer questions raised, or resolve problems posed by students. The students plan the inquiry/problem solution, carry out the inquiry or trial the solution, and answer the question/solve the problem. The Open Inquiry part of this type of practical can be related to the experimental laboratory described by Kirschner (1991). It is also described throughout the literature as, for example; open-ended, inductive, discovery orientated, unstructured project, laboratory or investigation (Fairbrother, 1986; Gott & Duggan, 1995; Hackling, 1998; Jones, Simon, Black, Fairbrother, & Watson, 1992;). The origin of experimentation has been traced back to the Greeks, in spite of their general aversion to referring to facts. Anaximenes (c. 550 B.C.) recorded and interpreted observations of facts. Pythagoreans experimented on the pitch of musical sounds discovering principles that still, more than 2000 years later, form the science of acoustics. Almost a century later, Empedocles investigated the nature of air by experiment. His interpretations of experimental observations appealed to nature and he inferred that air was a substance capable of exerting pressure. Anaxagoras repeated the experiment and demonstrated that force was needed to compress air (Jeans, 1947). The value of experimentation was described by Roger Bacon in 1268 (Thatcher, 1901). He recognised two ways of acquiring knowledge; one through reason and the other through experiment. He considered that it was impossible to know anything thoroughly without experiment. Developments in science education stress the importance of school students developing understandings of the nature of science and scientific inquiry. This has been promoted by science curriculum organisations, for example; American Association for the Advancement of Science (AAAS) (1995); Curriculum Corporation (1994b); Curriculum Council (1998); National Research Council (1996). The importance of understandings of the nature of science and scientific inquiry has been linked to the development of scientific literacy for all citizens. Science educators are encouraged to provide students with opportunities to do science inquiry through open-ended science projects and, where possible, extra curricular mentored work with scientists. Scientists and educators support involving students in authentic scientific research (Gallagher, 1991; Hackling, 1998;Lemke, 1990; National Research Council, 1996; Rock & Lauten, 1996; Schmidt, 1967; Solomon, 1991; Tobin & Gallagher, 1987). Involvement in scientific research may range from brief investigations, which answer relatively simple questions, to complex cooperative research projects involving groups of students that may or may not be mentored by professional scientists. The more authentic the research experience the greater the understanding of the nature of science. Open Inquiry/Problem Solving provides students with unparalleled opportunities to be creative. Novak (1964) described inquiry, in general terms, as behaviours involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious. Hodson (1993) considered describing the processes of science to be problematic and therefore not directly teachable, as he explained:

> Because the ways in which scientists work are not fixed and not predictable, and because they involve a component that is experience-dependent in a very personal sense, they are not directly teachable. That is, one cannot learn to do science by learning a prescription or set of processes to be applied in all situations. The only effective way to learn to do science is by doing science alongside a skilled and experienced practitioner who can provide on-the-job support, criticism and advice. (p. 120)

The focus of Open Inquiry is an active search for understanding to satisfy curiosity, by the collection and interpretation of information to answer student questions. Inquiry encourages students to develop understanding and meaning by interpreting their experiences obtained by working directly with natural phenomena in a variety of contexts, supported by discussion and teacher interaction (Driver, 1989). Inquiry based programs promote scientific literacy and understanding of scientific processes (Lindberg, 1990). There is disagreement and uncertainty about what inquiry is (Abell, 1999). The value of inquiry as a way of providing students with positive experiences continues to be debated. Kirschner (1991) writing about experimental laboratories, which have been described earlier, wrote: "Unfortunately,…these types of laboratories are usually doomed to failure" (p. 59). My personal experience suggests that this view would be consistent with the views of many science teachers. But curriculum documents continue to promote inquiry, and science education journals contain reports of successful inquiry leading to improvements in student attitudes towards science learning, for example, Abell (1999), Crawford (2000), Gott and Duggan (1995), Hackling (1998), Hackling, Goodrum,, and Rennie, L. J. (2001), Moscovici (1998), and Yerrick (2000). These studies, and others, suggest that: inquiry learning is appropriate for students of a wide range of abilities, not just for the gifted and talented. There are many different approaches to inquiry, not just one step-by-step procedure to be followed. Inquiry requires high levels of student-teacher collaboration. If students are to understand the nature of scientific inquiry, they need a holistic experience instead of a step-by-step, reductionist approach like the linear steps of explicit teaching models (Crawford, 2000; Gott and Duggan, 1995). There is a need for further research in the area of inquiry-based learning to explore different approaches to open inquiry learning, as well as the collaborative roles of students and teachers. It is important that the students own the inquiry. Inquiry learning should not be an exercise in teacher control.

OECD/PISA (1999) identifies the scientific processes that involve knowledge of science and promote scientific literacy as: recognising scientifically investigable questions; identifying evidence needed in a scientific investigation; drawing or evaluating conclusions; communicating valid conclusions; and demonstrating understanding of scientific concepts. (p. 62). A full description of the theoretical framework of scientific processes is provided by OECD/PISA(2003). Hackling, Goodrum and Rennie (2001, p. 7) consider that the ideal picture of science education is centred on inquiry as students "investigate, construct and test ideas and explanations about the natural world".

OECD/PISA (2003) have also developed a theoretical framework for the domain *Problem Solving*, which answers comments from several writers about the lack of an agreed, comprehensive definition of problem-solving. Problem solving is a central educational objective within every country's school program. The OECD/PISA documents recognise problem-solving within each of the domains of reading, mathematical and scientific literacy as well as considering a broader range of problems to be solved that extends across the boundaries of traditional curricular areas. Science practicals that involve the resolution of student-identified problems, which impinge on the development of scientific literacy, are located in the

MEANINGFUL/DISCOVERY segment of the science practicals theoretical framework.

Gott and Duggan (1995) have developed the importance if inquiry and problem solving in practical science education under the less specific term, investigation. For the purposes of this study, Open Inquiry/Problem Solving is described as the active search for understanding to answer questions raised, or resolve problems posed by students. The students plan the inquiry/problem solution, carry out the inquiry or trial the solution, and answer the question/solve the problem.

3.3.7 Directed Inquiry/Problem Solving: for answering teacher questions

Practicals located in the DISCOVERY/ROTE octant of the theoretical model, are grouped as practicals type, *Directed Inquiry/Problem Solving*. Many of the points made in the discussion of issues associated with Open Inquiry/Problem Solving can also be made regarding Directed Inquiry/Problem Solving. The distinction between the two types of practicals is the extent to which the teacher directs the Inquiry/Problem Solving. As more of the investigation is prescribed by the teacher the practical moves towards the Laboratory Experiment and the learning becomes more rote and less meaningful in outcome. The Directed Inquiry/Problem Solving practicals are regarded as a compromise between Laboratory Experiment and Undirected Activity. Directed Inquiry/Problem Solving may be considered similar to the *divergent laboratory* (Lerch, 1971) in which parts of the experiment are set by the teacher and are standard for all students. After the initial common stage, the experiment can develop in many possible directions determined by the creativity of the students in their search for answers, to the set questions or find the solutions to the predetermined problems.

For the purposes of this study, Directed Inquiry/Problem Solving is described as practicals in which, the teacher sets the inquiry question/problem, then the students plan the inquiry/solution, carry out the inquiry/trial the solution, and answer the inquiry question/solve the problem.

3.3.8 Creative Feedback: for conceptual reconstruction and performance of understanding

Practicals located in the MEANINGFUL/RECEPTION octant of the theoretical model, are grouped as practicals type, *Creative Feedback*. Creative Feedback practicals are important for the development of understanding and the creation of meaning whether learning is discovered or received. In both learning styles, learning is meaningful if "the learning task is related in a non-arbitrary, substantive fashion to what the learner already knows and if the learner adopts a corresponding set to do so" (Ausubel, 1963, p. 18). Ausubel considered that discovery learning has two phases. In the first phase, the student rearranges information obtained during the learning experience to form a new understanding or conceptual framework. The second phase involves the internalisation of the new framework as it is integrated with the existing cognitive framework; this is similar to reception learning. Meaningful reception learning is considered to be an active process that involves judgement of relevance and some degree of reconciliation between existing knowledge and the resolution of differences and conflicts. New knowledge is often reorganised and given a personal interpretation consistent with the student's culture. Creative Feedback practicals enable students to consolidate meaningful learning, whether discovered or received. Creative Feedback practicals include, for example, group discussions (Bently & Watts, 1989; Kirschner, 1991; Tamir, 1977); investigation reports and problem solution reports (Keys, Hand, Prain, & Collins, 1999); construction of charts and models (Gilbert, 1993); simulations, simulation games and multimedia presentations, and concept mapping (Mason, 1992; Novak, 1990, 1992, 1998; Novak, Gowin, & Johansen, 1983); and dramatic representation and role-play (Chester & Fox, 1966). Other suggestions for Creative Feedback practicals can be found in science curriculum documents, such as, Curriculum Corporation (1994b). Creative Feedback practicals provide students with opportunities to demonstrate their understandings of the substantive knowledge and the syntactical knowledge of the scientific world. Creative Feedback practicals are an essential part of a science learning program that will take full advantage of the learning experiences provided to maximize understandings and the creation of meaning. Creative Feedback activities are within the definition of science practicals presented at the beginning of this chapter although they may not normally be included in traditional scientific processes. There is a need for research on the identification and use of Creative Feedback practicals that promote student creativity, understanding and the acquisition of meaning.

For the purposes of this study, Creative Feedback is described as practicals that require students to demonstrate their understandings by, for example, group discussions, investigation reports, problem solution reports, construction of charts, models, simulations, simulation games, multimedia presentations, concept mapping, dramatic representation and role-play.

3.4 SUMMARY AND CONCLUSION

Practical work is an essential part of science education, designed to promote science learning according to the goals and aims of the program. Practicals are didactic methods for learning and practising all the concepts, skills and processes involved in the development of scientific literacy. Science educators have a responsibility to teach students the substantive structure of science as well as the syntactical structure of science consisting of, knowledge, skills and contexts. The knowledge skills and contexts of science are all important in the development of understanding. Science practicals provide students with a wide range of interpretive experiences, promoting student understandings of their world and constructing meaning for their lives. The traditional rationales for practicals are generally theoretically flawed and have not responded to the view of science as a sociological, creative and institutionalised activity. Practical work in science has too many objectives many of which are not achieved (Sere, 2002). It is important for science teachers to be clear about their goals and objectives and to be selective where necessary. A theoretical model that draws on hermeneutic traditions provides a basis for reviewing new rationales for science practicals. The interpretive Theoretical Model for Science Practicals has been developed by changing the scope and limitation of the map of learning after Ausubel (1963) and Elton (1987). Eight types of science practicals and their rationales have been described.

Demonstration: The teacher, or other expert, presents science phenomena to support science theory and directs student attention and discussion of results.

Directed Activity: Students are required to follow instructions and answer questions provided by the teacher to support science theory or experience scientific phenomena.

Skill Development: The acquisition and development of basic scientific skills to do science.

Laboratory Experiment: Students follow set instructions for the aim of the experiment, to set up apparatus, to collect data, to recognise and correct for errors, to apply theory to achieve the result, to draw conclusions and write experiment reports to confirm science concepts and theory.

Undirected Activity: Informal hands-on activities, including, for example, play, trial and error, and tinkering; to increase student experience of science phenomena, leading to the posing of questions and the identification of problems.

Open Inquiry/Problem Solving: The active search for understanding, to answer questions raised, or resolve problems posed, by students. The students plan the inquiry/problem solution, carry out the inquiry/trial the solution, and answer the question/solve the problem.

Directed Inquiry/Problem Solving: Students seek understanding by answering /solving the teacher's questions/problems. The teacher sets the inquiry question/problem, then the students plan the inquiry/solution, carry out the inquiry/trial the solution, and answer the inquiry question/solve the problem.

Creative Feedback: Students demonstrate their understandings through performance activities, such as, group discussions, investigation reports, problem solution reports, construction of charts, models, simulations, simulation games and multimedia presentations, concept mapping, dramatic representation and role-play.

The types of practicals used in science programs will depend on the particular emphasis and goals of the program. The practicals may be part of science programs or used as part of cross-disciplinary context-based programs. Chapter 4 explores appropriate strategies for collecting information about the use of practicals in science programs.

CHAPTER 4

Collecting Perceptions of the Use of Practicals in Science Programs

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4.1 INTRODUCTION

Well-focused research questions have enabled a thorough literature review to be discussed. And the construction of a comprehensive theoretical model of science practicals was presented in the previous chapters of this study. In this chapter the design of the study is described. The research questions are restated. The research approaches for collecting perceptions of the use of practicals in science programs, which are pertinent to this study, are reviewed. The methods used to answer the research questions are described. The research methodologies used in this study collected data in two forms, quantitative and qualitative. Descriptions of the collection of these two types of data comprise the main sections of this chapter. The chapter concludes with a summary of the research design and a statement of the assumptions and limitations of the study.

4.2 THE RESEARCH QUESTIONS

The main aim of this study is to explore and develop an understanding of the issues involved in the theoretical bases, rationale, and implementation of practicals in junior secondary science programs. To improve the focus of this research study, the general purpose of the study is expressed as a number of research questions. The research questions central to this study are:

1. What are the theoretical bases and rationale for practicals in science programs?
2. What are the requirements for practicals as specified in published curriculum documents developed from *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b)?

3. What are teacher perceptions of practicals and their educational value in their science programs?
4. What are student perceptions of practicals and their educational value in their science programs?
5. What are the implications of this study for science curricula?

Another purpose of the study is to develop a research instrument that will: be useful in evaluating the use of practicals in science programs, assist with professional learning of science teachers, and provide guidelines for the use of practicals in science program renewal.

The first two research questions have been considered in Chapters 1 and 2 of this study. The next section outlines the research design of the study to explore research questions 3 and 4.

4.3 THE RESEARCH DESIGN

The questions addressed in this study required methods of gathering information that would describe, clarify, and improve understanding of issues associated with the use of science practicals. Field methods were considered more appropriate to this study than experimental or quasi-experimental methods. Zelditch (1971) described three types of field research methods:

1. Participant observation
2. Informant interviewing
3. Enumeration and samples (p.77)

Participant observation was considered the best method of obtaining information on *incidents* and *histories*. These were defined as a log of events, with explanations reported by participants considered as data (Zelditch, 1971). However, participant observation was rejected, due to time constraints and the size of this study.

Informant interviewing was considered particularly useful for collecting information regarding perceptions of systems (Zelditch, 1971). In terms of the whole study, informant interviewing, as with participant observation, was rejected, as time involved to carry out an appropriate interview schedule would have been lengthy. However, informant interviewing was used to provide triangulation for the analysis of qualitative data and to assist with the development of the questionnaire.

Enumeration and sampling, which included the use of sample survey questionnaires, was selected as a field research method appropriate to this study. Sample survey questionnaires were described as efficient information gathering devices, which produce data that could be processed by standard statistical methods (Zelditch, 1971).

> …out of the findings of such surveys often comes the basis for the formulation of fruitful hypotheses about phenomena, or at least for some education in confusion about phenomena. (Hyman, 1955, p. 77)

The use of a sample survey was considered to be particularly useful for this study for the following reasons:

1. The large number of variables and interactions involved in the research questions of the study require a large sample for meaningful statistical analysis.
2. Its use was appropriate in view of the limited resources of time and personnel.
3. The information required could be presented in straight-forward questions.
4. Junior secondary science students with extensive experience of their science programs and a high level of interest in the subject of the questionnaire would be willing and able to complete the questionnaire with an aim of assisting with the improvement of the use of practicals in science programs.
5. During the last 30 years researchers in the growing field of classroom learning environments have completed studies involving the use of quantitative methods, and have generated various widely-applicable questionnaires that have been used effectively with large samples in a variety of countries (Fraser, 1986).

6. It has been found that there are potential advantages to be realised by combining qualitative methods with quantitative methods within the same study in researching learning environments (Fraser & Tobin, 1991).
7. Study of the use of practicals in science programs involves issues that impinge on learning environments.

As researcher, I believe that the learning environments research field has a lot to offer this research study. The next section will explore the development and procedures of learning environments research as they are appropriate to this study.

4.4 THE LEARNING ENVIRONMENTS RESEARCH FIELD

4.4.1 Developmental Overview

Since the enunciation of the Lewinian formula, B=f(P,E), which suggests that behaviour (B) is a function of personality (P) and environment (E), there has been remarkable progress in conceptualising, assessing, and investigating the determinants and effects of social and psychological aspects of classroom and school environments (Fraser, 1998). Murray (1938) introduced the terms *alpha press,* which describes the environment assessed by a detached observer, and *beta press,* to describe the environment observed by those from within the environment. These ideas were developed to distinguish individual perceptions of the environment (*private beta press*) and those shared by the group (*consensual beta press*) (Stern, Stein, & Bloom, 1956). It was recognised that the different perspectives of individuals could lead to different interpretations of an environment. The *Learning Environment Inventory* (LEI) was developed by Walberg (1968) as part of the evaluation of Harvard Project Physics, to assess learning environments in physics class rooms. Moos and Trickett (1974) developed a series of environment assessment tools that concluded with the *Classroom Environment Scale* (CES). Moo's three basic types of dimensions were *Relationship Dimensions*, *Personal Development Dimensions*, and *System Maintenance and System Change Dimensions (Fraser, 1998)*. The environment was described using the CES in terms of nine scales: *involvement affiliation, teacher support, task orientation, competition, order and organisation, rule clarity, teacher control, and innovation.* Both the LEI and the CES asked students about their perceptions of the whole-class environment. The extensive use of these two questionnaires for varied research purposes followed. This research provided models for the development of further classroom-level and school-level environment instruments for different purposes (see Fraser, 1994, 1998). The instruments were usually available in an ‘actual’ version, which asked students about the experienced learning environment, and a ‘preferred’ version, which asked about the students’ ideally preferred learning environment. In the context of this study, practical work in science learning was done by students organised into classes. These classes may not necessarily occur in science classrooms or laboratories, and individuals or small groups may be working separately within them. Consequently, examination of the use of different types of practicals in science learning required an investigation at the class level. Exploration of the factors that determine the use of practicals in science learning was not the subject of this study.

Questioning the assumptions made in the use of learning environment questionnaires, the role of the teacher, and the nature of the learning process suggested that there was a need for the development of a better instrument for assessing learning environments. The use of questionnaires to assess the whole-class environment involved an assumption that there was a unique learning environment in the classroom that was experienced by all students in that class. This assumption of a uniform learning environment, experienced by all students in the classroom, was questioned towards the end of the 1980s. Tobin (1987) suggested that there were groups of students (called target students) who were more involved in the classroom activities and had more favourable perceptions of the learning environment than their classmates. This presented a potential problem with using the traditional form of learning environment instruments. When studying differences between the perceptions of groups of students within a class, the instrument recorded student perceptions of the class as a whole, rather than the individual student’s view of the learning environment and their place in it (Fraser & Tobin, 1991). Thus there was a need for an individual form of learning environment instruments.

The traditional teacher’s role of transmitting learning in the form of knowledge to be received by the students was being questioned in favour of a view that meaningful learning can be received or discovered, and is an active process in which the learner interprets experiences of their world with reference to existing knowledge. The interpretation is often a social process involving negotiation and consensus building with others (Tobin, 1993; von Glasserfield, 1989). However, learning is essentially a matter for the individual and their interaction with others, rather than a uniform process involving the whole class. Perceptions of the impingements on that process are also individual, rather than uniform across the whole class.

Questioning the traditional role of the teacher and the nature of the learning process led to the development of a new form of instrument that is better suited to the assessment of differences in perceptions of different students in the same class, than the conventional class form. Fraser, Giddings and McRobbie (1992) proposed a new form of learning environment instrument, which asked students for their personal perception of their role in the environment of the classroom, rather than the learning environment of the class as a whole. The two forms of the learning environment instruments were called the *Personal Form* and the *Class Form* respectively. The Personal Form of the instrument had the potential to characterise the learning environment in a classroom from the perspective of the changed views of learning. Personal Forms of classroom environment instruments were more valid, particularly in research that involved case studies of individual students or explored the differences between the perceptions of subgroups within the same classroom, for example, gender differences (McRobbie, Fisher, & Wong, 1998). The Personal Form of the instrument was the most suitable for this study, as the study involves different approaches to learning and aims to explore gender differences in student perceptions of the use of practicals in science education.

4.4.2 Learning environment instruments important to this study

Fraser (1998) identified the following historically important and contemporary instruments: *Learning Environment Inventory* (LEI*); Classroom Environment Scale* (CES); *Individualised Classroom Environment Questionnaire* (ICEQ*); My Class Inventory* (MCI), *College and University Classroom Inventory* (CUCEI); *Questionnaire on Teacher Interaction* (QTI); *Science Laboratory Environment Inventory* (SLEI*); Constructivist Learning Environment Survey* (CLES); and *What Is Happening In this Class?* (WIHIC) questionnaire. The instruments that were most important to this study were the SLEI and the QTI. Each of these instruments will now be discussed.

4.4.2.1 *Science Laboratory Environment Inventory (SLEI)*

Much of the early research into classroom learning environments was aimed at science teaching and learning. Little of this research involved the learning environment of science laboratory classes (Hegarty- Hazel, 1990). Concerns about laboratory instruction and the lack of an instrument to investigate student perceptions of laboratory learning environments led to the development of the SLEI. Personal and Class Forms were developed for use with senior high school or higher education students (Fraser, Giddings, & McRobbie, 1993, 1995; Fraser & McRobbie, 1995). The five scales of the SLEI each had seven items with the following five response alternatives: *Almost Never, Seldom, Sometimes, Often,* and *Very Often*. 'Actual' and 'preferred' forms of the instrument were available. Fraser (1998) identified examples of typical items of the SLEI as, 'I use the theory from my regular science class sessions during laboratory activities' (Integration) and 'We know the results that we are supposed to get before we commence a laboratory activity' (Open-Endedness). The Open-Endedness scale was included because of the importance given to open-ended laboratory activities in the literature. The SLEI was field tested, validated and cross-validated with large samples of students, across seven different countries including 1592 Grade 10 chemistry students in Singapore (Fraser, 1998).

The SLEI was a validated instrument designed to investigate student perceptions of their science laboratory learning environment. It had been used successfully in research projects internationally and in Australia. Although there was some overlap between the scales of the SLEI and the subject of this study; the use of the different types of practicals in science learning, it was considered that the SLEI was not directly applicable as an instrument for this study. However, the SLEI provided a suitable model for the development of a new questionnaire, the *Science Practicals Inventory* (SPI). The instructions and the general design of the SLEI were directly applicable with minor editing. The style of the SLEI items was appropriate for the items of the SPI. The response alternatives for the items of the SLEI could be used without alteration. An 'actual' and a 'preferred' form of the questionnaire were prepared. The items for the different scales were to be randomly arranged on the questionnaire. A model for the theoretical basis for the scales and the linked items was provided by the *Questionnaire on Teacher Interaction* (QTI), which is discussed in the next section.

4.4.2.2 *Questionnaire on Teacher Interaction*

The Questionnaire on Teacher Interaction (QTI) was developed from research in the Netherlands that focused on the nature and quality of interpersonal relationships between teachers and students (Creton, Hermans, & Wubbels, 1990; Fraser, 1998; Wubbels, Brekelmans, & Hooymeyers, 1991; Wubbels & Levey, 1993). The QTI was developed using a theoretical model of two behavioural dimensions, *proximity* (cooperation-opposition dimension) and *influence* (dominance-submission dimension). The presentation of these two behavioural dimensions as two separate orthogonal behavioural parameters, led to the description of eight behaviour aspects that could be used to assess the quality of teacher-student interpersonal relationships (see Figure 4.1).

Although the use of the QTI began in the Netherlands at the senior high school level, cross-validation and comparative work were completed in the USA (Wubbels & Levey, 1993), Australia (Fisher, Henderson, & Fraser, 1995) and Singapore (Goh & Fraser, 1996) at various grade levels. The QTI has been modified to form the *Principal Interaction Questionnaire* (PIQ) to assess the interaction of principals with teachers (Cresswell & Fisher, 1997).

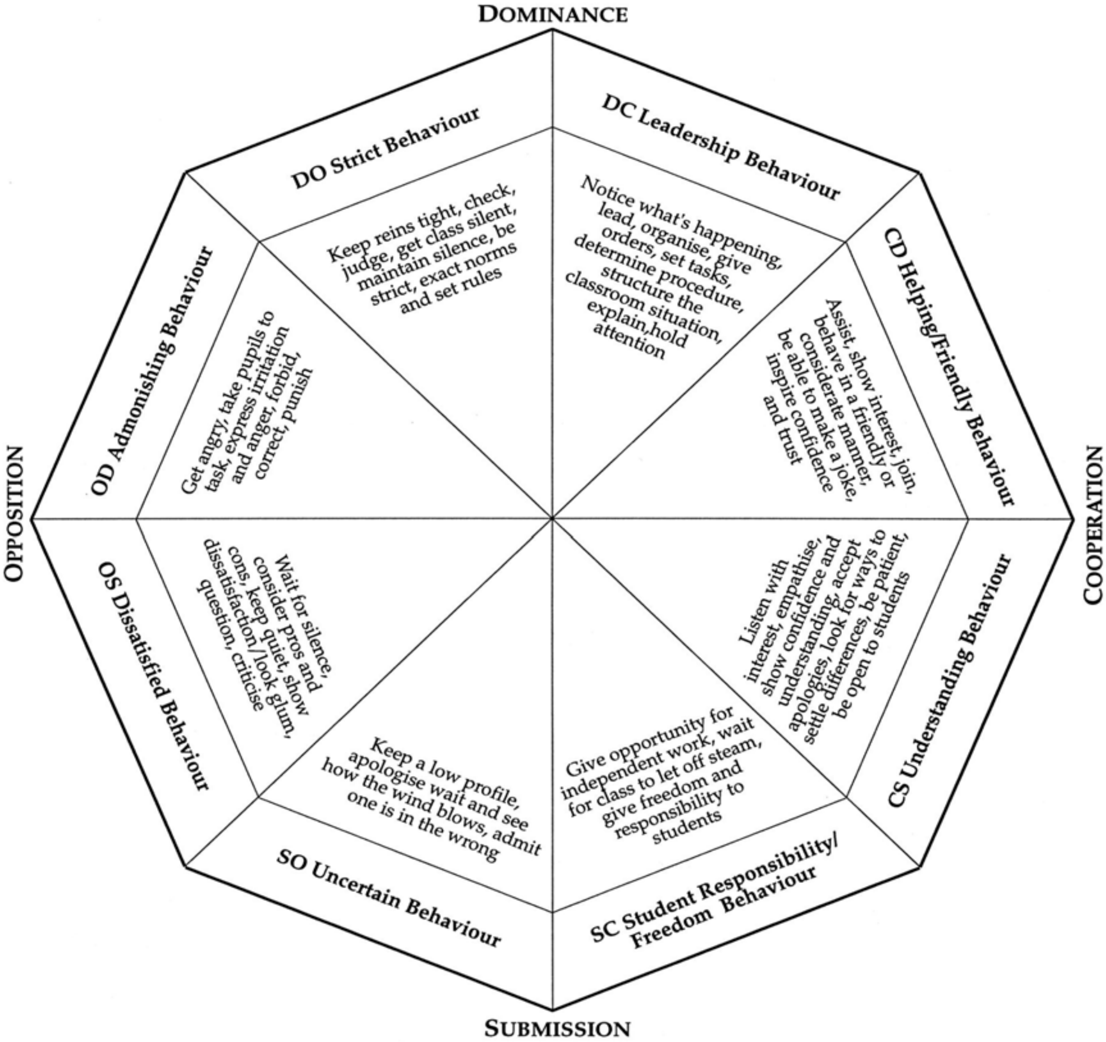

Figure 4.1 The Model for Interpersonal Teacher Behaviour (Wubbels & Brekelmans, 1998, p. 569).

The use of the two dimensional, orthogonal, theoretical model for interpersonal teacher behaviour in the development of the QTI was considered an appropriate exemplar for the use of the theoretical model for science practicals, discussed in Chapter 3, in the development of the new questionnaire, the SPI. The presentation of the two separate orthogonal learning parameters, the rote-meaningful dimension and the reception- discovery dimension, led to the description of eight types of practicals and the eight scales of the questionnaire. The next section describes the population and sample for the study.

4.5 POPULATION AND SAMPLE

The target population of this study was Australian science teachers and students. For the study sample I considered it useful to use ten science classes from a high school in southern Tasmania, nine science classes from high schools throughout Tasmania and ten science classes from a high school in Perth, Western Australia. The sample was chosen in order to maximize the value of the supportive network associated with Science and Mathematics Education Centre at Curtin University of Technology in Western Australia and a network of science teachers in Tasmania. Tasmania and Western Australia provided an appropriate sample of schools, science classes, science teachers and students outside the study sample for group interviews and pre-tests conducted during the development of the questionnaire. Care was taken to achieve gender balance in the sample by including students from single gender and coeducational schools. The study sample was not large enough and sufficiently diverse to be considered representative of Australian junior secondary science teachers, and students. The sample was a sample of convenience, appropriate for the validation of the survey instrument. Further research is necessary to produce results generalisable Australian junior secondary science teachers and students. The next section outlines the approval of the study.

4.6 APPROVAL FOR THE STUDY

Approval for this study was obtained at four levels, the Education Department and Curtin University of Technology, the school principals, the science teachers and through them, the students who completed the questionnaires. Approval for the study to be conducted in Tasmanian high schools was given by the Deputy Secretary (Education Strategies) on 18 June 2002 (see Appendix A). To obtain the approval of school principals, the initial approach was made by email, followed by a telephone call. The email requested permission to approach science teachers to allow their students to complete the questionnaire. The email stated the purpose of the study and that it was approved by the Education Department and was under the supervision of Curtin University of Technology, Western Australia. This was done to give the study official status and increase the likelihood of a favourable response (Oppenheim, 1966). Confidentiality of information, and anonymity of the schools and the participants in the study was assured, and feedback of results of the study was promised. Notification of the follow-up phone call was given in the email. This approach was considered appropriate as I know most of the principals. The aim was to receive a quick, positive, verbal response. Follow-up phone calls were made to principals and senior science teachers, and approval was obtained for all schools in the sample. Details of the data gathering procedures are described in the next section.

4.7 DATA GATHERING PROCEEDURES

Senior science teachers organised the schedule for administering the questionnaires to students during normal science class times. The questionnaires were presented to the students by the author. This was followed by the procedure for self-administered questionnaires described by Oppenheim (1966).

> The self-administered questionnaire is usually presented to the respondents by the interviewer or someone in an official position… The purpose of the inquiry is explained and then the respondent is left alone to complete the questionnaire, which may be sent or collected later. (Oppenheim, 1966, p. 36)

The questionnaires were collected on completion, in exchange for chocolate frogs. As the study sample consisted of science students with a high level of interest in making science education more meaningful, a self-administered questionnaire was considered appropriate for this study. The chocolate frogs were introduced after the first pilot to improve the reception and the response rate of the questionnaires. The questionnaires were prepared for analysis as they were collected.

4.8 DEVELOPMENT OF THE SCIENCE PRACTICALS INVENTORY (SPI)

4.8.1 Construction of the pre-test questionnaire

This section describes the construction of the pre-test questionnaire, the aim of which was to test the suitability of the draft items for collecting data about student perceptions of the use of practicals in science education programs, and their use in a wider validation exercise as part of the development of the SPI as an instrument for science program evaluation, the professional learning of science teachers and science program renewal. The construction of the pre-test questionnaire drew heavily on the types of science practicals described in the *Theoretical Model for Science Practicals,* which was developed for this study and described in Chapter 3. The eight types of science practicals were used as scales in the questionnaire. The eight scales of the questionnaire were: *Undirected Activity, Open Inquiry/Problem Solving, Creative Feedback, Directed Activity, Demonstration, Skill Development, Laboratory Experiment*, and *Directed Inquiry/Problem Solving*. Six draft items were prepared for each scale, together with ten science attitude items, to produce a questionnaire of optimum length for use with secondary students, of similar length to the SLEI and the QTI, which have been used successfully with secondary students. The draft items for the SPI pre-test 1 are shown in Table 4.1. All items are shown here, as the questionnaire was an important part of the study and was developed from a new theoretical model for science practicals.

Table 4.1
Draft Science Practicals Inventory Items for Pre-test 1.

SCIENCE PRACTICALS INVENTORY (Pre-test 1)

SCALES **DRAFT ITEMS**

Undirected Activity

1. I am encouraged to follow my ideas with the equipment provided.
2. I am encouraged to do my own experiments with the substances provided.
3. My teacher doesn’t tell me what to do with equipment and substances.
4. I am able to choose the equipment and substances for my own experiments.
5. I am encouraged to play with the equipment and substances.
6. I work scientifically.

Open Inquiry/Problem Solving

1. I am encouraged to suggest study questions for investigations.
2. I am encouraged to suggest problems to be solved during science practical lessons.
3. I am encouraged to plan investigations to answer my study questions.
4. I am encouraged to design solutions to problems I have identified.
5. I am encouraged to investigate my study questions or trial solutions to problems I have identified.
6. I am encouraged to find answers to my study questions or solutions to problems I have identified.

Directed Inquiry/Problem Solving

1. My teacher gives me study questions to be investigated.
2. My teacher gives me problems to be solved.
3. I am encouraged to plan investigations of my teacher's study questions.
4. I am encouraged to design solutions to problems given by my teacher.
5. I am encouraged to carry out my investigations to answer my teacher's questions or trial solutions to my teacher's problems.
6. I am encouraged to suggest answers to my teacher's questions or solutions for my teacher's problems.

Creative Feedback

1. I am required to describe my practicals to other students in my class.
2. I am required to write reports about my science practicals.
3. I am required to make models to explain the work I am doing in science lessons.
4. I am encouraged to discuss my science practical work with my teacher and other students.
5. I design and make posters, mind maps or charts as part of science practicals.
6. Drama is used to role-play or represent science ideas or processes.

Directed Activity

1. Hands-on science activities are carried out during science practicals.
2. I enjoy hands-on science activities.
3. Instructions for hands-on science activities are provided by the teacher.
4. Questions are provided by my teacher/worksheet to be answered as I do hands-on science activities.
5. Hands-on science activities increase my experiences of science.
6. Hands-on science activities increase my understanding of science.

Demonstration

1. My teacher presents science demonstrations.
2. My teacher's demonstrations help me understand the theory covered in other science classes.
3. My teacher's demonstrations are linked to my regular science class work.
4. My teacher tells me what to look out for in science demonstrations.
5. My teacher asks students questions about the science demonstrations.
6. Students are encouraged to ask questions about my teacher's science demonstrations.

Skill Development

1. I use equipment to carry out science procedures such as dissolving, filtering, evaporating.
2. My teacher shows me how to use the equipment correctly.
3. I am required to make and record observations.
4. My teacher shows me how to measure different quantities with different measuring instruments when needed.
5. My teacher shows me how to use a microscope correctly as required.
6. My teacher outlines safety precautions for using science equipment.

Laboratory Experiment

1. Laboratory experiments are carried out during science practicals.
2. I follow instructions provided when doing laboratory experiments.
2. My teacher decides the best way for me to carry out laboratory experiments.
3. My teacher tells what I should have learned from laboratory laboratory experiments.
4. If I finish the laboratory experiment I am allowed to do some of my own experimenting.
5. I must follow set guidelines for writing laboratory experiment reports.

6. Laboratory experiments are linked to my regular science class work.

Date 25.03.01

The pilot questionnaire was constructed by listing one item from each of the scales, and rotating through the scales until all items were listed in the questionnaire.

In order to investigate any relationship between science practicals and student attitudes the questionnaire included items to collect information about student attitudes to science programs. A short questionnaire consisting of ten items, which had been used successfully with junior secondary students (Fraser, 1978), was adapted to the SPI to complete the form used in this study.

The development of the questionnaire was supported by collection of qualitative data using a group interview of a science teacher focus group. The science teacher group interview is described in the next section.

4.8.2 Science teachers group interview: Teacher Focus Group

The *focus group* or *group interview* was an appropriate method for collecting qualitative data to support the development of the questionnaire. This method involved interview discussion, using an unstructured interview with a relatively small number of science teachers that acted as a focus group (Greenbaum, 1998), also described as a group interview by Fontana and Frey (1998). A secondary purpose of the focus group was to explore the different types of practicals recognised and used by science teachers to support the *Theoretical Model for Practicals* presented in Chapter 3. The group interview was the type of focus group in which the setting was formal and preset; the role of the interviewer was directive; the question format was unstructured; and the purpose was exploratory (Fontana & Frey, 1998). The group interview was considered inexpensive, data rich, flexible, stimulating to participants, recall aiding, cumulative and elaborative, over and above individual interviews. Blumer (1969) noted the importance of interviewing a select group of participants "who are acute observers and who are well informed…. A small number of such individuals brought together as a discussion and resource group, is more valuable many times over than any representative sample" (p. 41).

The science teaching staff of a high school in southern Tasmania provided such a group. The science teaching staff consisted of five teachers, Bob (Advanced Skills Teacher 3 with responsibility for science), Kate, Mike, Sarah, and Tom. All teachers had more than ten years science teaching experience, with a high level of knowledge and commitment to practical work in their science programs. The group satisfied the requirements for a focus group, as specified by Blumer (1969). To maximize the positive working relationship previously established with the members of the group, the interview was scheduled in the normal science department meeting time, after classes had ended. Although the teachers were not paid for their participation, appropriate refreshments were provided for consumption during the interview. This assisted with the establishment of a relaxed, receptive, rapport between myself, as the interviewer, and the group. I was a member of the science teaching staff as well as an assistant principal at the school. And as a senior member of the science education community, with service at the state and national level, I am known to all members and thus, an appropriate interviewer of the group. As interviewer, I aimed to be flexible, objective, empathic, persuasive and a good listener. Care was taken to prevent the domination of the discussion by one, or several, members of the group. Participation from all members of the group ensured full coverage of the topic (Fontana & Frey, 1998). The interview began with an attempt to put the members of the group at their ease, by thanking them for allowing me to attend their staff meeting, followed by a statement of purpose and an assurance that the research was general in nature. The interview was relatively unstructured, beginning with open questions related to the rationale for practical work in science education, working through supplementary questions to specific items from the pilot questionnaire. The purpose and value of practical work in science was considered before any reference to pilot questionnaire items was made, so the teachers' responses to the open question in the unstructured part of the interview were not influenced. Recording the interview on audiotape was agreed to. Transcription of the audio recording of the interview enabled the production of the field text and the following interpretation. The direct quotations are selected as relevant to the research questions of this study. However, they may or may not support the theoretical model presented in Chapter 3. Links with the types of practicals shown in the model are recorded in brackets. The direct quotations include suggestions for making changes to the wording of items in the pilot questionnaire.

The group interview of the science teachers is reported at this stage, as their discussions and perceptions contributed to the development of the pilot questionnaire.

Once introduced to the intention of the focus group, the members were invited to explore the purpose and value of science practical work. As interviewer, I suggested that we start with going round the table in a way that was not too formal and intimidating. Bob, the coordinator of science and the most senior of the group, agreed to start the discussion. He considered that there were a number of purposes for practical work.

> I'd say it helps reinforce their theory, the work they do, their understanding of scientific theories.

He went on to say:

> I think also it gives them some hands-on experience of working scientifically. I think it sometimes gives an opportunity to solve a problem, a real problem (Open Inquiry/Problem Solving) that they see or the teacher sees (Directed Inquiry/Problem Solving), I suppose, as well as the kids, or hopefully both, as something which is worth solving, worth looking at, and so they undergo some methods if you like to try and get answers.

Bob believed that there were:

> Smaller side benefits which help students understand in different ways, actually hands-on stuff rather than just looking at books, reading things and similar information like that.

Mike said he thought that:

> Scientific inquiry is certainly a specialised way of thinking and, it's definitely a process, it's not easily taught just didactically, so you really need the experience of getting involved in the steps and going through them, for people to have a fair chance of understanding what's involved in the process of scientific inquiry. (Open Inquiry/Problem Solving)

Kate supported Bob, saying that:

> Practical work was really good for kinaesthetic learners. They need to pick up things and handle them. Stuff in books doesn't mean anything to them so it's a different way of learning.

She thought that:

> It adds interest and I think you need to learn the skills in really basic types of experiments before you can do open-ended ones, (Skill Development) like we were talking this afternoon, we had kids doing experiments on water quality out in the Derwent River, and some of them had no idea that the fact that they left a little bit in the bottom, like 20mls, in the bottom of their measuring cylinder was significant for their comparability to other peoples samples.

Kate went on to argue that:

> Unless you go through those basic experiments (Laboratory Experiment) first, there's no academic rigour in the open-ended investigations that they do.

She thought that:

> Those little, funny little things we do when we start them off in Grade 7, separating mixtures and stuff like that (Laboratory Experiment) are actually really valuable and they need to get the skills and learn how to handle the equipment properly before they can be turned loose to do their own investigations. Open-ended investigations make science real for them so that's your end point. You want to get to the point when they can actually conduct valid investigations. (Skill Development and Open Inquiry/Problem Solving)

The discussion was continued by Tom, who declared a strong commitment to practical work in his lessons, but only after he had introduced science theory.

> I like them to use that theory to build something, like catapults we did with our Grade 7's. Then they can use that theory, put it into practice, find that it doesn't always work, nice and neat and tidy, and try other options, and maybe even develop some more, some more learning from what they're actually doing.
>
> We're doing catapults at the moment and you can talk all you like about catapults, and when you actually come to build one you find that you have to fine-tune it, they can use the practical work to do that. A number of my kids said they find

> out little things they've never even thought of before, you've never even thought of when talking about the theory, they then have to learn how to use it as well.
>
> Play around with Hooke's Law and things like that, various aspects of that sort of thing and they've got to use that. (Open Inquiry/Problem Solving)

When I asked Tom if he thought that there should be a relationship between the practical work and theoretical science, he replied:

> Yeah. Steamboats are probably a better example. They learn all about different types of metals, conduction, convection, all those sorts of things (Directed Activity) and they can put it all together to build their final product. (Open inquiry/ Problem Solving)

Bob said that he found Tom's account very interesting but he tended to approach it differently, he said:

> For example, levers and motors, throw the stuff to them and get the kids to fiddle around with it and try and find something themselves and then come back and do the theory later and say, well, this is what you saw here and this illustrates a bit of the theory, but I know you do it the other way around, like going through bits of theory first and then getting them to use it. (Directed Inquiry/Problem Solving)

Kate reacted quickly, saying:

> Sometimes though that playing around, if it hasn't got a direction to go in then its really hard for people to make sense, you know I reckon things are mixed, it just depends on what you're doing like, if you gave them some steamboat material and told them to build it, they wouldn't know. I mean they instinctively, probably make the boilers out of......... but they wouldn't know why they were doing it, would they?

Tom agreed, saying, They've got to have a starting point and a finishing point.

Sarah's students and their parents became highly motivated after a less formal practical class. She said that:

> Problem solving with some sorts of practical work where children are actually designing things themselves, I think it adds some novel things to it, to keep their interest as well… some of my children went away and actually did a lot of work at home with their parents and got their parents involved. (Open Inquiry/Problem Solving)

Kate said that:

> The kids loved the steamboat and I was really reluctant to do it and I didn't know what they were going to get out of it, but actually, they loved it and when they gave me feedback it was very positive. They had to produce posters and say all the science parts that were applied (Creative Feedback), so it was a pretty good activity and those who, as I say, are often

> not the stars of the class in academic performance were recognised by the others in the group as "gee you did a great job building the…"

Sarah asked a question about how much background the students were given before starting the steamboat and Kate replied:

> Well, I did that basic stuff like conduction, convection and radiation, the energy trolley, the community trolley, all that stuff, you include, insulators and conductors, (Demonstration and Directed Activity) and then I did the boat.

Kate reported that she said to the students:

> This is the equipment, you can have anything here on this trolley, or you can have anything you've brought from home but it's got to be a steamboat and it's got to have the jet thing out the back, and you've got to have a fire safety consideration, apart from that, go for it. (Directed Inquiry/Problem Solving)

The group agreed that there was a place for the teacher to provide the basic science knowledge and some demonstration, before starting the task (Demonstration). Tom gave another example of his work with Grade 9 students in forensic science.

> They started off doing a course on basic forensic science, fingerprints and the rest of that stuff, then they go out and do it, use it all to find out who did it, with a scenario, and when they've done that bit and they've arrested somebody, they still have to do the same thing again at the trial. So

> they become lawyers, and, judges....It is a different way again. (Directed Activity, Directed Inquiry/Problem Solving and Creative Feedback)

Tom described the role-play as double-barrelled feedback.

At this stage the interview became more structured as the group moved to consider the individual items of the pilot questionnaire. Teachers were asked to comment on the appropriateness of the items, and the pros and cons of the particular approach. The teachers commented on the appropriateness of each item for the pilot and explored their perceptions of an approach to practical science that may go on their classes further. The items were considered in the order that they occurred in the pilot questionnaire. The items were edited after pilot 1, so the wording of the items may be different from those listed in Table 4.1. The type of practical, with respect to the theoretical model of science practicals, was not indicated to the members of the group, in order not to unduly influence the responses of the science teachers. The following discussion includes comments that led to the modification of items or explored the teachers' perceptions of the use of science practicals further.

I am encouraged to follow my ideas with the equipment provided.

Mike began the discussion, he said:

> I'd try to make that a high priority, so I would at least be saying often, if not very often. (Undirected Activity)

He described how his Grade 8 class had researched and made model electric motors using simple basic designs.

> . …At least two groups went off on significant tangents and tried to come up with a novel design of their own - unsuccessfully, but at least they, they were encouraged to

pursue it as far as they were able. (Open Inquiry/Problem-Solving)

Sarah said:

> I'm a lot more structured. I mean I don't think they had a lot of opportunity to actually follow their own ideas. Unless we're doing something open-ended like the rubber band insect, machines and things like that, but I think generally I tend to direct my kids into doing particular activities. (Directed Activity)

Kate drew attention to the constraints that tend to increase the amount of teacher direction.

> First of all you've got a certain body of work to get through, a lot of it can't just produce magically equipment for you, you've got to book things ahead and so forth, so you have to use certain amounts of equipment sometimes…. I think it's something that adds an ideal to be pursued but constraints mean I have to do it sometimes or often.

Bob identified constraints as class size and the type of kids

Mike ended the discussion on this item by saying:

> But if kids come up with novel ideas it's a little bit off the line of what you were intending to do, as long as they go about things in an appropriate way and ask, and discuss with you, I'd encourage them to pursue their own

> ideas....(Undirected Activity) I'd only cut off those avenues if you are concerned that they might not see some significant things that you wanted them to see. You don't want to have to guide them too much, if you don't have to.

My investigation is discovering new knowledge

This item stimulated discussion about what was meant by *new knowledge*. Was it new knowledge for the student, new knowledge for the teacher, or new knowledge for the scientific community? It was generally agreed that that it could be all of those but it would be unlikely to be the latter. Sarah recognised that:

> In advanced science classes… the children did their own investigations, where they picked their own topic and investigated it through the term. (Open Investigation/Problem-Solving)

She went on to say that it was very time-consuming and not always successful.

> I mean you did get some really good results out of some of the students, but, it got a lot of stress on the teacher because you're actually sitting there with some children doing very little and others are doing quite a lot of work.

Although, it was considered that the discovery of new knowledge was unlikely, there was no suggestion to remove the item.

I'm encouraged to investigate my teacher's study questions

According to Mike, this item referred to:

> The ones that we set up. We do that with a purpose in mind. We want them to find some key relationship, or key piece of, or verify often some key piece of knowledge. (Depending on the amount of teacher direction this could be categorised as Directed Inquiry/Problem-Solving or Laboratory Experiment). Along with that, if they're on top of what they're doing and they've got the get up and go to want to investigate further, then encourage that too.

Bob considered this a good item. He continued by saying:

> If I didn't encourage them to do the questions like I set them, to investigate those things then they wouldn't do anything or they'd just muck around. Kids like that have got to be directed. For example, we did some CASP work, which is a project throughout Australia and which was meant to be a student centred project to try and retain their interest and many of those groups over six weeks did next to nothing.

He recognised that:

> Some students got a tremendous amount out of it, so I think it depends so much on the group size and your group type, but I think it's a good question to have in there.

I'm shown how to use measuring instruments to measure different quantities, for example, mass, length, time and temperature.

After much discussion it was agreed that this was a useful item. It would be answered differently by students of different grades. Students in junior grades are taught the basic science skills, with the younger less experienced students, 'often', and the more experienced and more able students, 'less often'. (Skill Development) Tom admitted that with Grade 7 students, "I do it all the time". Bob summarised the view of the group when he said:

> In the junior grades… I think here most of us would probably ensure that the kids are shown how to do those things because we regard them as basic skills for investigation as they get older.

My teacher shows me how to use equipment correctly

It was generally agreed that this was an important item which would receive a 'very often' response from inexperienced students and a 'sometimes' response from experienced students. Kate believed that it was necessary to explicitly teach the skills to Grade 7 students.,

> While in the older grades you'd probably expect that most people would have some idea.

Mike said that he intervenes with the older students as he is always on the lookout for bad technique.

> It doesn't matter what age, I'll step in if I can see bad technique. It's just a fact that I have to step in more often for the junior kids because they're more likely to not have developed a technique. (This could be categorised as Skill Development or Demonstration, depending on the involvement of the teacher).

I must write reports about my science practical

Comments about this item included, often, not always, yeah, often and I tend to do it most of the time.

Tom said:

> With the catapult one, I just expect them to sort of write down a little note – what went wrong, why they went wrong, what worked, what didn't…

Kate summarised the group's approach by saying:

> I don't expect a full conclusion like five paragraphs talking about patterns and trends and then talking about errors. I don't expect that for every single prac they do because it takes them .... I mean some of them are writing three and four page conclusions now, and if you expected that on every prac.... You should see Monica, she's really at level of a first year university student, already.

I'm encouraged to do my own experiments with substances provided

After discussion about the need for limits, blown up electrical equipment, and flattened batteries, Mike summarised the view of the group by saying:

> I often encourage covertly, I would only encourage the students that I rate as reliable and sensible, in fact I would actively discourage for the whole group, but then say if someone has a conversation with me and you can see that

> they're thinking, and they've got, they might be on to something, I'll say 'Why don't you try that out?'

I work scientifically

The group was concerned about students not knowing the meaning of 'work scientifically'. They agreed to the item 'I work as a scientist' being better wording. They all agreed that having the experience of acting like a scientist was an important rationale for science practical work.

The question of the importance of *the science method* arose at this point in the discussion. The following transcript of the conversation has been quoted as evidence that there has been a reduced emphasis on teaching the science method, at least, among this group of science teachers.

> Mike: An interesting difference between the perception and the actual there. I would like to think if I'm doing a good job the students will work scientifically. Whether they understand that they are, that's probably an added bonus, I guess I'd like them to think they are too but it would be more important for me if they are doing it, rather than they think they're doing it. If they're doing it but not knowing it then that's probably quite good really because it's a way of functioning. I mean the cleverer kids should know that they're doing it.

> Kate: Being able to label it as scientific method or just realising that I've got to have results that mean something, so, I've got to work in a particular way, yeah, I think a lot of kids would say 'I've got to work in a particular way to get reasonable results' but they might not realise that it's called, you know, scientific method. That's why we do this, this and

this, so it's really, I suppose we don't spend a lot of time teaching scientific method per se.

Mike: Not theoretically, but we teach them the steps or process to go through and you hope they pick that up.

Kate: Yes. We don't actually say 'This is scientific method' and come up with a hypothesis, mainly we do that probably with my better Grade 10 kids, when they're doing their planning stuff.

Bob: So it's not formally

Kate: Not any more, we used to when I first started.

Tom: Yeah, I'd say we would have done it more.

I'm encouraged to solve my teacher science problems

Mike summarised the comments of the group, he said:

Just through time constraints we tend to set up the teachers problems for the class to solve more often than we set up the kids problem, or we encourage them to figure out the problem and then the solution for themselves, but, I would be sad if there wasn't a bit of an opportunity at least sometimes for the students to pose the problem. I think we should be encouraging that.

Kate seemed to recognise the importance of prior knowledge and 'child science'.

> Though in order to get to the point of posing problems you've got to have a bit of background information, and really I think the kids start in Grade 7, they don't know much about anything.
> I mean, they know lots about the world but being able to crystallize that into formulating your own problems is a very difficult task. It's quite advanced I'd say, and to think about how they would actually go about making some sort of valid test or experiment to test.

Mike thought Kate's expectations were too high, he argued:

> But they can be at different entry levels I would think. Say if you're just doing work with magnets say, you can just give the students the stuff and say you know, 'What do these things do?' And they can propose things to investigate and test so, they do. You can probably predict what they're going to test, but they're given the opportunity to state it themselves. It doesn't have to be terribly rigorous.

At this point Kate revealed her true priorities

> No, my only frustration with that is I'm obsessive about good use of time I suppose, and that can be really time consuming, taking that approach, but it is important to take it at times, like I find it really frustrating, constantly trying to overcome time constraints.

Constraints and determinants of inquiry science were not the subjects of this study.

My teacher's demonstrations are linked to science class work

There was general agreement that a close link between demonstrations and science class work was desirable. The discussion then developed into complaints about the impact that safety considerations were having on what could be demonstrated in class.

I learn how to do science procedures like heating, dissolving, filtering and evaporating

It was generally agreed by the group that the formal teaching of science procedures, such as those in this item, was limited to junior classes. More senior students were expected to be able to use the procedures.

I must follow set guidelines for writing experimental reports

Sarah said that:

> In most of my classes when we're doing a formal little experiment in class, I would expect them to have an Aim, Equipment, Method…

Kate said that sometimes her students did follow set guidelines. She then went on to describe how when they did the steamboat experiments she didn't require report guidelines at all.

> I had them keep a diary and produce a poster as a group and the arrows going to all the different science applications (Creative Feedback), so it just depends on what experiment it is and whether you want a group analysis or individual.

Mike considered guidelines important, he said:

> I hammer away at set guidelines, but my set guidelines aren't the old formal report writing guidelines. I insist that students always have diagrams that are labelled and with

> captions or descriptions. I insist that they always write paragraphs about what they've done and I insist that they write paragraphs about what they have learned, discovered, or what new things that they can talk about (Creative Feedback), but, that's the level of my guidelines that every report has to have, sometimes I'll extend them into the more formal but that's a minimum, and I always insist on that at least.

Kate questioned whether scientists actually write 'aim, apparatus, method, results, and conclusion'. She considered keeping a diary of experiments as they are being worked on as more useful. The group differentiated between working notes kept in a journal or diary and a formal report when presenting information. The form of the notes or report depended on the audience and purpose of the information.

I do hands-on science activities to help my understanding of science

It was generally agreed that hands-on science activities were an important part of science learning. Bob summarised the view of the group by saying that:

> If the kids engage, it keeps them interested, gives them variety in their learning processes.

I do research like real scientists

Tom responded by saying, Often My Grade 7's now are the Engineers Corps for Alexander the Great. While Sarah said, I don't think my children do. I don't think I do it very often.

The student response to this question will depend on the approach of their science teacher. It was considered an appropriate question.

From this point on the discussion became very repetitive and responses were limited to how often the practice was used in their science classes. There were no indications of inappropriate items. The discussion concluded with a brief description of the theoretical model for science practicals. The model and the eight types of science practicals had been supported by the discussions. As each type of practical had been addressed by several pilot items and the group responses had become repetitive, further discussion of the transcript was not considered necessary for the purposes of this study.

The science teacher focus group considered practical work important in science learning. The teachers indicated that the main rationale for practical work in science learning was perceived to reinforce students' understanding of science theory, as well as giving students hands-on experience of working scientifically, sometimes giving them the opportunity to solve real problems or answer real questions. The teachers perceived that practical work in science learning helped reinforce the learning of science theory without being subservient to it. They considered that theory and practical work are mutually supportive in science learning. The teachers recognised different types of practical work, and their discussions supported the *Theoretical Model for Science Practicals* proposed in Chapter 3, as all eight types of practicals were identified in the field text. The relative importance of science theory and practical work changed with the different aims and emphases of particular parts of the science program. The field text indicated that the science teachers in the focus group were at different stages of professional development with respect to the Four Stage Model of shift towards inquiry outlined by Moscovici (1998). The aims of individual class programs depended on the professional development of the individual science teacher. The teachers understood the different types of practical work represented by the questionnaire items. They approved the items, with suggestions for minor editing. The next section reports on the questionnaire pilot 1.

4.8.3 Pilot 1 of the questionnaire

4.8.3.1 *Pilot 1 sample and procedures*

The pilot sample consisted of 386 junior secondary high school students from government and non-government schools in Hobart, Tasmania and Perth, Western Australia. The composition of the pre-test sample is shown in Table 4.2.

Table 4.2.
Distribution of the Pilot Sample by Grade Level and Gender (N= 386).

Number of students	Grade	Male	Female
22	7	14	12
105	9	48	57
259	10	125	134
Totals 386		187	199

As students were asked to consider their science practicals experience the research sample was biased towards the senior grades of high school. It was assumed that students from Grades 9 and 10, in view of their longer experience, would have more knowledge of science practicals to than those from the junior grades. There was a balance of gender and the sample included students from single gender and coeducational schools. As researcher, I administered the 'actual' form, which was completed individually, before the 'preferred' form, in one sitting held during a timetabled science lesson. The student response data were entered on a spreadsheet for analysis.

4.8.3.2 *Results of Pilot 1*

The results of the first analysis were disappointing. The factor analysis using the SSPS (Nie 1975) did not produce results indicating grouping of the data to support the proposed eight scales of the SPI; the eight types of practicals elicited from the theoretical model of science practicals. I believe that the problem could have been with the sample or with the wording of the items. I also questioned whether there were four scales, as in the QTI, instead of eight from the theoretical model for science practicals. Thus the pilot sample was modified.

The age range of the pilot sample was reduced and the bias towards more experienced students was increased by removing the Grade 7 student data. The pilot sample was enlarged by adding response data from seven more Grade 10 classes (an additional 152 Grade 10 students), bringing the total to 516 student responses. The factor analysis was then run again before the questionnaire was modified. The results were encouraging but far from satisfactory for continued analysis for validation of the pilot questionnaire. The grouping of the data, although tending to support eight scales, often placed the item responses in different groups from those for which they were designed, for example, three items designed for *Laboratory Experiment* were grouped with four items designed for *Directed Activity*, and four *Demonstration* items were grouped with three skill development items and one *Laboratory Experiment*. The most discrete group included five items that were designed for *Directed Inquiry/Problem Solving*

The results suggested that the problems were with some of the items. The scale descriptions were examined carefully. The grouping of the items in each of the factors was examined with a view to editing the wording of some of the items and to write new items as required. The aim was to align the wording of the items to the scale descriptions. Wording of the items describing student activity was made much more personal, using ‘I’ rather than ‘my teacher encourages me to…’. The aim was to have at least six items per scale in the questionnaire for pilot 2. New ‘actual’ and ‘preferred’ forms of the questionnaire were prepared for pilot 2. The questionnaires did not include the open-ended questions used to collect qualitative information about student perceptions of science practicals. Discussion of the pilot questionnaire with science teachers and students was part of the development process. The next section of this chapter reports on pilot 2.

4.8.4 Pilot 2

4.8.4.1 *Pilot 2 sample and procedures*

The pilot 2 sample was similar to pilot 1. It consisted of junior secondary high school students from six government and non-government schools in Tasmania and Western Australia. The composition of the pilot 2 sample is shown in Table 4.3.

Table 4.3
Distribution of the Pilot Sample by Grade Level and Gender (N= 281)

Number of students	Grade	Male	Female
175	9	93	82
106	10	50	56
Totals 281		143	138

The pilot 2 questionnaires were administered following similar procedures to those used in pre-test 1. Pilot 2 packs for participating science classes in Western Australia and northern Tasmania were mailed to science teachers, who administered the questionnaires as requested. I collected the completed questionnaires for analysis.

4.8.4.2 *Results of Pilot 2*

The factor analysis of the pilot 2 data was much more encouraging. The rotated component matrix, with values of 0.4 or greater, indicated that student response data were distributed between six main clusters. This was a significant improvement on the results from pilot 1. Responses to six of the seven items assigned to the *Creative Feedback* scale formed a definite cluster. These items were included in the *Science Practicals Inventory Version 3* (SPI3), which was prepared for pilot 3 followed by full validation analysis. Five items assigned to *Laboratory Experiment* were grouped, enabling them to be selected for SPI3. The grouping of the data suggests that students had a problem answering the items referring to free activity or play that were assigned to the *Student Directed Activity* scale. Teachers do not usually encourage play or free activity, so students may believe that it should not occur in science classes. The value of free activity in science learning may not be appreciated by students. It has also been difficult to write a set of appropriate items for the *Student Directed Activity* scale. Response data for this scale have been grouped with those of the *Open Inquiry/Problem Solving* scale. Eight items were selected from this group for the *Open Inquiry/Problem Solving* scale in SPI3. New items were written for the *Student Directed Activity* scale. More attention needed to be given to the wording of items to clearly distinguish between, and produce clear grouping of response data for the scales *Directed Activity*, *Demonstration* and *Skill Development*. The grouping of the response data suggest that the items do not enable students to distinguish between involvement of the teacher with students in hands-on science activities, the development of skills, or science demonstrations. Careful editing was required of items for the scales *Directed Activity*, *Demonstration* and *Skill Development* to be included in SPI3.

After the second pilot it seemed there was a need to improve the efficiency of collecting the 'actual' and 'preferred' data. The use of two forms of the questionnaire was time consuming and expensive. Many students, during pilots 1 and 2, looked back to their 'actual' responses before making their 'preferred' responses. It seemed reasonable to me to allow the students to have access to their 'actual' responses when giving their 'preferred'. In this way they could clearly decide their preferred responses for practices. Collection of 'actual' and 'preferred' data in one learning environment questionnaire has been used successfully in at least two research studies (Aldridge, Fraser, & Fisher, 2003; Yaxley, Fisher, & Fraser, 2000). SPI3 was redesigned to enable the collection of 'actual' and 'preferred' data on one questionnaire. A student focus group was used to check SPI3 for ease of understanding and appropriate wording of items, as well as for clarity of intent in the collection of 'actual' and 'preferred' responses.

4.8.5 Students group interview: Student Focus Group

The student focus group consisted of twelve, Grade 9 and Grade 10, students from a small non-government school on the outskirts of Hobart, Tasmania. The students were presented with a form of the pre-test questionnaire, SPI3, in which the items for each type of practical were grouped together under scale headings. I established rapport with the students by introducing myself and outlining the intention of the focus group. They were asked to complete the questionnaire by following the instructions. After carefully reading the items, ‘actual’ and ‘preferred’ responses were to be placed in the spaces provided. Students were asked to complete the questionnaire and comment on any items that they found difficult to understand or had difficulty answering. Students were invited to suggest improvements to the wording of the questionnaire. The interview was recorded on audiotape and a field text prepared.

The students worked through the pilot questionnaire without any problems. Typical comments about the instructions included, “clear and easy to understand” and “no problems”. There were no recommendations for rewording. A question was asked about the meaning of ‘play’ in item number 6. The students found the notion of being able to plan their own activities as “strange” and they were “not used to it”. They considered it important to leave items that referred to free activity in the questionnaire, as “you can play around with equipment. It is an interesting and useful learning procedure. You can do what you like and have fun”. Safety considerations were important. They recognised that it was a matter of trust, and “not about blowing up the school or other students”. They admitted that they “did not know what real scientists do”, but they “just guessed” the response to that item. They volunteered the comments that as Grade 9 and 10 students their courses “contained a lot of theory work, with lots of note taking, little demonstration or student practical work”. No questionnaire items were identified as difficult to understand or unsatisfactory. There were no recommendations for rewording or removal of items. There were no apparent problems with answering ‘actual’ and preferred’ responses on the same form. The next section reports the details of SPI3.

4.8.6 Science Practicals Inventory Version 3 (SPI3)

As the development of the SPI is an important part of this study, the SPI3 is presented prior to its validation analysis. SPI3 is presented in Table 4.4.

Table 4.4.
Science Practicals Inventory Version 3 (SPI3).

SCIENCE PRACTICALS INVENTORY (SPI)

Directions

This questionnaire contains statements about practices that could take place in science practicals. You will be asked **how often** each practice **actually** takes place.
You will also be asked **how often** you would **prefer** the practice to take place.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted.

Think about how well each statement describes what the science practical is **actually** like for you. Draw a circle around

1	if the practice **actually** takes place	ALMOST NEVER
2	if the practice **actually** takes place	SELDOM
3	if the practice **actually** takes place	SOMETIMES
4	if the practice **actually** takes place	OFTEN
5	if the practice **actually** takes place	VERY OFTEN

Think about how often you would **prefer** each practice to take place. Draw a circle around

Be sure you give an answer to all questions. If you change your mind about an answer, just cross it out and circle another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Practical Example. Suppose that you were given the statement: "Students work on their own when doing science practicals." You would need to decide whether you thought that you **actually** work on your own *Almost Never*, *Seldom*, *Sometimes*, *Often* or *Very Often.* For example, if you selected *Almost Never*, you would circle the **actual** number **1** on your Answer Sheet. If you would prefer to work on your own *Often*, you would also circle the **preferred** number **4.**

Please write your name and other details below.

THANK YOU FOR ASSISTING WITH THIS RESEARCH PROJECT

NAME______________________SCHOOL___________________CLASS ______Male/Female

Remember that you are describing your **actual** *science practicals and then your* **preferred** *science practicals.*		Almost Never / Seldom / Sometimes / Often
DM UNDIRECTED ACTIVITY / PLAY		
1. I am given freedom to find out for myself in science.	actual preferred	1 2 3 4 5 1 2 3 4 5
2. I am allowed free activity in science practicals.	actual preferred	1 2 3 4 5 1 2 3 4 5
3. I am allowed free activity which makes science practicals fun.	actual preferred	1 2 3 4 5 1 2 3 4 5
4. I play with equipment and substances.	actual preferred	1 2 3 4 5 1 2 3 4 5
5. I am allowed to find out for myself.	actual preferred	1 2 3 4 5 1 2 3 4 5
6. Freedom to do what I like in science practicals is part of my science learning.	actual preferred	1 2 3 4 5 1 2 3 4 5
7. I am allowed free activity making science practicals more interesting.	actual preferred	1 2 3 4 5 1 2 3 4 5
8. I use trial and error to find the answers in science practicals.	actual preferred	1 2 3 4 5 1 2 3 4 5
MD OPEN INQUIRY / PROBLEM SOLVING		
9. I am encouraged to follow my ideas with the equipment provided.	actual preferred	1 2 3 4 5 1 2 3 4 5
10. My investigations discover new knowledge.	actual preferred	1 2 3 4 5 1 2 3 4 5
11. I am encouraged to do my own experiments with substances given.	actual preferred	1 2 3 4 5 1 2 3 4 5
12. I do practical work like scientists do.	actual preferred	1 2 3 4 5 1 2 3 4 5
13. If I finish the laboratory experiment I am allowed to do my own experimenting	actual preferred	1 2 3 4 5 1 2 3 4 5
14. I research questions that my teacher does not know the answers to.	actual preferred	1 2 3 4 5 1 2 3 4 5
15. I am encouraged to suggest study questions for investigations.	actual preferred	1 2 3 4 5 1 2 3 4 5
16. I am encouraged to suggest practical problems to be solved.	actual preferred	1 2 3 4 5 1 2 3 4 5
DR' DIRECTED INQUIRY/ PROBLEM-SOLVING		
17. I am encouraged to investigate my teacher's study questions.	actual preferred	1 2 3 4 5 1 2 3 4 5
18. I must write reports about my science practicals.	actual preferred	1 2 3 4 5 1 2 3 4 5
19. I am encouraged to solve my teacher's science problems.	actual preferred	1 2 3 4 5 1 2 3 4 5
20. I must follow set guidelines for writing experiment reports.	actual preferred	1 2 3 4 5 1 2 3 4 5
21. My teacher gives me study questions to investigate.	actual preferred	1 2 3 4 5 1 2 3 4 5
22. My teacher gives me science problems to be solved.	actual preferred	1 2 3 4 5 1 2 3 4 5

MR CREATIVE FEEDBACK		
23. I make science posters to show what I have found out.	actual preferred	1 2 3 4 5 1 2 3 4 5
24. I make models to explain the work done in science lessons.	actual preferred	1 2 3 4 5 1 2 3 4 5
25. I make charts to explain the work done in science lessons.	actual preferred	1 2 3 4 5 1 2 3 4 5
26. I use mind maps to explain the work done in science. .	actual preferred	1 2 3 4 5 1 2 3 4 5
27. I use drama to role-play or represent science ideas or processes.	actual preferred	1 2 3 4 5 1 2 3 4 5
28. I prepare POWERPOINT presentations to explain my science work.	actual preferred	1 2 3 4 5 1 2 3 4 5
RR' DEMONSTRATIONS		
29. My teacher's demonstrations are linked to science class work.	actual preferred	1 2 3 4 5 1 2 3 4 5
30. My teacher demonstrates how to use a microscope before I use it.	actual preferred	1 2 3 4 5 1 2 3 4 5
31. My teacher's demonstrations help me understand the theory covered in science classes.	actual preferred	1 2 3 4 5 1 2 3 4 5
32. My teacher questions students while doing science demonstrations.	actual preferred	1 2 3 4 5 1 2 3 4 5
33. I am encouraged to ask questions during my teacher's science demonstrations	actual preferred	1 2 3 4 5 1 2 3 4 5
34. My teacher's demonstrations are important to my science learning.	actual preferred	1 2 3 4 5 1 2 3 4 5
R'R SKILLS DEVELOPMENT		
35. I learn how to use measuring instruments to measure different quantities, for example; mass, length, time, temperature.	actual preferred	1 2 3 4 5 1 2 3 4 5
36. I learn how to use equipment correctly.	actual preferred	1 2 3 4 5 1 2 3 4 5
37. I learn how to do science procedures like heating, dissolving, filtering, evaporating.	actual preferred	1 2 3 4 5 1 2 3 4 5
38. I learn how to use a microscope correctly when required.	actual preferred	1 2 3 4 5 1 2 3 4 5
39. I learn how to use instruments to measure quantities, such as; length, weight, time and temperature.	actual preferred	1 2 3 4 5 1 2 3 4 5
40. I learn safety rules for using science equipment.	actual preferred	1 2 3 4 5 1 2 3 4 5
41. I learn how to use measuring instruments, such as; stop watch, thermometer, metre rule.	actual preferred	1 2 3 4 5 1 2 3 4 5
PLEASE TURN THE PAGE TO ANSWER THE QUESTIONS ON THE BACK		
R'D LABORATORY EXPERIMENTS		
42. The AIM of each experiment is clearly stated.	actual preferred	1 2 3 4 5 1 2 3 4 5
43. Equipment I use in experiments is listed as APPARATUS.	actual preferred	1 2 3 4 5 1 2 3 4 5

44. I draw diagrams of equipment used in experiments.	actual preferred	1 2 3 4 5 1 2 3 4 5
45. In experiments I follow instructions listed as METHOD.	actual preferred	1 2 3 4 5 1 2 3 4 5
46. I describe what happens in experiments as RESULTS.	actual preferred	1 2 3 4 5 1 2 3 4 5
47. I describe what I have learned from experiments as CONCLUSIONS.	actual preferred	1 2 3 4 5 1 2 3 4 5
48. Conclusions of my experiments confirm science theory work.	actual preferred	1 2 3 4 5 1 2 3 4 5
RM DIRECTED ACTIVITY		
49. I am given hands-on science activities to help my understanding of science.	actual preferred	1 2 3 4 5 1 2 3 4 5
50. I have instructions to follow when I do laboratory experiments.	actual preferred	1 2 3 4 5 1 2 3 4 5
51. I am told what to do when I do experiments.	actual preferred	1 2 3 4 5 1 2 3 4 5
52. I am given instructions for hands-on science activities.	actual preferred	1 2 3 4 5 1 2 3 4 5
53. I have worksheet questions to answer as I do hands-on science activities.	actual preferred	1 2 3 4 5 1 2 3 4 5
54. I am told what to do to help me learn science.	actual preferred	1 2 3 4 5 1 2 3 4 5

Items 1-10 below consist of a number of statements about any science lessons you might have in this class. You are asked what you think about these statements.
There are no 'right' or 'wrong' answers. Your opinion is what is wanted.
For each statement, draw a circle around
1 if you DISAGREE, **2** if you are NOT SURE, or **3** if you AGREE with the statement;

1. I look forward to science lessons.	1	2	3	
2. Science lessons are fun.	1	2	3	
3. I enjoy the activities I do in science.	1	2	3	
4. I find what I do in science among the most interesting things I do at school.	1	2	3	
5. I want to find out more about the world in which I live.	1	2	3	
6. Finding out new things is important to me.	1	2	3	
7. I enjoy science lessons in this class.	1	2	3	
8. I like talking to my friends about what we do in science.	1	2	3	
9. We should have more science lessons each week.	1	2	3	
10. I feel satisfied after a science lesson.	1	2	3	

THANK YOU FOR ASSISTING WITH THIS PROJECT

The analysis of the questionnaire responses is described in the next section.

4.9 ANALYSIS OF QUESTIONNAIRE RESPONSES

This section outlines the procedures used to prepare the data from the questionnaires for analysis, and the analysis of the data. The stages of treatment and analysis of the data from questionnaires has been described by Warwick and Lininger (1975) as:

1. Editing
2. Coding
3. Preparation for analysis
4. Analysis.
5. Reporting

Stages 1-4 are described in this section. Stage 5 is described and discussed in Chapter 5 of this study.

4.9.1 Editing

Editing involved the examination of the questionnaires to eliminate errors and incomplete responses, to ensure the information was sufficiently complete to be useful. It was assumed that all errors and ambiguities were corrected during the pilot phase of the questionnaire development. Editing included the classification of data obtained by open responses. The main purpose of editing was to facilitate coding. As each questionnaire was received it was given an identification number of three parts: the code of the school and class, the number of students in the class, and the grade and gender. For example, T1 2 10 2 identified the questionnaire as the second student in class 1 from Taroo High School, in Grade 10 and female. The questionnaires were ready for coding.

4.9.2 Coding

The coding process for this study involved the establishment of a Microsoft Excel spreadsheet data file containing all the information SPSS needed to identify the variables used in this study. Microsoft Excel was chosen for its flexibility in controlling data and the graphics options available for reporting the findings of this study.

4.9.3 Preparation for analysis

The response data were prepared for analysis by transferring the responses from the questionnaire to the Microsoft Excel data file. As the responses had already been coded the response data were entered directly from the questionnaire to the data file. Examination of the data was made for inconsistent and improbable responses. The data was ready for analysis.

4.9.4 Analysis

The main purpose of the analysis of the questionnaire responses was to provide a summary of the data that answered the research questions (Warwick & Lininger, 1975). The data consisted of the ‘actual’ and ‘preferred’ responses to each item of the SPI and the responses to the attitude scale. The first task of the analysis was to determine the reliability and validity of the questionnaire. The data were examined for their factor structure by carrying out a principal components factor analysis combined with varimax rotation. Principal components analysis was considered appropriate for this study, as no particular assumption about the underlying structure of the variables was required. The internal consistency and discriminant validity of the scales was examined. The alpha reliability coefficient was used as the index of scale internal consistency. The mean correlations between pairs of scales were used to test the discriminant validity of the SPI. The ability of the SPI to differentiate between the perceptions of students in different classrooms was examined using a one-way ANOVA for each scale, with class membership as the main effect. Associations between student attitudes and science practicals were investigated using simple and multiple correlation analyses. The eta^2 statistic was calculated to provide an additional indication of the degree to which each scale could differentiate between the perceptions of students in different classes. The ‘actual’ and the ‘preferred’ means for all scales were compared so the use of different types of practicals in science learning could be aligned with the practicals that are preferred by students. The consequent alignment could result in an improvement in student attitudes to science programs. Gender differences between the ‘actual’ and ‘preferred’ means for all scales and attitudes to science were examined.

The statistical analysis of the data collected in this study enabled conclusions to be drawn about students’ perceptions of the use of science practicals in junior secondary science programs and their attitudes to science learning. The analysis enabled judgements to be made about the use of practicals in science programs.

Recommendations can be made to improve science learning and students' attitudes to science.

The methodology and assumptions of this study are summarised in the next section.

4.10 SUMMARY AND ASSUMPTIONS

The main aim of this study is to explore the issues involved in the use of practicals in junior secondary science programs. A field research study consisting of several stages has been completed. The *Theoretical Model of Science Practicals* was developed from the literature. The main research instrument, *the Science Practicals Inventory* (SPI), developed from the *Theoretical Model of Science Practicals*, was modelled on two questionnaires from the learning environment research field, a series of pilots, and group interviews of science teachers and junior high school students. The development and administration of the questionnaires followed the processes and strategies of learning environments research. The instrument was used with science students in Tasmania and Western Australia. The response data was analysed to determine the reliability and validity of the questionnaire. Qualitative data was obtained from open questions answered by students and group interviews of science teachers and students. Further analysis of quantitative and qualitative data enables recommendations to be made for the improvement of science programs.

The major assumption underlying this study is that the data gathered is valid and reliable, providing information about the current use of practicals in junior secondary science programs in Australia. This study collected qualitative data from science teachers and students to support the development of the questionnaires and to confirm information collected by questionnaires. The use of the self-administered questionnaire is justified in this study, as it is an initial study of the use of science practicals in Australia. The breadth of cover and the size of the sample made the questionnaire the most appropriate measuring instrument within the limits of the resources of the study. Questionnaires have been used with success in the learning environments research field, particularly when supported by qualitative data (Fraser, 1998).

The assumptions are kept in mind when considering the results of the data analysis and interpretation. These results and interpretations are reported in Chapter 5.

CHAPTER 5

Analysis of the Data

5.1 INTRODUCTION

A new instrument for the evaluation of science practical programs, the *Science Practicals Inventory* (SPI), was developed from the *Theoretical Model for Science Practicals* based on the work of Ausubel (1963; 1968), Novak (1978) and Elton (1987). The development of the questionnaire followed the procedures and strategies of the learning environment research field. The learning environment instruments, the *Science Laboratory Environment Inventory* (SLEI), and the *Questionnaire on Teacher Interaction* (QTI), were used as models for the SPI. As part of the development, before such an instrument can be released for general use, it is necessary to statistically validate the instrument using a large representative sample of respondents. The validation process and other relevant information are described and discussed in this chapter. The purpose of the analysis of the data is to provide a summary of the findings to support the validation of the SPI and to answer the research questions, restated below.

The main aim of the study is to explore, clarify and improve understanding of issues involved in the theoretical bases, rationale and implementation of practicals in junior secondary science programs. The research questions central to this study are:

1. What are the theoretical bases and rationale for practicals in science programs?
2. What are the requirements for practicals as specified in published curriculum documents developed from *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b)?
3. What are teacher perceptions of practicals and their educational value in their science programs?

4. What are student perceptions of practicals and their educational value in their science programs?
5. What are the implications of this study for science curricula?

The secondary purpose of the study is to develop a research instrument that will: be useful in evaluating the use of practicals in science programs, assist with the professional learning of science teachers, and provide guidelines for the use of practicals in science program renewal. The first three research questions have been explored in Chapters 2, 3 and 4 of this study. The next section outlines students' perceptions of science practicals from the analysis of qualitative data, followed by the validation of the SPI from quantitative data.

5.2 STUDENTS' PERCEPTIONS OF SCIENCE PRACTICALS FROM QUALITATIVE DATA

5.2.1 Collection of the qualitative data

The development of the *Science Practicals Inventory* (SPI) questionnaire provided an opportunity to collect qualitative data as well as the quantitative data usually collected during the questionnaire validation process. In this study students were asked to answer one open item about science practicals before completing each of the 'actual' and 'preferred' forms of the SPI during the first of a series of pilots (pilot 1), carried out during the development of the questionnaire. The purpose of the items was to encourage students to focus on the positive experiences of science practicals, including experiences that they found interesting and possibly exciting. By considering both open items, students were able to identify ways of improving science practical programs. The eight categories were not explained or defined to the students prior to completing the survey. The researcher took great care to administer the questionnaire in an identical manner to each class of students. Students were asked the 'actual' open item: 'Before beginning the questionnaire, please describe in a few words the best science practical that you have had'. The students were asked the 'preferred' open item: 'Before beginning the questionnaire, please describe in a few words the science practical that would be an essential part of your science practical program'. The 'actual' form was answered before the 'preferred' form of the questionnaire. Students were exposed to the range of activities that could be included in a science practical program as they completed the ‘actual’ form of the survey. Responses to the ‘preferred’ open item were not restricted by the instructions to suggestions received during completion of the ‘actual’ form of the questionnaire. Following this procedure it was possible to collect a large amount of unrestricted qualitative data on student perceptions of science practicals. The responses were analysed with respect to eight types of practicals that were also used as the scales for quantitative data from the SPI. Coding of the student responses is presented in Appendix B. The research sample was the same as that used for pilot 1. It consisted of 386 junior secondary high school students from Hobart, Tasmania and Perth, Western Australia. The composition of the study sample is presented in Table 4.1 and described in Section *4.8.3.1.*of the previous chapter.

The analysis of the ‘actual’ open item: ‘Before beginning the questionnaire, please describe in a few words the best science practical that you have had’ was done with reference to the practicals types shown in Table 5.1.

Table 5.1
Distribution of Student Responses to the ‘Actual’ Open Item by Practical Types (N=386)

Practical Types	Number of responses	%
No Response	59	15.3
Undirected Activity	2	0.5
Inquiry/Problem-Solving	7	1.8
Creative Feedback	5	1.3
Directed Activity	80	20.7
Demonstrations	13	3.4
Skill Development	120	31.1
Laboratory Experiments	66	17.1
Directed Inquiry/Problem-Solving	34	8.8

The analysis of the ‘preferred’ open item: ‘Before beginning the questionnaire, please describe in a few words the science practical that would be an essential part of your science practical program’, with reference to the practicals types, is shown in Table 5.2.

Table 5.2

Distribution of Student Responses to the 'Preferred' Open Item by Practical Types (N=386)

Practical Types	Number of Responses	%
No Response	187	48.4
Undirected Activity	0	0
Inquiry/Problem Solving	19	4.9
Creative Feedback	5	1.3
Directed Activity	1	0.3
Demonstration	55	14.2
Skill Development	55	14.2
Laboratory Experiment	63	16.3
Directed Inquiry/Problem Solving	1	0.3

5.2.2 Discussion of Student Responses

No Response:

It is disappointing that 59 students were unable to or chose not to identify a 'best science practical' in the 'actual' open item. Most response spaces in this category were left empty. Several students confessed that they did not like science or science practicals. Another group of responses indicated that the students were not interested or excited by science practicals, for example, some students said: "I haven't found any of them particularly memorable", "I prefer to go to the computer room", and "I can't think of one I like". Other students said that they enjoy all science practicals, some emphasising that the practicals should be "eye-catching and give a good time" or when "something big happens". One Grade 10 student pleaded for science practicals to "be fun and exciting like in Grade *7*". Although science practicals are taught in class groups, only one student reported that: "*w*e don't do much practical work*"*. Perhaps his classmates were among the other non-respondents.

Non-respondents to the 'preferred' open item increased to 188 or 48.4% of the sample. Although many of these responses could not be assigned to a practicals type, many of the comments are of interest. One student "did not know or care what happens in an ideal science class*"*. However, most responses were positive, with valuable suggestions for the improvement of science practicals. Many responses made suggestions for science content and excursions rather than improvements within the practicals types. Many students considered practicals important in all science areas. One student reminded us, "This does not mean that we enjoy it". Many students asked for science courses to be "more relevant to the interest of teenagers", "real life", "more to do with what matters to me" and "different every year". They wanted the courses to allow "students to think for themselves". There were requests for "blowing up stuff", "burning things" and "dangerous stuff". These comments were associated with words such as, fun, more interesting, exciting, and not boring. Six students requested to answer their own questions and not the teacher's questions. 24 responses referred to excitement, interesting, or fun. One student summarised the comments of many by listing essentials as: "something fun", "with an element of danger or excitement", "purely to learn from the experiment", and "not to write a report".

Undirected Activity

Undirected Activity, including play, was not perceived by many students to be important in science practicals. It was only referred to by two Grade 7 students, who said that "Playing with Bunsen burners" was their best science practical. *Undirected Activity* was not considered essential in any response to the 'preferred' open question.

Inquiry/Problem Solving

Seven responses to the 'actual' open item were assigned to the *Inquiry/Problem Solving* practicals type. At 1.8% of the sample, this indicates either a low occurrence of *Inquiry/Problem Solving* practicals in science programs or a low student acceptance of *Inquiry/Problem Solving*. 19 responses to the 'preferred' open question, or 4.9% of the sample, were assigned to the *Inquiry/Problem Solving* practicals type. This suggests that students would like to have more *Inquiry/Problem Solving* in their science practical programs. This is consistent with the earlier requests for more opportunity to investigate students' questions and suggests that this would be more interesting to students. Students responding in this category listed: "things we designed ourselves in groups", "environmental investigations", "energy investigations", and "investigations and experiments I designed myself" as the best practicals that they had experienced. The students believed that essential science practicals included: "student-suggested experiments", "environmental investigations" and "more independence". This indicates that students are looking for more *Inquiry/Problem Solving* practicals.

Creative Feedback

Five responses to the 'actual' open item were categorised as *Creative Feedback* practicals. All involved model building. Five responses listed *Creative Feedback* practicals as essential, including: "model making of cells, animals and atoms"; "discussion of ideas involved"; "clear instructions"; and "the development of more understanding of what we are doing".

Directed Activity

80 (20.7%) of responses to the 'actual' open item were assigned to the *Directed Activity* practicals type. Students identified a wide range of learning activities and experiences as best practicals. Comments emphasised "the fun of doing it for ourselves" and described, "hands-on activities [as,] being interesting and fun". Responses to the 'preferred' open item identified an equally varied and extensive list of 'hands-on' activities and experiences as essential. Many comments stressed the importance of "learning by doing", "exciting reactions", "more hands-on activities we can do on our own", "fun with equipment" and "more practicals".

Demonstration

13 responses (3.4%) were assigned to *Demonstration.* Most described the reaction of active metals in water as their best practical with comments, such as: "…*a*ctive metals in water to make a bang and flames" and "[we] watched the teacher put stuff in water, it exploded". Other demonstrations identified were the Breaking Bar Apparatus and the Exploding Volcano. One response summarised this section of responses by saying: "something big happens"! *Demonstrations* were not considered essential practicals. The single response assigned to this category listed "practicals showing main points in science theory to be learned", as essential.

Skill Development

120 (31.1%) of 'active' open item responses have been assigned to *Skill Development.* This is the largest group of responses. The majority of responses identified the dissection of rats, animal hearts or eyes as their best science practicals.

The next largest group identified: using Bunsen burners; heating water; and separating mixtures by filtration, evaporation, and crystallization as the best practicals. Fewer students listed using chemical apparatus and substances for testing for gases and doing titrations. The number of responses to the ‘preferred’ open item assigned to *Skill Development* dropped to 55 or 14.2%. The majority of responses in this category listed dissection as an essential practical. Other essentials identified and given the same level of support included: how to use scientific equipment, Bunsen burners, microscopes, rock and fossil descriptions, and the Hydrogen Pop Test.

Laboratory Experiment

66 or 17.1% of responses to the ‘actual’ open item were assigned to the *Laboratory Experiment*. Responses included the term experiment(s) or described laboratory experiments that are traditionally included in practical programs. The majority listed experiments with chemical reactions, Bunsen burners and titrations as best practicals. Other practicals supported included, for example: physics experiments using electricity, gravity, motion and traffic; and food testing experiments with animals and bacteria. Experiments were considered essential to science programs with subjects similar to those listed as best practicals. There were requests for more experiments particularly related to everyday life and the interests of teenagers. Pleas were made for less routine report writing and more emphasis on learning, discussion of results and writing their own conclusions.

Directed Inquiry/Problem Solving

34 (8.8%) responses to the ‘actual’ open item were assigned to the *Directed Inquiry/Problem Solving* practicals type. This suggests that students have been exposed to *Directed Inquiry/Problem Solving* practicals. As they have listed them as the best science practicals, they value this style of science practicals and the teacher direction associated with it. However, as only one response to the ‘preferred’ open item was assigned to the *Directed Inquiry/Problem Solving* practicals type it suggests that there is little demand for more teacher direction. Best practicals identified include, for example: fun chemistry investigations, energy investigations, strong bridge building from spaghetti, concrete testing, battery testing, separation of salt and water, owl pellet analysis, and preventing ice melting. One student commented: “I have not enjoyed science practicals except making strong bridges from spaghetti with

my friends". The task identified as essential was the design and building of a weight-bearing bridge.

Throughout the students' responses to the open-ended items about their favourite and essential practicals, many comments occurred relating to the effect that the practicals had on their interest, for example: "fun and exciting", "something big happens", "exciting reactions", "hands-on activities [are] interesting and fun", "exciting and not boring", "more relevant to the interest of teenagers" and "I haven't found any of them particularly memorable". The spontaneous comments are both positive and negative in nature. This suggests a third dimension relating to interest could improve the description of science learning. This dimension would be in addition to the dimensions proposed by Ausubel (1963) to describe verbal learning. These were used earlier in this study to produce the *Theoretical Model of Science Practicals*. This proposal is consistent with that of Roberts (1982), who outlined a proposal to arrange programs of different emphases that are interesting to students. The proposed dimension would be described by the exciting--not interesting continuum and could add a third learning dimension to the *Theoretical Model of Science Practicals*.

Discussion of the qualitative data on students' perceptions of science practicals, collected as responses to open questions at the beginning of the SPI, has been presented. The next section reports the analysis of the quantitative data and the validation of the SPI.

5.3 VALIDATION OF THE SCIENCE PRACTICAL INVENTORY (SPI)

5.3.1 Details of the sample and preliminary analysis

The validation sample consisted of students from government and non-government high schools in Tasmania and Western Australia. The sample was biased towards more experienced students. Students from Grades 9 and 10 were considered to have more experience of science practicals than those from the junior grades. Every effort was made to have a balanced sample with respect to state of origin, grade level and gender. The validation of the SPI was carried out towards the end of November 2003, which was after Grade 10 students had left school in Western Australia. This affected the grade balance of the sample, but was not considered of significant effect on the validation. A total of 552 questionnaires were administered, 394 to Tasmanian high school students and 138 to high school students in Western Australia. I administered and collected the questionnaires completed by Tasmanian students. The questionnaires completed by the Western Australian students were administered and collected by their science teachers and mailed to me. I did not administer the Western Australian responses so those students were not rewarded with chocolate frogs after completion of the questionnaires. 15 of the questionnaires from Western Australia had not been completed appropriately and were counted as non-response. The non-response rate of 2.7% was very low and was not considered significant. Reasons for non-response were not included. The details of the validation sample (N=537) are reported in Table 5.3.

Table 5.3
Distribution of the Validation Sample by State, Grade Level and Gender (N=537)

Number of students		Grade	Male	Female
Tas.	W.A.			
	46	8	20	26
231	97	9	193	135
163		10	98	65
Totals	537		311	226

Responses to 537 questionnaires were entered directly on to a Microsoft Excel spreadsheet. Responses to 54 items that related to the eight scales, and responses to 10 attitude items were entered on the spreadsheet. Individual item non-responses were entered as blanks and were not counted as responses by the analysing computer program. Hence, the value of N varied in different sections of the analysis. Examination of the response data for any underlying structure is reported in the next section.

5.3.2 Factor analyses of the 'actual' and 'preferred' responses to the SPI

The first validation task of the analysis was to examine the response data for any underlying structure. The SPI with an *a priori* structure of 54 items arranged in eight scales was subject to a principal components factor analysis, followed by varimax rotation. Factor analyses were done for the ‘actual’ and ‘preferred’ responses to the SPI. The factor analyses of the ‘actual’ and ‘preferred’ responses to the SPI are presented in Table 5.4. Factor loadings of 0.4 or greater were reported to support the *a priori* structure of the questionnaire. The *a priori* factor structure of the questionnaire was replicated with nearly all items loading on their *a priori* scale and no other scale. Four of the six items that load with the *Demonstration* scale in the ‘actual’ responses also load with the *Skill Development* scale in the ‘preferred’ responses. This may suggest that students perceive that teacher demonstration is an important part of skill development. It was considered that the overall grouping of the data, as reported by the factor analyses, supported the *a priori* organisation of the 54 items of the questionnaire into eight scales. The *Theoretical Model of Science Practicals*, on which the questionnaire scales were based, was also supported by the factor analyses although the boundaries between the different types of practicals are not distinct.

The factor loadings were indicative of the success of individual questionnaire items. The aim was to produce a questionnaire with six items per scale, with a total of at least 48 items. It was possible to examine the factor loadings of individual items to identify unsuccessful items with a view to removing them from the questionnaire.

Table 5.4

Factor Analyses of the 'Actual' and 'Preferred' Responses to the SPI

SCALES	Item No.	1 A	1 P	2 A	2 P	3 A	3 P	4 A	4 P	5 A	5 P	6 A	6 P	7 A	7 P	8 A	8 P
		Factor Loading -'actual' (A) and 'preferred' (P)															
	1	.47	.44														
	2	.74	.70														
Student	3	.72	.67														
Directed	4	.48	.52														
Activity	5	.54	.50														
	6	.65	.73														
	7	.72	.72														
	8	.38	.37		.33												
	9	.47	.40		.44												
Open	10	.35			.47												
Inquiry	11			.45	.46												
Problem-	12			.43	.46												
Solving	13			.44	.44												
	14			.58	.61												
	15			.67	.66												
	16			.69	.65												
	17					.55	.62										
Directed	18					.57	.54										
Inquiry	19					.58	.62										
Problem-	20					.58	.56										
Solving	21					.72	.73										
	22					.57	.59										
	23							.57	.69								
	24							.73	.72								
Creative	25							.56	.67								
Feedback	26							.58	.66								
	27							.60	.62								
	28							.54	.61								
	29									.57							
	30									.48	.57		.42				
	31									.60			.54				
Demonstration	32									.52	.47		.42				
	33									.52			.45				
	34									.58			.45				
	35											.63	.69				
	36											.61	.74				
Skill	37											.72	.70				
Development	38											.63	.68				
	39											.69	.76				
	40											.53	.68				
	41											.67	.73				
	42										.56			.54	.35		
	43													.40	.49		
Laboratory	44													.52	.44		
Experiments	45													.74	.65		
	46													.80	.71		
	47													.74	.70		
	48													.70	.60		
	49											.39	.36	.38	.32	.34	
Directed	50															.56	.56
Activity	51															.72	.72
	52															.69	.68
	53															.67	.56
	54															.64	.57
%Variance		19.8	20.8	8.9	9.2	4.6	5.8	3.9	3.5	3.4	3.3	3.1	3.0	2.8	2.7	2.3	2.4
CumulativeVariance		19.8	20.7	28.7	30.0	33.3	35.8	37.2	39.3	40.6	42.6	43.7	45.5	46.5	48.3	48.8	50.6
Eigenvalue		10.7	11.2	4.8	5.0	2.5	3.1	2.1	1.9	1.8	1.8	1.7	1.6	1.5	1.5	1.2	1.3

Factor loadings indicated problems with item numbers 8, 9, 10 and 49. In item 8 I considered that the students did not understand the use of the term *trial and error*. Item 9 loaded equally in the two scales *Undirected Activity* and *Open Inquiry/ Problem Solving*. In item 10 it seems that students, like the science teachers in the group interview, had difficulty with the term *new knowledge*. Factor loadings for item 49 grouped with the scales: *Skill Development, Laboratory Experiment* and *Directed Activity*. This suggests that students used the term 'hands-on activities' as a general term to describe a range of different practicals The use of the term 'hands-on activities' did not appear to be a problem in item 53. Responses to items 8,9,10 and 49 were removed from the data and the items were removed from the final version of the SPI, thus improving the results of the subsequent statistical analysis and the final version of the SPI. Subsequent analysis was done on the amended data and is reported in the following sections.

5.3.3 Reliability, internal consistency and discriminant validity of the SPI, and its ability to differentiate between classes

The SPI was used to collect information about the perceptions of junior secondary science students in Tasmania and Western Australia of the use of practicals in their science learning. Validation of psychomotor tests such as the SPI, required the use of Cronbach's (1951) alpha reliability coefficient, as an index of internal consistency. Internal consistency is the extent to which items in the same scale measure the same factor. A satisfactory level of internal consistency is indicated by alpha reliability coefficient values of greater than 0.5 (De Vellis, 1991) or 0.6 (Nunally, 1978). The amended SPI data, obtained from its use with science students from high schools in Tasmania and Western Australia, indicated that all scales of the instrument have a good level of internal consistency. Alpha reliability coefficients from the personal data ('actual'), for all scales, ranged from 0.70 to 0.88 and from the personal data ('preferred'), for all scales, ranged from 0.72 to 0.88. When the class means were taken as the units of analysis, the alpha reliability coefficients were higher except for the scales: *Open Inquiry/Problem Solving* 'actual', *Creative Feedback* 'actual' and *Creative Feedback* 'preferred'. Alpha reliability coefficients obtained with the class means ('actual') as the units of analysis, ranged from 0.62 to 0.95, and class means ('preferred') ranged from 0.73 to 0.94. Cronbach alpha reliability values obtained in the reliability analysis of the SPI were consistently greater than 0.6. The generally high values obtained indicate that the SPI is a reliable instrument to investigate Australian students' perceptions of the use of science practicals (Nunally, 1978). The results suggest that the use of the class means obtained from using the SPI is generally more reliable than the use of personal data and that the SPI can be used equally well with individual or class mean data. The full alpha reliability analysis is presented in Table 5.5.

Table 5.5
Scale Internal Consistency (Cronbach Alpha Reliability Coefficients), Discriminant Validity (Mean Correlation with Other Scales) and Ability to Differentiate Between Classrooms (ANOVA Results, eta^2) for the SPI

Scale	No. of Items	Data	Cronbach Alpha Reliability Coefficient (>0.6)		Mean Correlations (<0.4)		ANOVA Results eta^2
			Actual	Preferred	Actual	Preferred	Actual
Undirected Activity	7	Personal	0.77	0.75	0.19	0.12	
		Class	0.85	0.83			0.11***
Open Inquiry/ Problem Solving	6	Personal	0.70	0.72	0.21	0.26	
		Class	0.62	0.74			0.07
Creative Feedback	6	Personal	0.71	0.79	0.16	0.26	
		Class	0.63	0.73			0.11***
Directed Activity	5	Personal	0.80	0.77	0.26	0.30	
		Class	0.89	0.85			0.16***
Demonstration	6	Personal	0.79	0.80	0.36	0.36	
		Class	0.90	0.92			0.15***
Skill Development	7	Personal	0.88	0.88	0.36	0.36	
		Class	0.95	0.94			0.18***
Laboratory Experiment	7	Personal	0.82	0.80	0.32	0.36	
		Class	0.92	0.89			0.22***
Directed Inquiry/ Problem Solving	6	Personal	0.73	0.78	0.28	0.34	
		Class	0.86	0.87			0.17***
			N=531-535 Number of Classes = 29				*** $p < 0.001$ ** $p < 0.01$

The SPI response data were analysed to check the discriminant validity of the scales of the questionnaire. Mean correlations of one scale with the other seven scales were calculated for the 'actual' and 'preferred' responses as an indication of the discriminant validity of the scales. Mean correlation values of less than 0.4 were considered an indication of the extent to which each scale measured a factor different from those measured by the other scales (Nunally, 1978). The mean correlations of the scales ranged from 0.16 to 0.36 for the 'actual' responses, and from 0.12 to 0.36 for the 'preferred' responses. These values were considered small enough to suggest that each of the scales of the SPI measured different science practicals, even though the different types of practicals were adjacent to each other in the *Theoretical Model for Science Practicals* and may merge into their neighbouring practicals. The detail of the discriminant validity analysis is presented in Table 5.5.

In order to be a useful evaluation instrument for the use of practicals in science programs, as delivered by different teachers in separate classes, it is important that the SPI can differentiate between perceptions of students in different classes. Although students may be individual learners, students within the same class may view the classroom learning environment differently from students in other classes (Fraser, 1994). The ability of the SPI to differentiate between individual students' perceptions of the use of science practicals in different classes was measured by using a one-way analysis of variance (ANOVA), with class membership as the main effect. The amount of variance explained by class membership was indicated by the eta^2 scores that ranged from 0.07 to 0.22 for 'actual' responses. The results for the 'actual' data indicate that each of the scales, except *Open Inquiry/Problem Solving*, significantly differentiated between classes ($p<0.001$). The overall results, presented in Table 5.5, supported the validity of the SPI. The lower eta^2 values for the scales: *Undirected Activity*, *Open Inquiry/Problem Solving*, and *Creative Feedback* may have reflected the lower levels of use of those types of practicals in science programs, as indicated in the descriptive statistics presented and discussed in the next section. The results reported in Table 5.5 support the conclusion that the SPI can differentiate significantly between the perceptions of students from different classes about the use of science practicals.

5.3.4 'Actual' and 'preferred' differences in the response data of the SPI

The perceptions of students about the use of science practicals, as recorded by the SPI, have been summarised in Table 5.6. This table presents the recorded differences between students' perceptions of their 'actual' and 'preferred' use of practicals in their science programs. Mean differences between the 'actual' and the 'preferred' individual responses, together with the results of paired samples t-tests for each scale, indicated that the 'actual' and 'preferred' responses were highly significantly different for every scale ($p<0.001$-$p<0.05$).

The 'actual' responses indicated high levels of teacher direction with high usage (scale mean>3.50) of *Skill Development*, *Directed Activity* and *Laboratory Experiment* and *Demonstration*, in order of reducing usage. The 'actual' responses indicated low levels of student-initiated activity with low usage (scale mean < 3.50) of *Creative Feedback, Open Inquiry/Problem Solving*, *Undirected Activity* and *Directed Inquiry/Problem Solving*, in order of increasing usage. The mean differences indicate that the students would generally prefer more use of practicals in their science learning, with more use of practicals involving student-initiated activity, that is, *Undirected Activity*, *Open Inquiry/Problem Solving*, and *Creative Feedback*. Positive mean differences for the scales: *Skill Development*, *Demonstration* and *Laboratory Experiment* indicated student recognition of the importance of the teachers in the successful achievement of science learning outcomes. The students were definite about their preference for less *Directed Activity* and *Directed Inquiry/ Problem Solving*, as indicated by negative mean differences.

Table 5.6

Scale Means, Standard Deviations and Paired Samples Correlations for 'Actual' and 'Preferred' Responses to the SPI

Scale	Scale Mean Actual (A) Preferred (P)		Standard Deviation	Mean Difference (P-A)	Paired Samples Correlation	Paired Samples t values
Undirected Activity DM UDACT	A	2.64	0.67	1.11	0.23***	-31.86***
	P	3.75	0.61			
Open Inquiry/ Problem Solving MD OIPS	A	2.28	0.69	0.99	0.34***	-27.66***
	P	3.27	0.74			
Creative Feedback MR CRFB	A	2.01	0.67	0.78	0.44***	-20.88***
	P	2.79	0.90			
Directed Activity RM DACT	A	3.90	0.79	-1.11	0.38***	2.36*
	P	2.79	0.79			
Demonstration RR' DEM	A	3.69	0.81	0.09	0.64***	-3.23**
	P	3.78	0.79			
Skill Development R'R SKLD	A	3.92	0.82	0.19	0.59***	-6.04***
	P	4.11	0.76			
Laboratory Experiment R'D LABX	A	3.89	0.76	0.10	0.55***	-3.11**
	P	3.99	0.73			
Directed Inquiry/ Problem Solving DR' DIPS	A	3.45	0.79	-0.30	0.41***	8.45***
	P	3.15	0.79			
	N=531-537			***p<0.001,	**p<0.01,	*p<0.05.

The scale means of the 'actual' and 'preferred' response data are presented graphically in Figure 5.1. This illustrates graphically that students perceive the practicals involving teacher directions occur more often than those which involve student initiative. Generally, students would prefer more practical work. They would like more *Undirected Activity, Open Inquiry/Problem Solving*, *Creative Feedback* and *Skill Development*. They would like less *Directed Activity* and *Directed Inquiry/Problem Solving.*

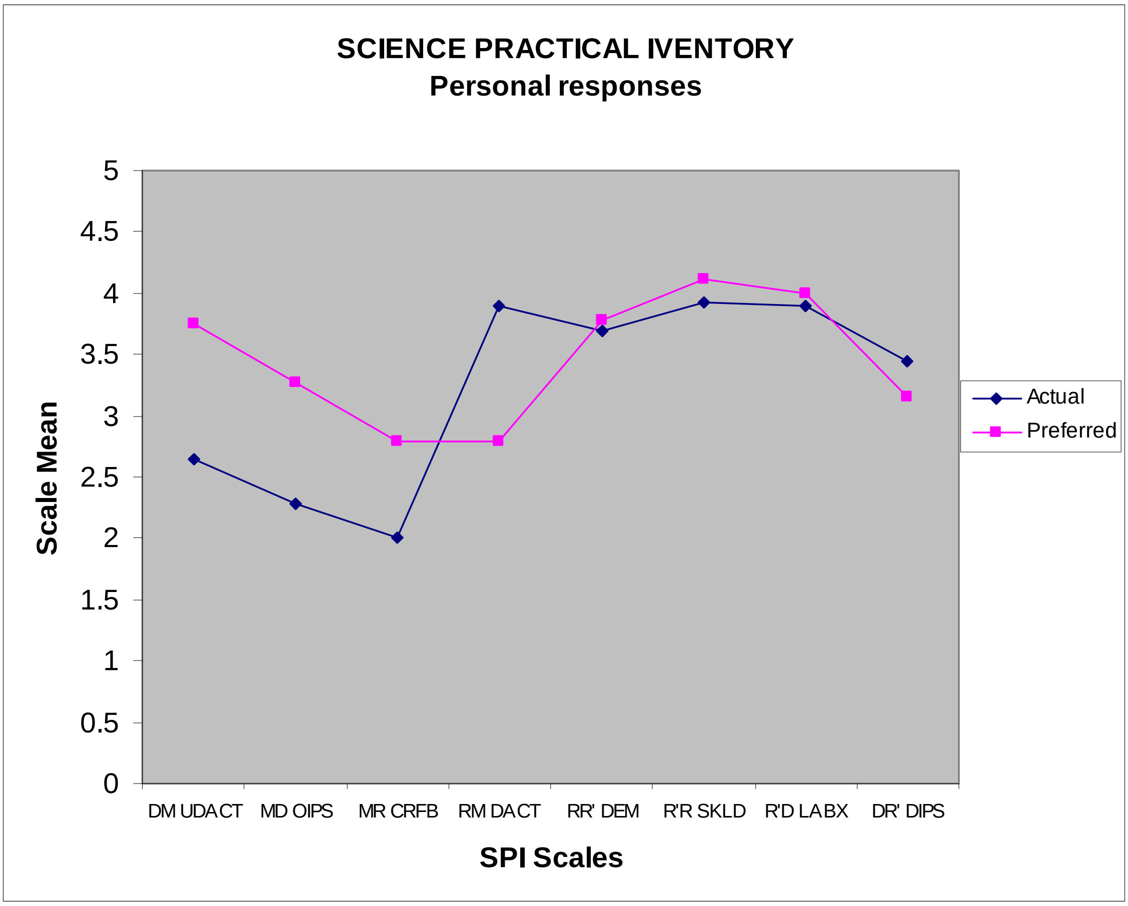

Figure 5.1. 'Actual' and 'preferred' scale means against SPI scales.

Further analyses were completed to explore the inter-scale correlation in the SPI. The different types of science practicals, on which the scales of the SPI were based, were arranged in a circular pattern in the *Theoretical Model of Science Practicals*. In order to be considered a circumplex model, the correlations between two adjacent scales were to be the highest, with the correlations gradually decreasing, as the scales were further apart, until opposite scales were negatively correlated. An illustration of the inter-scale correlations for the *Undirected Activity* scale is shown in Figure 5.2.

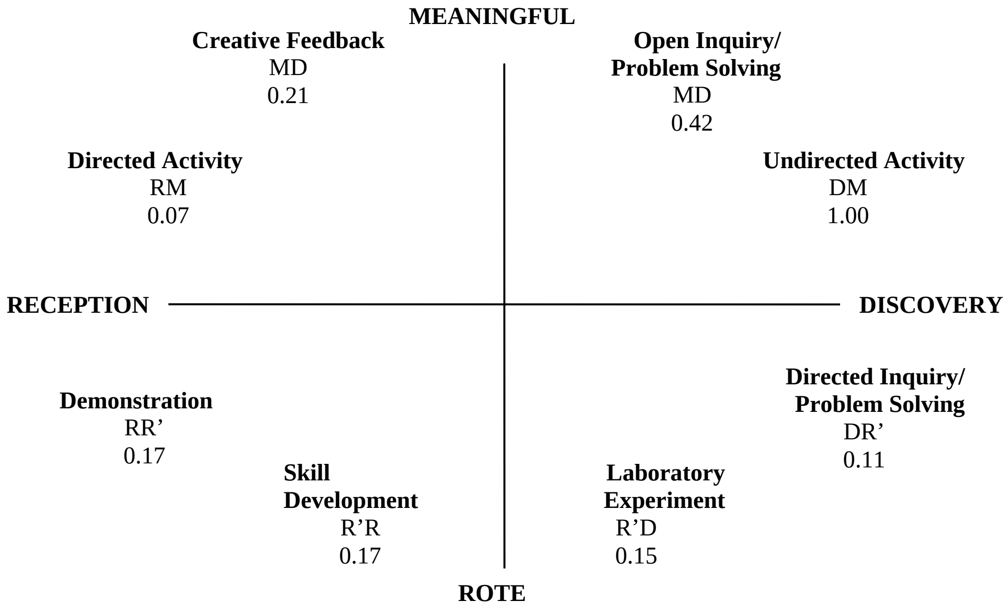

Figure 5.2. The theoretical model of science practicals and inter-scale correlations.

The correlations between two adjacent scales, for example, *Undirected Activity* and *Directed Inquiry/Problem Solving*, were not the highest. The correlations did not gradually decrease, as the scales were further apart. Opposite scales were not negatively correlated. The results of the inter-scale correlations did not support the hypothesis that the *Theoretical Model of Science Practicals* is a circumplex model. This was surprising, as the model was developed from continua using a process that has previously developed circumplex models, for example, the QTI. The collection of further data using the SPI will enable the circumplex model question to be tested again.

Relationships between the scales of the SPI and student attitudes to science are explored in the next section

5.3.5 Relationships between Student’s Attitudes and the Scales of the SPI

Earlier in this study concern was expressed about the rather negative attitudes that Australian high school students had towards science learning (Goodrum et al., 2001). It is an aim of this study to make recommendations for the modification of science practical programs to improve students' attitudes to science learning. Science practical work has a generally positive relationship with senior students' attitudes to science learning (Henderson & Reid, 2000).

The data about student attitudes to science learning collected in this study are reported in Table 5.7.

Table 5.7

Attitudes to Science Learning Items, Response Mean and Standard Deviation.

N=537, Response Range 1-3

Attitudes to Science Learning Items	Response Mean	Standard Deviation
1. I look forward to science lessons.	1.83	0.74
2. Science lessons are fun.	1.85	0.70
3. I enjoy the activities I do in science.	2.08	0.75
4. I find what I do in science among the most interesting things I do at school.	1.65	0.76
5. I want to find out more about the world in which I live.	2.30	0.74
6. Finding out new things is important to me.	2.54	0.65
7. I enjoy science lessons in this class.	2.03	0.77
8. I like talking to my friends about what we do in science.	1.84	0.80
9. We should have more science lessons each week.	1.34	0.58
10. I feel satisfied after a science lesson.	1.79	0.70

The data reported in Table 5.7 indicate that students have generally negative attitudes towards their science learning experiences. This is consistent with the findings of Goodrum, Hackling and Rennie (2001). Although finding out about new things is important to students and they want to find out about the world in which they live, as indicated by high response means 2.54 and 2.30 respectively, they do not agree with, or are unsure about, the statements that they enjoy the activities they do in science (response mean 2.08) and that they enjoy science lessons in their particular classes (response mean 2.03). Students generally do not agree that science lessons are fun (response mean 1.85). They do not enjoy talking to their friends about what they do in science (response mean 1.84). Generally, students do not look forward to science lessons (response mean 1.83). They do not feel satisfied after a science lesson (response mean 1.79). What the students do in science is not among the most interesting things they do at school (response mean 1.65) and there is more agreement that on any other item that they should not have more science lessons each week (response mean 1.34 and standard deviation 0.56).

Although students' attitudes to science learning are not a main focus for this study, it is important to investigate any possible relationship between the scales of the SPI and student responses to the attitude scale as it may be possible to improve the attitudes of science students by changing the type of practicals in science programs. Simple correlation coefficients were calculated between each scale of the SPI and the attitude responses. A multiple regression analysis, of all eight SPI scales, with attitude as the dependent variable, was conducted. This would provide a test of any relationship of each scale with attitude, when all other scales were controlled. Table 5.8 reports the relationships of each scale of the SPI with the students' attitude responses.

Table 5.8
Relationships Between the SPI Scales and Students' Attitude in Terms of Simple Correlations (r) and Standardised Regression Coefficients (β)

Scale	Attitude to science learning	
	r	*β*
Undirected Activity DM UNDACT	0.24 ***	0.18 ***
Open Inquiry/ Problem Solving MD OIPS	0.13 **	0.00
Creative Feedback MR CRFB	0.07 *	0.01
Directed Activity RM DACT	0.17 ***	- 0.05
Demonstration RR' DEM	0.32 ***	0.16
Skill Development R'R SKLD	0.32 ***	0.14 *
Laboratory Experiment R'D LABX	0.30 ***	0.16 **
Directed Inquiry/ Problem Solving DR'DIPS	0.14 **	- 0.05

N=530-534 Attitude Cronbach Alpha =0.85 ***p<0.001, **p<0.01, *p<0.05
R=0.41**, R Square= 0.17

The results of the simple correlation analysis indicated a statistically significant and positive relationship between students' attitudes to science learning and all eight scales of the SPI. The relationships for the scales: *Undirected Activity, Directed Activity, Demonstration, Skill Development* and *Laboratory Experiment* were highly significant (p<0.001). The relationships between attitudes and *Open Inquiry/Problem Solving, Directed Inquiry/Problem Solving and Creative Feedback* are smaller and less significant. The relationship between the set of scales of the SPI and students' attitudes to science learning was indicated by the multiple correlation value. The multiple correlation (R) of 0.41 was statistically significant (p<0.01). The R Squared value of 0.17 indicated that 17% of the variance in students' attitudes to science learning could be attributed to their perceptions of the use of science practicals. Regression analysis compensates for any relationships between scales. The standardised regression coefficients (β) indicated which SPI scales contributed most to the variance of students' attitudes. It was found that *Undirected Activity* (β=0.18 p<0.001), *Laboratory Experiment* (β=0.16 p<0.01) and *Skill Development* (β=0.14 p<0.05) were positively related to students' attitudes to science learning, in order of decreasing significance. These results suggested that students considered practical work, involving laboratory experiments and skill development, important to their science learning, but they would like much more responsibility for their science practical activities and less teacher direction. Gender differences of perceptions of the use of science practicals are presented in the next section.

5.3.6 Gender differences of perceptions of science practicals and the SPI

The relationships between students' perceptions of the use of science practicals and gender were analysed by splitting the sample into two subgroups: subgroup 1 (300 male students), and subgroup 2 (223 female students). The data were analysed by computing the mean scores of male and female students for each scale of the SPI. The significance of gender differences in students' perceptions of the use of science practicals were analysed using an independent t-test. An analysis of the gender differences for both the 'actual' and 'preferred' responses was considered valuable for this study.

The 'actual' results indicated that the students' perceptions of the use science practicals were really very similar. Perceptions of male students were not significantly different from those of female students, except for the *Open Inquiry/Problem Solving* scale. Female students perceive that practicals involving teacher direction occur more often than practicals that involve student initiative. Male students perceive that they had more opportunity to exercise choice and initiative in practicals than female students, for example, in the use of scales: *Undirected Activity*, *Creative Feedback and Open Inquiry/Problem Solving*, listed in order of increasing mean difference. The difference between the males and females perceptions of how often *Open Inquiry/ Problem Solving* occurs was significant with a t value of 2.93 ($p<0.05$). The practicals perceived to be used most often by males and females are: *Skill Development, Laboratory Experiment, Directed Activity* and *Demonstration,* listed in order of decreasing occurrence (summed scale means >7.00). The type of practical perceived to be used least often by both males and females was *Creative Feedback*. The results of the analysis of gender differences in 'actual' responses to the SPI are presented in Table 5.9.

Table 5.9
Scale Mean and Standard Deviation of Gender 'Actual' Responses by SPI Scales

Scale	Gender	Scale Mean 'actual'	Standard Deviation	Mean Difference (Male-Female)	t
Undirected Activity DM UDACT	Male Female	2.65 2.62	0.67 0.69	0.03	0.55
Open Inquiry/ Problem-Solving MD OIPS	Male Female	2.35 2.17	0.70 0.67	0.18	2.93 *
Creative Feedback MR CRFP	Male Female	2.07 1.95	0.68 0.65	0.12	1.97
Directed Activity RM DACT	Male Female	3.85 3.94	0.76 0.81	-0.09	-1.23
Demonstration RR' DEM	Male Female	3.64 3.75	0.81 0.82	-0.11	-1.49
Skill Development R'R SKLD	Male Female	3.87 3.99	0.86 0.78	-0.12	-1.64
Laboratory Experiment R'D LABX	Male Female	3.90 3.92	0.77 0.70	-0.17	-2.55
Directed Inquiry/ Problem Solving DR' DIPS	Male Female	3.45 3.46	0.72 0.78	-0.01	-1.19

Male N=298-300
Female N=219-223

*$p<0.05$

The results for the gender difference of 'actual' SPI scale means are presented graphically in Figure 5.3.

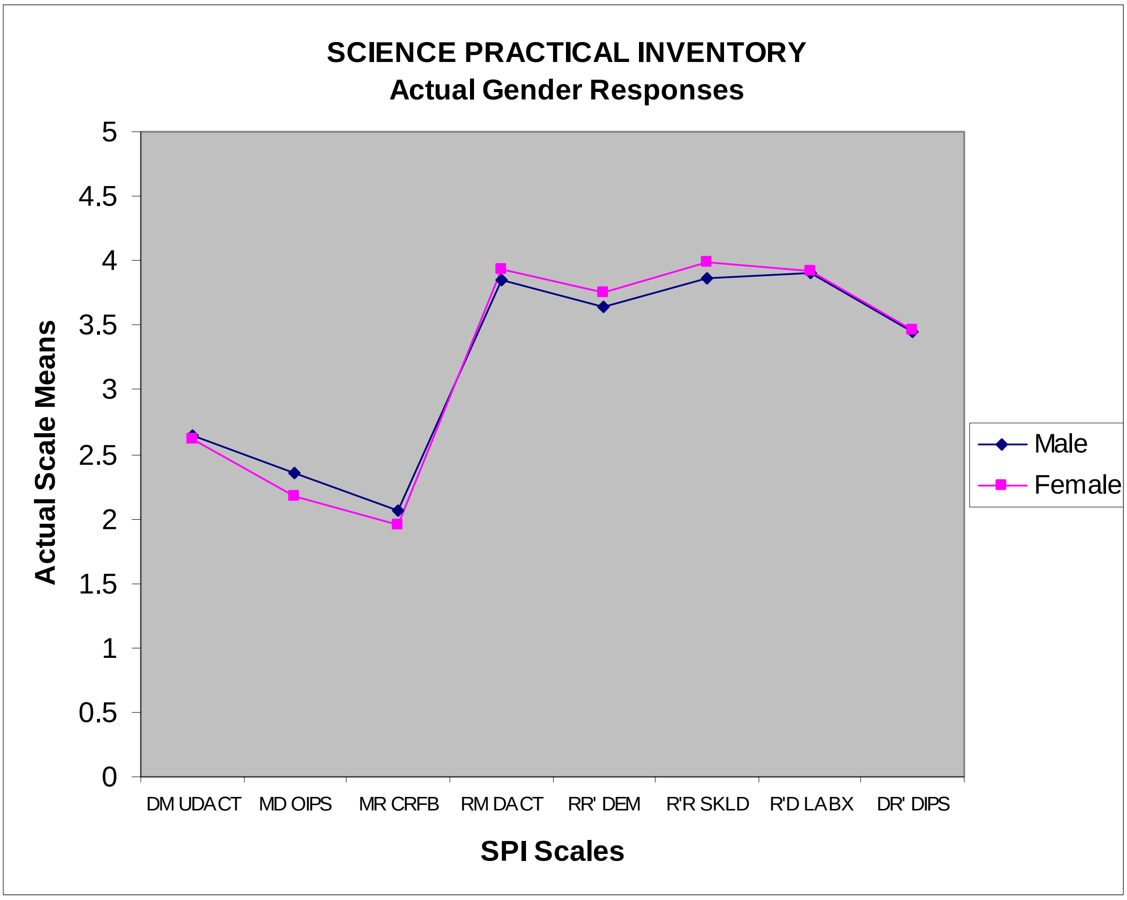

Figure 5.3. SPI 'Actual' gender scale means against scales.

Figure 5.3 illustrates graphically how the male and female students' perceptions of the 'actual' use of science practicals are similar.

The 'preferred' results indicated general similarity between the male and female students' preferred use of science practicals in their science learning. However, significant differences between male and female perceptions of science practicals were indicated in scales: *Open Inquiry/Problem Solving* and *Directed Activity*. Male preference for *Open Inquiry/Problem Solving* was significantly different from the preference of females for that type of practical (t value = 3.24, *p*<01). Female preference for Directed Activity was highly significantly different from the preference of males for that type of practical (t value = -3.97, *p*<001). Gender differences for other types of practicals were not significant. Male and female preferences for scales, and types of practicals, were indicated by sums of scale means and were listed in order of reducing preference as follows: *Skill Development*, *Laboratory Experiment*, *Directed Activity*, *Demonstration* and *Undirected Activity* (sums of scale means > 7.00). *Creative Feedback*, with equal scale means (2.79), had the lowest preference of any type of practical. This seemed to reflect the low ‘actual’ usage reported in Table 5.9. Gender ‘preferred’ responses are reported in Table 5.10.

Table 5.10
Scale Mean and Standard Deviation of Gender ‘Preferred’ Responses by SPI Scales

Scale	Gender Mean	Scale Preferred	Standard Deviation	Mean Difference (Male-Female)	t values
Undirected Activity DM UDACT	Male	3.79	0.60	0.10	1.71
	Female	3.69	0.63		
Open Inquiry/ Problem Solving MD OIPS	Male	3.37	0.70	0.22	3.24**
	Female	3.15	0.77		
Creative Feedback MR CRFB	Male	2.79	0.91	0.00	0.01
	Female	2.79	0.90		
Directed Activity RM DACT	Male	3.69	0.80	-0.27	-3.97***
	Female	3.97	0.75		
Demonstration RR’ DEM	Male	3.74	0.80	-0.13	-1.87
	Female	3.87	0.76		
Skill Development R’R SKLD	Male	4.07	0.83	-0.10	-1.6
	Female	4.17	0.66		
Laboratory Experiment R’D LABX	Male	3.98	0.70	-0.07	-1.15
	Female	4.05	0.73		
Directed Inquiry/ Problem Solving DR’ DIPS	Male	3.16	0.80	-0.27	0.02
	Female	3.16	0.74		
	Male N=298-300				** $p<0.01$
	Female N=219-223				*** $p<001$

The results for the gender difference of ‘preferred’ SPI scale means are presented graphically in Figure 5.4.

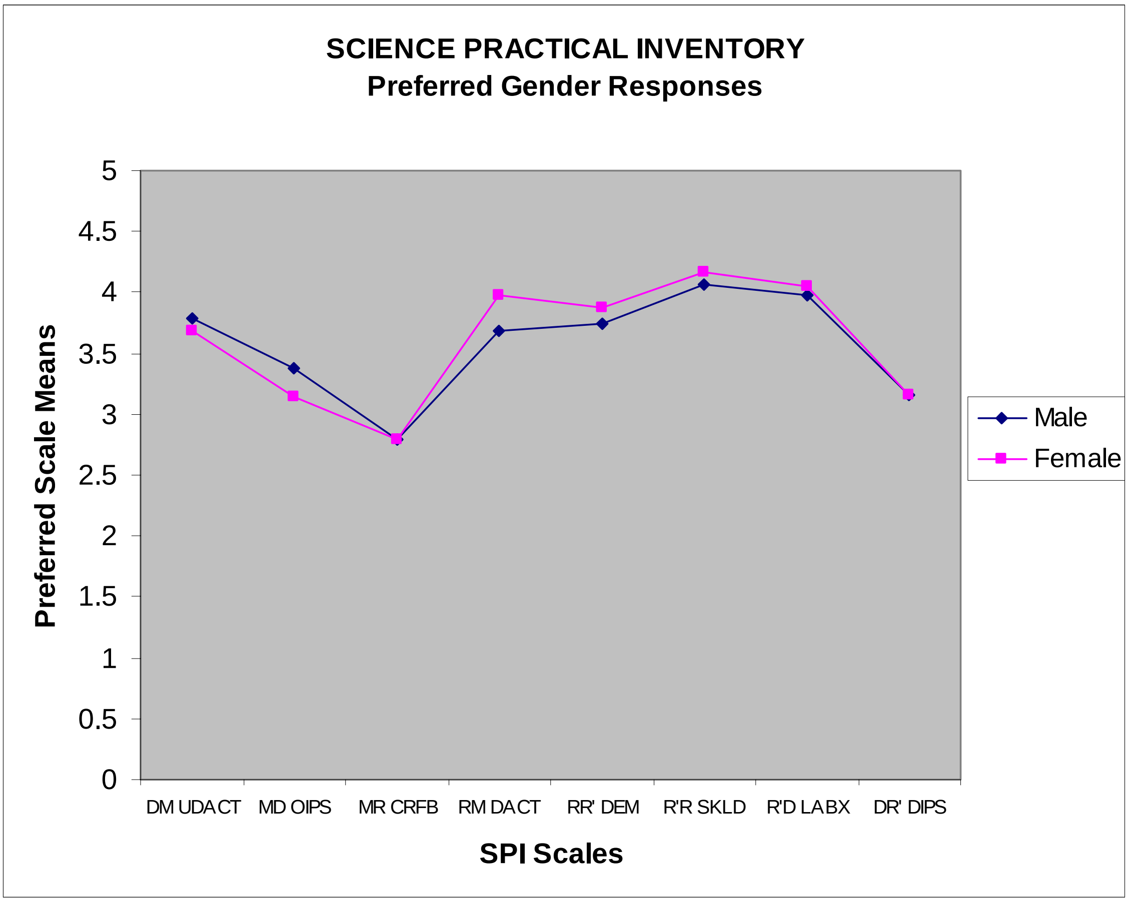

Figure 5.4. SPI 'Preferred' gender scale means against scale.

Figure 5.4 illustrates graphically how similar the male and female students' perceptions of the 'preferred' use of science practicals are. The different gender profiles show the male preference for student initiated activities and the female preference for teacher direction.

The data analysis and conclusions are summarised in the next section.

5.4 SUMMARY AND CONCLUSIONS FROM THE DATA ANALYSIS

This chapter reported on the analysis of qualitative and quantitative data. Qualitative data were collected in association with the administration of a student questionnaire, the *Science Practical Inventory (SPI)*. Open items in association with procedures used in studying learning environments were useful in obtaining qualitative data in the exploration of student perceptions of science practicals. Students were asked to indicate their favourite practicals and those which they considered essential to a practical science program. Although there were a small number of negative comments and types of practicals with little or no representation in the responses, students responded well to these open items (see Appendix B). Students, in general, enjoy science practicals and consider science practicals are essential components of science programs. Indeed, there was a strong request for more practical work, to improve the motivation of students, and to promote the development of meaning and understanding of the world they live in.

Students recognise that teachers have an important role in directing their study programs but would like to have more opportunities for independent investigations. Analysis of SPI responses with respect to gender suggests that females prefer teacher direction. This finding is contrary to the position taken by Gott and Duggan (1995, p. 143), who report general agreement that investigative work engages students' interest and that girls prefer the open approach. The teaching of science and manipulative skills is appropriate if opportunities are provided to develop and use them. Demonstrations have an important role in helping students understand science theory work. Links between science theory and practicals are important. 'Hands-on activities', directed by the teacher, provide ways of doing this as well as demonstrations. Students asked to be allowed to plan their own experiments and draw their own conclusions in order to answer their questions. In general, students are looking for less teacher direction and more independence in science practicals. While recognising that safety is important, they would like to see more fun and excitement in science. Discussion of ideas of science is important to improve understanding. Opportunities for creative feedback activities should be provided throughout the science practical program. It seems that students would welcome opportunities for safe play with equipment and chemicals. It is noted that many of the "best practicals" identified by more senior students were conceptually undemanding and introduced early in high school.

The occurrence of many comments from students relating to student interest in science practicals suggested that a third interest dimension could improve the description of science learning. The dimension would be described by the exciting--not interesting continuum and could add a third dimension to the *Theoretical Model of Science Practicals.*

There is a place for more qualitative data in the exploration of student perceptions of science programs.

The *Science Practicals Inventory* (SPI) was developed from a theoretical model for science practicals based on the work of Ausubel (1963; 1968), Novak (1978) and Elton (1987). The development of the SPI followed the procedures and strategies of the learning environment research field. The SPI was validated by statistical methods involving factor analysis, tests for reliability, internal consistency and discriminant validity, and the ability of the questionnaire to differentiate between classes. The factor analyses supported the *a priori* organisation of 50 of the 54 items of the questionnaire into eight scales. The *Theoretical Model of Science Practicals*, on which the questionnaire scales were based, was also supported by the factor analyses. The Cronbach alpha reliability coefficient values and the mean correlations indicated that each of the scales of the SPI measured different science practicals. The ANOVA results supported the conclusion that the SPI can differentiate significantly between students' perceptions of the use of science practicals from different classes. The validity of the SPI was generally supported by the statistical analysis. Further consideration of the inter-scale correlations from the data collected in this study, did not support the hypothesis that the *Theoretical Model of Science Practicals* is a circumplex model.

Student responses to items seeking information about their attitudes to science learning indicated that students have generally negative attitudes to science learning even though finding out about new things is important to students and they want to find out about the world in which they live.

Investigation of possible relationships between the scales of the SPI and students' attitudes to science learning suggested that students considered practical work, involving laboratory experiments and skill development, important to their science learning. It was found that the scales: *Undirected Activity, Laboratory Experiment* and *Skill Development* were positively related to students' attitudes to science learning, but they would like much more responsibility for their science practical activities and less teacher direction. Students support the development of metacognitive skills or metacognition as described by Baird (1990). This finding is consistent with findings of the analysis of the qualitative data.

Exploration of the whole sample of student perceptions of the use of practicals in science learning indicated that practicals involving teacher direction occur more often than practicals that involve student initiative. Exploration of gender differences of perceptions found that male students perceive that they had more opportunity to exercise choice and initiative in practicals than female students did. There was divergence of male and female preferences for science practicals in their science learning in two scales. Females preferred *Directed Activity* while males preferred *Open Inquiry/ Problem Solving*. Both males and females perceived *Creative Feedback* as used the least and also as the least preferred type of science practical. This should be of great concern to science educators, as the case has been made earlier in this study for the importance of *Creative Feedback* in the achievement of meaningful learning and the development of understanding.

The final version of the SPI used in this study is a generally valid instrument, suitable for general use in the evaluation of Australian science practical program. The grouping of the data, as reported by the factor analyses, supported the *a priori* organisation of the questionnaire items into eight scales. Cronbach alpha reliability values obtained in the reliability analysis of the SPI were consistently greater than 0.6. The generally high values obtained indicate that the SPI is a reliable instrument to investigate Australian students' perceptions of the use of science practicals (Nunally, 1978). The mean correlations of the scales for the 'actual' responses, and the 'preferred' responses were all less than 0.4 (Nunally, 1978). These values suggest that each of the scales of the SPI measured different science practicals, The ability of the SPI to differentiate between individual students' perceptions of the use of science practicals in different classes was measured by using a one-way analysis of variance (ANOVA), with class membership as the main effect. The SPI has a place in the collection of quantitative data and is suitable for use with other quantitative and qualitative methods to research junior secondary science education in Australia. The next chapter discusses possible applications of the SPI.

CHAPTER 6

Applications for the Science Practicals Inventory

6.1 INTRODUCTION

The primary aim of this study is to explore and clarify the understanding of issues involved in the theoretical bases, rationale and implementation of practicals in junior secondary science programs. For more than a decade, the Australian Government has been concerned about the maintenance of teacher quality and the renewal of science education programs (Committee for the Review of Teacher Education, 2003; Schools Council of National Board of Employment Education and Training, 1989, 1990). The Committee for the Review of Teacher Education (2003) called for a re-invigoration of junior secondary school science, technology and mathematics education, by the strengthening of curriculum and pedagogy. The *Australian School Innovation in Science, Technology and Mathematics* (ASISTM) *Project (Department of Education Science and Training, 2005),* part of the Australian Government's *Boosting Innovation in Science, Technology and Mathematics Teaching (BISTMT) Program,* has been established to encourage the development of clusters of stakeholders and schools to improve the coordination of science, technology and mathematics between primary and secondary schools. The project aims to help connect learning across disciplines, and promote innovative approaches and cultures in schools.

The *Science Practicals Inventory* (SPI) is an instrument based on the theory, procedures and strategies of learning environments research. It is a product of this study. The SPI is now available to science educators and applications in the areas of science program evaluation, science teacher professional learning and science program renewal. The SPI is appropriate, with other devices, for assisting teachers to re-invigorate science learning programs. The development and validation of the SPI were described in Chapter 5. This chapter will consider some possible applications and discuss the use of the SPI to further these purposes.

6.2 USING THE SPI FOR SCIENCE PRACTICAL PROGRAM EVALUATION

International research efforts into the conceptualisation and assessment of, and inquiry into, perceptions of psychosocial aspects of the classroom environment have established the classroom environment as a fruitful and important field of study (Fraser, 1994, 1998; Fraser & Tobin, 1991; Fraser & Walberg, 1991). Classroom environment research has extended to science laboratory classroom environments (McRobbie & Fraser, 1993). This study reports the development of the *Theoretical Model of Science Practicals.* The SPI is based on that model. The SPI is available as an instrument for action research by science education researchers or by individual teachers seeking information about their own class for the purpose of improving the focus of science practical work.

When the SPI was administered to junior secondary students in Tasmania and Western Australia (Grades 8-10), information was collected about student perceptions of the use of practicals in their science learning. The final version of the SPI, consisting of 50 items organised in eight scales, was shown to be a valid and reliable instrument for investigating student perceptions of the use of science practicals in Australia and can be used with individual or class data. The SPI can be used with groups containing large numbers of students, class groups or subclass groups. As science programs at the junior high school level are usually delivered to class groups of students by individual teachers, the use of the SPI for the evaluation of science programs at the class level would be most useful. The SPI has been used to collect data about students' perceptions of the 'actual' and their 'preferred use of different types of practicals in science programs. The comparison of 'actual' and 'preferred' class means were used to construct graphical profiles similar to those used earlier in this study, for example, Figure 5.1.

The SPI response data from three junior secondary science classes from different schools in Australia are presented in Table 6.1. The individual student's scale means of individual students were calculated from the sum of the responses to each scale item on individual questionnaires. Aggregating the individual scale means and dividing by the number of students in the class obtained class scale means for each scale. The ‘actual’ (A) and ‘preferred’ (P) class scale means are shown in Table 6.1. The separate class scale means were plotted on a chart. Graphical representation of students’ perceptions of the ‘actual’ and ‘preferred’ use of science practicals was produced by joining the plots to form ‘actual’ and ‘preferred’ profiles that were unique to each class of students. Examination of each profile enabled inferences to be made about the students’ perceptions of the ‘actual’ and ‘preferred’ science programs. The differences between the profiles allowed recommendations to be made for improving the science practical program of each class. While recognizing there needs to be an appropriate balance between the teacher’s instructional goals and the selection of practical types, particularly with respect to safety, coincident ‘actual’ and ‘preferred’ class profiles are aimed for, as this correlates with optimum learning outcomes (Fraser, 1998).

Table 6.1
‘Actual’ and ‘Preferred’ SPI Means for Three Science Classes

	Actual (A) Preferred (P)	Class H91A Scale Mean	Class C103 Scale Mean	Class T101 Scale Mean
Undirected Activity DM UDACT	A P	2.77 3.38	2.27 3.74	2.81 3.63
Open Inquiry/ Problem Solving MD OIPS	A P	2.57 3.07	1.96 2.37	2.47 3.30
Creative Feedback MR CRFB	A P	2.34 2.63	1.60 2.73	2.13 3.13
Directed Activity RM DACT	A P	3.57 3.30	3.87 3.85	3.50 4.04
Demonstration RR’ DEM	A P	2.85 2.91	2.91 3.60	3.69 4.02
Skill Development R’R SKLD	A P	3.15 3.17	3.66 4.09	4.23 4.47
Laboratory Experiment R’D LABX	A P	3.16 3.07	4.00 4.16	4.11 4.46
Directed Inquiry/ Problem Solving DR’ DIPS	A P	2.94 2.61	3.30 3.10	3.78 3.48
		N=16	N=15	N=16

Three class profiles are presented as examples of the use of the SPI to evaluate three class science practical programs. Each of the class profiles of students' perceptions of the use of science practicals in their science learning is discussed.

6.2.1 Discussion of the SPI responses from Class H91A

Class H91A was a Grade 9 science class from a high school in Perth, Western Australia, where science was a compulsory course for all students. The Grade 9 science classes at the school were not grouped according to ability or interest in science. The class consisted of 16 students (10 males and 6 females). The science teacher was very experienced and was also the science program coordinator for the school. The teacher administered the SPI without any problems. The questionnaires were collected and mailed to me, as researcher, for analysis. The students' responses were entered directly onto a spreadsheet. The class scale means were calculated and plotted on a chart to obtain the 'actual' and 'preferred' class profiles, as shown in Figure 6.1.

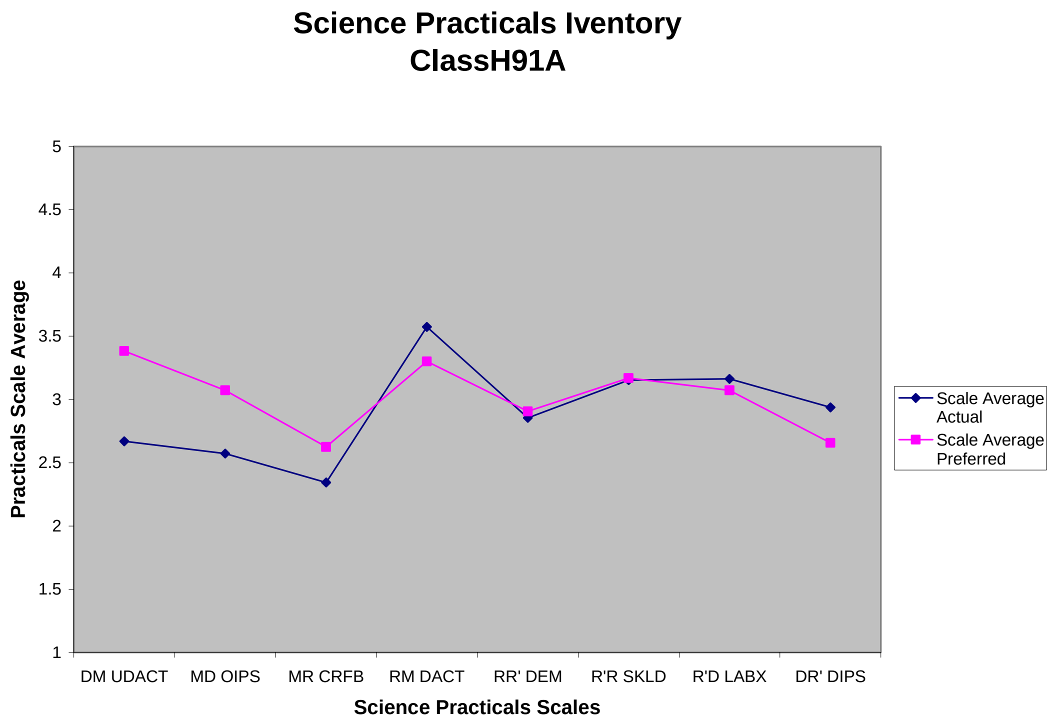

Figure 6.1. Science Practicals Inventory response profiles for Class H91A.

The particular form of chart selected to graphically present the class results of the SPI is the *composite line graph*, showing the students' 'actual' and 'preferred' responses with two separate line graph profiles. This form of graph is traditionally used in learning environment research with this type of survey. The charts show the overall picture of the students' perceptions, particularly the difference between the 'actual' and 'preferred' profiles, better than other types of charts, such as, the column or bar chart. As the SPI was developed from the *Theoretical Model for Science Practicals*, which included dimensions based on continua, the line graph profiles were selected as the best way to present the results of this study.

There was close proximity between the 'actual' and 'preferred' SPI response profiles for Class H91A, indicating a reasonable alignment of the students' perceptions of the actual use of practicals in their science learning and the way they would like practicals to be used. This is particularly evident in the *Demonstration* and *Skill Development* scales, indicating that the students value the role of the teacher in teaching them new aspects of science and how to do science. They would prefer less teacher direction of practical work, specifically, less *Laboratory Experiment* (scale mean difference = -0.09), *Directed Activity* (scale mean difference = 0.27) and *Directed Inquiry/Problem Solving* (scale mean difference = 0.33), in order of increasing scale mean difference. The greatest difference between the students' perceptions of the 'actual' and their 'preferred' is for *Undirected Activity*. The students would prefer more *Undirected Activity* (scale mean difference = 0.61), *Open Inquiry/Problem Solving* (scale mean difference = 0.50) and *Creative Feedback* (scale mean difference = 0.29), in order of decreasing preference. They would like much more opportunity to use their initiative and take responsibility for their science learning. *Creative Feedback* is perceived to occur less than any other type of practicals. There is a need for more *Creative Feedback* to promote meaningful learning and understanding. The generally horizontal orientation of the profiles indicates a balanced science practical program, which the students enjoy.

6.2.2 Discussion of the SPI responses from Class C103

Class C103 was a Grade 10 science class from a high school in southern Tasmania, where science was not a compulsory course of study for students after Grade 8. Nearly all students chose to study science in Grades 9 and 10. The Grade 10 science classes at the school were grouped according to ability in science. The class consisted of 15 students (5 males and 10 females) who were not aiming to follow the pre-tertiary science pathway in Grades 11 and 12. The science teacher was very experienced. I administered the SPI without any problems and collected the questionnaires for analysis. The students' responses were entered directly onto a spreadsheet. The class scale means were calculated and plotted on a chart to obtain the 'actual' and 'preferred' class profiles, as shown in Figure 6.2.

The students' perceptions of the use of practicals in the Class C103 science program indicate that the program is dominated by teacher direction. This is mainly through *Laboratory Experiment* (with an 'actual' class scale mean = 4.00) and *Directed Activity* (with an 'actual' class scale mean = 3.87).

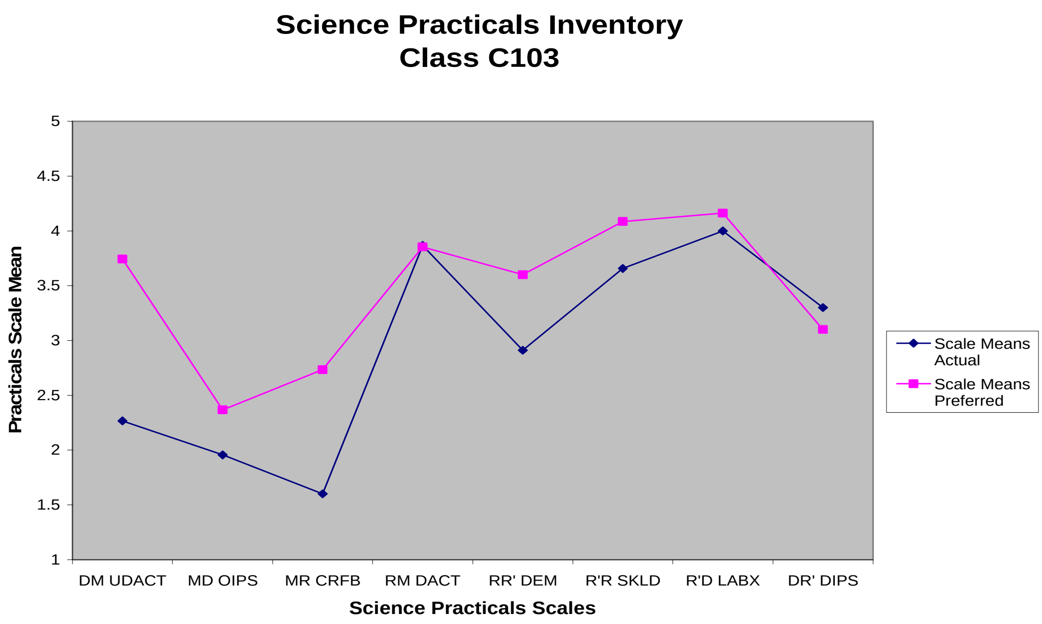

Figure 6.2. Science Practicals Inventory response profiles for Class C103.

There is alignment of the ‘actual’ and ‘preferred’ profiles for these practicals indicating that the students value the learning experiences provided by these practicals. The students would prefer the teacher to participate more in their practical science learning, as indicated by scale mean differences for *Demonstration* (0.69), and *Skill Development* (0.43). They would also prefer much more *Undirected Activity,* which seldom occurs (scale mean = 2.27). Similarly, they would prefer more *Open Inquiry/Problem Solving,* but not as frequently as *Directed Inquiry/Problem Solving,* which they would prefer slightly less frequently (scale mean difference = -0.20). *Creative Feedback* is perceived to be the least frequently used science practical (scale mean = 1.60). The students would prefer much more *Creative Feedback* as part of their science learning (scale mean difference = 1.13). Apart from more opportunity for *Undirected Activity,* students in Class C103 would prefer a science practical program that is largely directed by the teacher.

6.2.3 Discussion of the SPI responses from Class T101

Class T101 was a Grade 10 science class from a high school in southern Tasmania, where science was a compulsory course for all students. The Grade 10 science classes at the school were grouped according to ability in science. The science teacher was very experienced. The class consisted of 16 students (9 males and 7 females) who were not aiming to follow the pre-tertiary science pathway in Grades 11 and 12. I administered the SPI without any problems and collected the questionnaires for analysis. The students’ responses were entered directly onto a spreadsheet. The class scale means were calculated and plotted on a chart to obtain the ‘actual’ and ‘preferred’ class profiles, as shown in Figure 6.3.

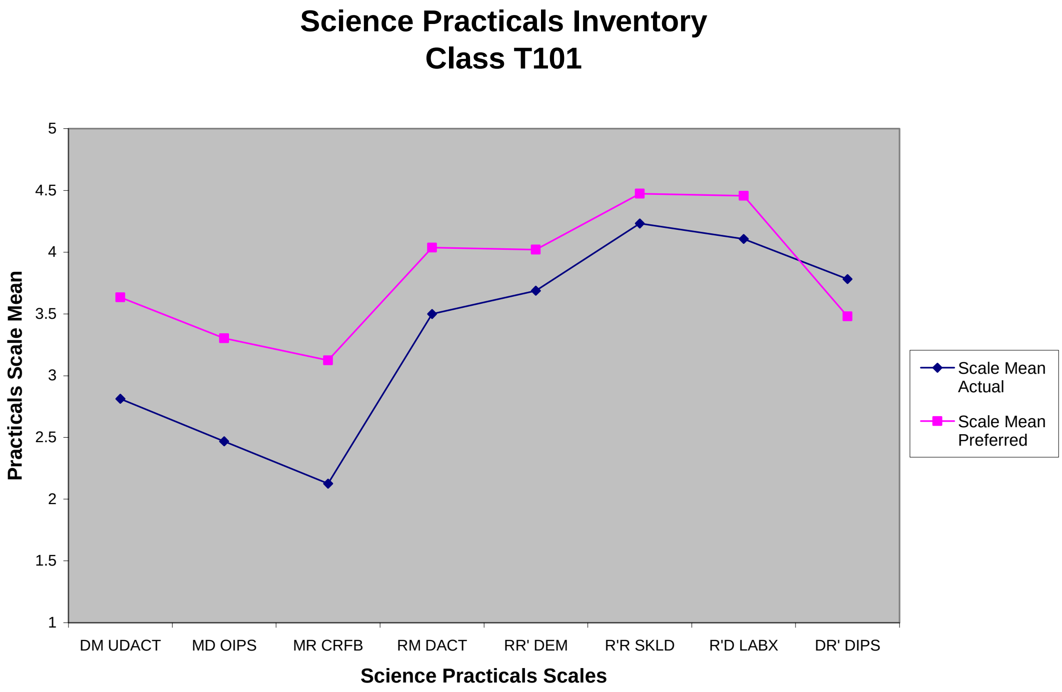

Figure 6.3. Science Practicals Inventory response profiles for Class T101.

The SPI response profiles of Class T101 are generally not in close proximity. The 'actual' profile indicates an unbalanced science practical program that emphasises teacher direction. The highest scale means were obtained for *Skill Development* (4.23), *Laboratory Experiment* (4.11) and *Directed Inquiry/Problem Solving* (2.94), in order of decreasing perceived occurrence. The lowest scale means were obtained for *Creative Feedback* (2.13), *Open Inquiry/Problem Solving* (2.47) and *Undirected Activity* (2.81), in order of increasing perceived occurrence. Comparison of both the 'actual' and the 'preferred' response profiles indicates that the students would prefer more practical work as part of their science learning. With the exception of *Directed Inquiry* (scale mean difference = -0.3), the students would like all types of science practicals to occur more often than they perceive them to occur in their current science program. The largest scale mean differences were obtained by *Created Feedback* (1.00), *Open Inquiry/Problem-Solving* (0.83) and *Undirected Activity* (O.82), in order of reducing scale mean difference. This indicates that students would prefer a science practical program with more opportunity for student initiative. The 'preferred' scale mean profile suggests that a more balanced science practical program would be preferred by the students, a program in which the role of the teacher is important. Teacher direction would continue to be highly valued by the students. However, when it comes to investigation and problem-solving, students would prefer to answer their own questions and solve their own problems, rather than those of the teacher. I have used the SPI successfully to research students' perceptions of the use of practicals in science programs. The use of the SPI by science teachers, to evaluate their own science programs, provides them with an opportunity for professional development.

6.3 USING THE SPI FOR SCIENCE TEACHER PROFESSIONAL LEARNING

As previously discussed, the SPI is based on the *Theoretical Model of Science Practicals*, with each of the eight scales corresponding to one octant of the model. The SPI can be used to raise science teachers' awareness of the different types of practicals and their purposes in science learning as indicated by the model. Teachers could design ideal science practical programs with particular program emphases. Using the SPI with their students, science teachers could increase their awareness of their students' perceptions of the science practical program. Science teachers will be able to make judgements about their science practical program, and make possible alterations to the program to improve student attitudes and science learning. Increased awareness of the theoretical background of science practicals and the students' perceptions of the science practical program, provide a basis for reflection and improved professional performance by science teachers. The SPI has the potential to be particularly useful in the pre-service development of prospective science teachers as they prepare for the provision of varied, student centred practical learning strategies. The increasing professionalism of science teachers, combined with valid instruments such as the SPI, could enable science teachers to engage in effective science program renewal.

6.4 SCIENCE PROGRAM RENEWAL AND THE SPI

The SPI is not directly useful in science program renewal. But the increasing awareness of the theoretical basis of the SPI and the different types of practicals promote systematic renewal of science practical programs. Awareness of the purpose of each type of practicals within each octant of the *Theoretical Model of Science*

Practicals provides a rational, rather than *ad hoc,* basis for constructing a science practical program. There is an abundance of available science teaching resources containing descriptions of practical activities. These activities can be classified according to the type of practicals and possibly selected for inclusion in the science practical program, depending on the particular emphasis of the program. Students' perceptions of the practical program may be investigated using the SPI during the program trial or implementation phase. In this way the SPI is a useful instrument to provide evidence on whether or not the students' perceptions of the program match those of the teacher.

6.5 SUMMARY AND CONCLUSION

For more than a decade the Australian Government has called for reports that have focused on the quality of science teachers, and the state of science teaching and learning in Australia. It has recently established projects to bring about the re-invigoration of science teaching in Australia. This study has developed the SPI as a valid, reliable and efficient instrument: to assist science teachers carry out action research, in the collection of information about their students' perceptions of their science practical programs; and to assist, with other devices, the evaluation of science programs. Science teachers can raise their awareness of the theoretical basis of science practicals through action research, by using the SPI with their own students, allowing them to make professional judgements about the renewal of their science programs. The SPI is a valid, reliable and efficient instrument, which can contribute to science program evaluation, science teacher professional learning and science program renewal. By successful use in these ways the SPI can contribute to improved students' attitudes to science and improved science learning outcomes.

CHAPTER 7

Summary and Conclusions

7.1 INTRODUCTION

The purpose of this final chapter is to summarise the intentions and findings of this research study and to clarify and understand the issues involved in the theoretical bases, rationale and implementation of practical work in junior secondary science programs. It also examines the development, validation, and application of the instrument, the *Science Practicals Inventory* (SPI). The study is reviewed in the next section, followed by the presentation of the major findings of the study. Limitations of the study are described and the significance of the study is discussed, followed by suggestions for further research and the conclusion to the study.

7.2 REVIEW OF THE STUDY

The stimulus for the study was a concern that secondary students do not seem to develop the same level of interest, or sense of wonder, excitement, and fun from their science learning as I and other students did, more than 40 years ago. Declining numbers of students choosing to study science at the tertiary level, newspaper reports and an examination of the science education literature indicated that there were problems with issues involving practical work in junior secondary science programs.

One would expect the use of practicals to vary with change of emphasis and purpose of particular science programs and the differing rationales for practicals in those programs. There have been changes to the goals and aims of science curricula with time. There have been developments in the philosophical view of the nature of science. There have also been changes in the design of science curricula that emphasise a constructivist view of the way children make meaning of their world, rather than the didactics of science. Although there is general agreement among scientists and science educators that practicals are an essential part of science education, there is no consensus about the pedagogical basis for the inclusion of practicals in science programs. The primary purpose of this study is to focus on the rationale and issues involved in the implementation of practicals in junior secondary science programs.

This study has developed and used a valid, reliable and efficient instrument to investigate students' perceptions of the use of practicals in their science learning. The development and validation of the SPI is a major part of the study that enabled the primary purpose to be achieved. It has also produced an instrument that is now available for use in science program evaluation, science teacher professional learning and science program renewal.

The *Science Practicals Inventory* (SPI) was developed from the *Theoretical Model of Science Practicals,* presented as part of this study. It was modelled on two questionnaires from the learning environment research field, the *Science Laboratory Environment Inventory* (SLEI) and the *Questionnaire on Teacher Interaction* (QTI). Development of the SPI involved a series of pilot studies and group interviews of science teachers and junior high school students. The development and administration of the questionnaires followed the processes and strategies of learning environments research. The instrument was used with science students in Tasmania and Western Australia. Statistical analysis provided evidence for the validation of the SPI as a reliable, valid and efficient instrument to investigate students' perceptions of the use of practicals in their science learning. The analysis suggests that the SPI can be used to collect individual responses from large groups of students; separate classes; and subclass groups, consisting of relatively small numbers of students.

Qualitative data were obtained from open-ended questions answered by students and group interviews of science teachers and students. The next section outlines the major findings of this study.

7.3 MAJOR FINDINGS OF THE STUDY

In this section the major findings of the study are addressed within the original intention of the study. The main aim of the study is to understand the issues involved in the theoretical bases, rationale and implementation of practicals in junior secondary science programs. The major findings are reported with reference to the research questions central to this study.

1. What are the theoretical bases and rationales for the implementation of practicals in science programs?

The study commenced with a comprehensive literature search, leading to an international, historical review of the changing role of practical work in science education. Practical work has been an important part of science education for more than 200 years. The value of practical work has been questioned at various times, as the stated purposes and emphases of science education changed. Issues that impinged on the rationale for the use of practical work in current science education programs were discussed including; the changing philosophy of science, changing views of the way children learn about the world they live in, and changing science curriculum development models and projects. The need to distinguish between practical work for scientific research, as practised by scientists, and practicals for science learning, as practised by science students, was important. The rationale for science education for all students was reviewed and the need for a new definition of practical work in science education was established. It was important for this study to revisit discussions of the purpose of science education for all as part of the search for a new definition of practical work. Scientific literacy was considered an appropriate overarching goal for science education for all, which is consistent with the acceptance of a broad definition of practicals for science learning.

Practical work for science learning needs to be more than laboratory work. For the purposes of this study, the view of *practicals* held by Hodson (1988) was appropriate. A *practical* was defined as a didactic method for learning and practising all the skills and processes involved in the development of scientific literacy. Science practicals provide students with a wide range of interpretive experiences that prompt revision of prior knowledge, promoting student understanding of their world and constructing meaning for their lives. Science practical work has an important role in teaching for understanding and the development of scientific literacy. Although there have been changes over time in the philosophy of science and improvements in knowledge of the way children learn and interpret the world, recent studies have reported concerns similar to those of researchers and science educators from 200 years ago. Generally, traditional rationales for practicals are theoretically flawed and have not responded to the view of science as a sociological, creative and institutionalised activity. A theoretical framework, which draws on hermeneutic traditions, provides a basis for reviewing new rationales for science practicals. Practical work and knowledge content of the learning program are interdependent.

This study, building on Ausubel's theory of verbal learning (Ausubel, 1963), developed and presented the *Theoretical Model of Science Practicals*. The model identified eight types of science practicals, arising from different purposes of practical work in science learning, for the promotion of understanding. The different types of science practicals identified in the model are listed below with summaries of their purposes.

Undirected Activity: for experiences and posing questions.
Open Inquiry/Problem Solving: to answer students' questions/solve students' problems.
Creative Feedback: to recall/perform understandings.
Directed Activity: to experience science concepts and natural phenomena.
Demonstration: to show science concepts, skills and natural phenomena.
Skill Development: for doing science.
Laboratory Experiment: to confirm science concepts and theories.
Directed Inquiry/Problem Solving: to answer teachers' questions/solve teachers' problems.

More detailed descriptions of the eight types of practicals have been provided in Chapter 3, pages 73-88. The eight different types of science practicals provide students with a variety of interpretive experiences, promoting student understandings of their world and the construction of meaning for their lives, which are consistent with modern views of the nature of science and our knowledge of the way children interpret their natural world. The types of practicals that are used in science learning depend on the purpose and emphasis of the science program.

Exploration of the inter-scale correlations in the SPI data in this study did not support the hypothesis that the *Theoretical Model of Science Practicals* was a circumplex model.

2. What are the requirements for practicals as specified in published curriculum documents developed from *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b)?

Disappointment with science curriculum projects of the 1960s and 1970s, which emphasised the discovery approach to science learning, with its reliance on inquiry and the now obsolete positivist scientific method, led to the development of national curriculum movements in America, Great Britain and Australia. Curriculum documents, such as *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b), were influenced by changes in the philosophy of science that emphasised science as a human social construct. The document recognised the influence of the dominant paradigm, or existing conceptual framework, of scientific researchers; and the importance of prior knowledge and existing beliefs in the learner's conceptual development and achievement of understanding. *Strand 1 - Working Scientifically* (Curriculum Corporation, 1994b) was described as a challenging interaction between existing beliefs; the goal of better understanding; and the processes and methods of exploring generating, testing and relating ideas. Working scientifically was linked to, and dependent upon, a number of attitudes: valuing ideas and seeking explanations; respecting evidence and logical reasoning; open-mindedness, critical-mindedness; scepticism about evidence and arguments; honesty and openness to new ideas; creativity and lateral thinking; and, accepting the provisional nature of knowledge. Working scientifically was presented as something students do in their normal everyday lives as a way of extending their understandings, making decisions and achieving practical outcomes. In general, the current science syllabuses and curriculum framework documents developed by the individual Australian States from *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b) provide appropriate, up to date, progressive, intended science curricula that are consistent with the nationally preferred curriculum, and the goal for science education of scientific literacy for all. However, this study has revealed a gap between the intended or 'preferred' curriculum and the 'actual' or implemented curriculum. This finding agrees with the findings of Hackling, Goodrum, and Rennie (2001), who found, in a major study of science teaching and learning in Australia, that although the science curriculum documents were consistent with the goal of scientific literacy for all, actual science programs had not moved to reflect the themes of the ideal science program that they developed (Hackling, Goodrum & Rennie, 2001, p. 7).

3. What are the teacher perceptions of practicals and their educational value in their science programs?

The science teacher focus group considered practical work very important in science learning. The teachers perceived the main rationale for practical work in science learning as to reinforce students' understanding of science theory, as well as giving students 'hands-on' experience of working scientifically; sometimes giving them the opportunity to solve real problems or answer real questions. (This thesis, pp.102-104)

The teachers perceived that practical work in science learning helped reinforce the learning of science theory without being subservient to it. They considered that theory and practical work are mutually supportive in science learning. (This thesis, pp. 105-106)

They recognised different types of practical work, and their discussions supported the *Theoretical Model for Science Practicals* proposed in Chapter 3, as all eight types of practicals were identified in their discussions. The relative importance of science theory and practical work varies with different aims and emphases of different science programs.

The science teachers in the focus group were at different stages of professional development with respect to Moscovici's *Four Stage Model* of shift towards inquiry (1998). The aims and content of individual class programs, and the extent to which the programs were consistent with the preferred programs as indicated in the curriculum documents, depended on the professional development of the individual science teacher.

There is reluctance by some science teachers to make inquiry central to learning in science as required by science literacy for all (Hackling, Goodrum & Rennie, 2001). There is a need for teachers to teach about the nature of science (Lederman, 1998) and concepts of the processes of science (Gott and Duggan, 1995).

4. What are the student perceptions of practicals and their educational value in their science programs?

Students' perceptions of the use of science practicals were collected as qualitative and quantitative data. The results of the analysis of the qualitative data collected as students' responses to open-ended items before completion of the questionnaire are summarised below.

Students in general perceive that science practicals are essential to science learning. Indeed, there was a strong request for more practical work to improve the motivation of students and promote the development of meaning and understanding of the world they live in.

Students recognise that teachers have an important role in directing their study programs but would like to have more opportunities for independent investigations. Students are looking for less teacher direction and more independence in science practicals.

Discussion of scientific ideas is important to improve understanding (Ausubel, 1963, 1968; Bently and Watts, 1989; Kirschner, 1991 and Tamir, 1977), as are investigation reports and problem solution reports (Keys, Hand, Prain, & Collins, 1999); construction of charts and models (Gilbert, 1993); simulations, simulation games and multimedia presentations, and concept mapping (Mason, 1992; Novak, 1990, 1992, 1998; Novak, Gowin, & Johansen, 1983); and dramatic representation and role-play (Chester & Fox, 1966). More opportunities for creative feedback activities should be provided throughout the science practical program.

While recognising that safety is important, they would like to see more fun and excitement in science. Students would welcome opportunities for safe play with equipment and chemicals. (This thesis, p. 136)

The students' perceptions indicated by the qualitative data were confirmed by the statistical analysis of the data collected using the SPI. These findings are summarised below.

The SPI was validated by statistical methods involving factor analysis, tests for reliability, internal consistency and discriminant validity, and the ability of the questionnaire to differentiate between classes. The factor analyses supported the *a priori* organisation of 50 of the 54 items of the questionnaire into eight scales. The *Theoretical Model of Science Practicals*, on which the questionnaire scales were based, was also supported by the factor analyses. The Cronbach alpha reliability coefficient values and the mean correlations indicated that each of the scales of the SPI measured different science practicals. The ANOVA results supported the conclusion that the SPI can differentiate significantly between student's perceptions of the use of science practicals from different classes. The validity of the SPI was generally supported by the statistical analysis. (This thesis, Tables 5.4 and 5.5)

The final version of the SPI used in this study is a valid instrument suitable for general use in the evaluation of Australian science practical programs. It has a place in the collection of quantitative data and is suitable for use with other quantitative and qualitative methods to research junior secondary science education in Australia.

Exploration of responses, from the whole sample, of individual student perceptions of the use of practicals, indicated that practicals involving teacher direction occur more often than practicals involving student initiative. Students would like more responsibility for their science practical activities and less teacher direction. This finding is consistent with findings of the analysis of the qualitative data. Females perceive that they have more teacher direction than males do and preferred more teacher direction than the males in this study (This thesis, p. 155-157, Figs. 5.3 and 5.4). This finding is different from the views based on anecdotal evidence in Gott and Duggan (1995, p. 143)

The notable feature of the comparison of the ‘actual’ and ‘preferred’ perceptions of males and females was the similarity of male and female perceptions of the use of the different types of practicals in their science learning. Exploration of gender differences of perceptions found that male students perceived they had more opportunity for choice and initiative in practicals than female students did. Females preferred *Directed Activity* while males preferred *Open Inquiry/Problem Solving*. Both males and females perceived *Creative Feedback* as the least used and also as the least preferred type of science practical. This should be of great concern to science educators as creative feedback is important in the achievement of meaningful learning and the development of understanding.

Students have generally negative attitudes towards their science learning experiences. This is consistent with the findings of Goodrum, Hackling and Rennie (2001), (This thesis, p. 151).

Investigation of possible relationships between the scales of the SPI and students’ attitudes to science learning suggested that students’ considered practical work, involving laboratory experiments and skill development, important to their science learning. It was found that the scales: *Undirected Activity*, *Laboratory Experiment* and *Skill Development* were positively related to students’ attitudes to science learning. (This thesis, p. 152)

The SPI is a valid, reliable and efficient instrument, which can contribute to science program evaluation, science teacher professional learning and science program renewal. It is available for individual science teachers to carry out action research about their own classes. The SPI, if used in these ways, can contribute to improved students' attitudes to science and improved science learning outcomes.

Analysis of the qualitative data suggested that there could be a third continuum to improve the description of science learning, the exciting learning—not interesting learning dimension. This continuum could provide a third dimension to the Theoretical Model of Science Practicals as shown in Figure 7.1. This dimension provides a possible direction of future development of the SPI.

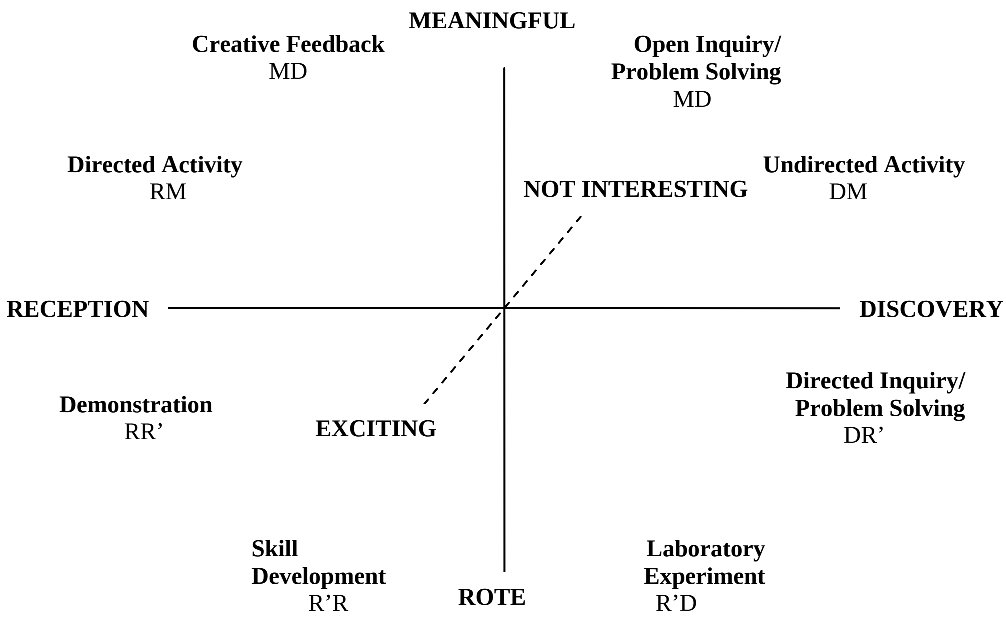

Figure 7.1. Theoretical Model of Science Practicals including the **EXCITING--NOT INTERESTING** dimension.

The findings of this study have implications for science curricula.

5. What are the implications of this study for science curricula?

There is general agreement between professional scientists, science educators and students that practical work is essential for meaningful science learning and the development of understanding of the world we live in (Trumper 2003, p. 645).

Practical work, following the research traditions of science, presents students with opportunities for interpretive experiences to help them understand their world.

It is necessary to distinguish practical work in science education from practical work in scientific research. This study clarifies what is meant by practical work in science education. Development of the *Theoretical Model of Science Practicals* has enabled the description of eight different types of practicals, and their purposes, in the promotion of meaningful science learning. Practicals and the knowledge content of science learning programs are interdependent in the promotion of meaningful learning and understanding of the natural and constructed world. Science practicals are important in the achievement of scientific literacy for all, which is an appropriate, and ambitious, overarching goal for science education. Science educators have a responsibility to teach students the substantive structure of science as well as the syntactical structure of science, consisting of knowledge, skills, and contexts, each having a relationship with understanding. Varying purposes for science learning programs should result in the selection of different combinations of science practicals to reflect the different emphases of learning programs and different interactions of the three dimensions that contribute to the description of science learning: received learning--discovered learning, rote learning--meaningful learning, and exciting learning--not interesting learning.

As the results from the SPI reported in Chapters 5 and 6 have shown, if students' attitudes to science learning are to be improved, teachers must continue to take directing and supportive roles in their science learning. But they should also provide more opportunities for students to take initiative, to develop and investigate their own questions, and to identify and solve their own problems. These opportunities will enable students to follow their interests in science and possibly gain excitement from their experiences.

The experiences students receive from practicals during their science learning should challenge their prior knowledge, or existing conceptual frameworks. (This thesis, p. 58 and p. 85) The science practical program should include *Creative Feedback* practicals, to further the restructuring of new conceptual frameworks, and to provide opportunities for discussions and demonstration of understandings, for example, the construction of charts, models, concept maps, role-play, and drama presentations. Microsoft PowerPoint provides a way of using information technology to support the use of practicals in science learning. Results from the SPI indicated that *Creative Feedback* was the least used type of practicals in all classes surveyed. As previously discussed in Chapters 3 and 5, creative feedback is important in meaningful learning and the development of understanding. There is a need for increased use of *Creative Feedback* practicals in science learning programs to maximise students' understandings, promote student creativity and allow the acquisition of meaning. This would be in line with students' preferences and would tend to increase students' understandings of their science learning. (This thesis, p. 138 and p. 149) More creative feedback practicals in science programs would be expected to result in greater understanding of science learning and lead to the achievement of more science outcomes and improved students' attitudes to science.

The development of the SPI has provided science educators with a valid, reliable and efficient instrument to investigate students' perceptions of the use of practicals in their science learning. The SPI can be used as part of the evaluation of science practical programs. It can contribute to the professional development of science teachers and provide a theoretical basis for science program renewal. The instrument can help science teachers to provide relevant, modern, and interesting science programs, which are consistent with the preferences of their students.

The next section describes the limitations of the study.

7.4 LIMITATIONS OF THE STUDY

This thesis reports an initial, comprehensive study of the use of science practicals in Australia. It was, therefore, inappropriate to develop pre-determined hypotheses (Cohen & Harrison, 1982; Curriculum Corporation, 1994b; Warwick & Lininger, 1975). The study is limited to clarification of and improvement in understanding the issues involved in the theoretical bases, rationale and implementation of practicals in junior secondary science programs. Information sought was limited to perceptions of the use of practicals in science programs. The study does not go beyond an initial exploration of what is meant by scientific literacy and its suitability as a modern overarching goal, or purpose, of science education for all. Science literacy is not the subject of this study beyond its relation to the rationale for practical work for science learning. The study did not collect information about other content of science programs at the class level, nor did it examine the science curriculum as specified in published curriculum documents beyond the requirements for practicals stated in documents developed from *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b). This study does not include investigation of the factors that influence teachers' choice of science practicals for their science programs.

The study sample was limited to junior secondary students in Tasmania and Western Australia but as researcher, I considered it to be a sufficiently large and diverse for the validation of the SPI. Further research is needed with students from each state for the sample to be representative for research findings to be extended to Australian students' perceptions of practical programs in Australia.

7.5 SIGNIFICANCE OF THE STUDY

The study is of significance to science educators, as there are many references in the literature to the need for clarification of the issues involving practicals in science learning, such as, Hodson (1991, 1996); Layton (1991); and Watts & Gilbert (1989). Promoters of science education for all, with the development of scientific literacy as its primary goal, stress the importance of practical work in science learning. Practical work requires a large allocation of resources, for example, time, equipment, laboratories, and specialised science educators. At a time of great pressure on resources of all kinds it is important that there is clarity and consensus about the use of practicals in junior secondary science. This study has clarified issues that impinge on the use of practical work in science learning.

With increasing importance of information technology in schools, it is important that issues involving the use of practicals in junior secondary science programs are clarified before resource pressures reduce the amount of practical work in science programs. The use of computers and online learning are examples of the pressures on practical work in science learning. There is a place for the use of information technology in science education but it should be in support of different types of science practicals, directed towards meaningful learning, rather than as an alternative to them. This is an area for further research.

The study involved the development and validation of an instrument to determine the student and teacher perceptions of their science programs. This instrument is useful to science educators who wish to evaluate their science programs.

The study provides information about student and teacher perceptions of their science programs and how they are achieving the goals of the curriculum documents: *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994b) and the *Profiles of the Common and Agreed National Goals For Schooling in Australia* (Curriculum Corporation, 1994a).

The study indicates ways in which science programs can be changed to improve science learning outcomes and students' attitudes to science and thus, further the educational pathways to science-based careers.

This study identifies areas of further research, which are reported in the next section.

7.6 RECOMMENDATIONS FOR FURTHER RESEARCH

This study is an initial investigation to research the issues involved in the theoretical bases, rationale and implementation of practicals in junior secondary science programs. It identifies areas of possible further research, outlined below.
The analysis of the data collected in this study does not support the hypothesis that the *Theoretical Model of Science Practicals* is a circumplex model. This was surprising, as the model was developed from continua using a process that has previously developed circumplex models, for example, the QTI. The collection of further data using the SPI will enable the circumplex model question to be tested again.

This study has proposed a third dimension to improve the description of science learning, the exciting learning--not interesting learning dimension. This dimension offers a new line of research that investigates possible relationships between it and the other dimensions of the *Theoretical Model of Science Practicals*. Any relationships between the interest dimension and students' attitudes to science may be also worthy of investigation.

There is a need for research on the identification and use of *Creative Feedback* practicals, which promote student creativity, understanding and encourage the acquisition of meaning.

The SPI is a new instrument validated by using a sample of junior high school students from Tasmania and Western Australia. The use of the SPI in areas of different cultural background, including indigenous Australians, and in different international settings is another avenue for potential research.

Students' preferences for more use of science practicals, which provide more opportunities for student initiative, requires further research to identify appropriate activities for students. There is a need to investigate the new role for science teachers; with greater emphasis on supporting students in their learning, answering their questions and solving their problems.

The SPI has been used to investigate students' perceptions of the use of practicals in science learning in junior secondary classes. The potential for use of the SPI with students in other levels of education is an area of possible research. The preparation of a questionnaire suitable for use with primary students is another potential development of the SPI.

This study collected qualitative data from group interviews of science teachers about their perceptions of the use of science practicals. The group interviews were part of the development process of the SPI. The SPI has the potential for development as an instrument to collect qualitative data about science teachers' perceptions of the use of practicals in their science lessons.

The use of the SPI to compare the perceptions of students and their teachers about the use of science practicals has the potential for a very worthwhile research project.

This study has been about the use of practicals in science learning. Exploration of the factors that determine the selection of practicals for use in science programs is another possible research project to follow this study.

The recommendations for further research are neither complete nor exhaustive. The suggestions indicate possible directions for further research as a follow-up to this study. This brings me to the conclusion of my study.

7.7 CONCLUSION

This study was stimulated by personal feelings of dissatisfaction and an awareness of a large problem in science education of declining student interest in science and science-based careers, at a time when the community has a need for increasing individual scientific literacy, and for professional scientists to continue the operation and development of an increasingly scientific world.

In this study, it is my intention to understand the issues involved in the theoretical bases, rationale and implementation of practical work in junior secondary science programs. I have reviewed the part that practical work has played in science education, internationally and in Australia. I noted that the statements that were being made by modern day researchers into science teaching and learning were similar to those made by science educators more than 200 years ago. I have drawn together the research traditions of the philosophy of science, science curriculum development, learning environments, and educational psychology in a multi stage field study. I used qualitative and quantitative methods to achieve the objectives of this study. I introduced the *Theoretical Model of Science Practicals,* which enabled the description and statement of purpose of eight types of science practicals. The model provided a theoretical basis for the development of an instrument, the Science Practicals Inventory, to investigate students' perceptions of the use of practicals in science learning, using the eight types of practicals as the scales of the SPI. The SPI was validated using high school students from Tasmania and Western Australia. An analysis of the quantitative and qualitative data in this study has enabled issues involved in the theoretical bases, rationale and implementation of practical work in junior secondary science programs to be clarified and better understood. I believe that this study is significant for science curriculum developers and science educators. The results of this study include implications for science curricula and recommendations for further research. I believe my intentions at the start of this study have been achieved.

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APPENDICES

Appendix A: Permission to carry out the research

A-1 Application to carry out research

A-2 Permission to carry out the research study

A-3 Request to High School Principals to carryout research

A-4 Invitation to science teachers to be part of the research study

A-5 Examples of emails used to request survey completion

Appendix B: Coding of Student Responses to Open Items

Appendix C: Examples of Class Students' SPI Response Charts

Appendix D: Science Teachers' Group Interviews Field Text

Appendix E: Final version of SCIENCE PRACTICALS INVENTORY (SPI)

Tasmania

DEPARTMENT OF EDUCATION

APPLICATION FORM FOR PERMISSION TO CONDUCT RESEARCH IN TASMANIAN GOVERNMENT SCHOOLS

1. Name(s) of investigator(s). *(Please indicate preferred form of address.)*	Mr Duncan Bradley
2. Academic qualifications. *(Indicate conferring institutions and dates.)*	Cert Ed (London 1961) BSc (Tas 1973) M.Curr Studs (Hons) (UNE 1985)
3. Present appointment or activities	Assistant Principal Clarence High School PhD Student (SMEC Curtin University of Technology)
4. Organisation or institution through which the research is to be conducted. *(if any)*	Science and Mathematics Education Centre, Curtin University.
(a) Has approval of relevant Ethics Committee(s) of sponsoring &/or administering institution(s) been obtained?	Yes
5. Name(s) and address(es) of supervisor(s) *(if applicable).*	Bevis Yaxley, Letitia House Darrell Fisher, Curtin University

6. If this study is to contribute towards an academic qualification, indicate which qualification.	PhD
7. If a body is providing a financial grant for this study, indicate the body.	
8. Title of the project.	**Practicals in science education - A study of the theoretical bases, rationale, and implementation of practicals in junior secondary science education**
9. Expected commencement and completion dates.	2000-2004
10. Aims and educational significance and/or benefits to school-aged children of the study.	Please refer to the attached summary of the research proposal.

11. Outline of proposal research plan. **(a) Preliminary investigations or pilot studies if intended.** **(b) General outline of methods to be used for collecting information.** **(c) Schedule of activities, including time-line for completion of entire program.**	
12. Number and type of schools required. If specific schools are required, give the names of these schools and reason for selection.	Clarence High School – main subject of the study. Rose Bay High School, New Town High School, Ogilvie High School, Rosetta High School and Taroona High school to validate the research questionnaires.

13. Subjects/students required. (a) Indicate year levels (or ages) and the approximate number of students required per school at each year (or age) level. State any other necessary characteristics of students. (b) Indicate whether students will be required individually or in groups. If in groups, give size. (c) Give approximate dates and amount of time required. Adults required. Number	Questionnaires will be completed voluntarily by students in class groups. For validation of the instrument it is hoped that students in a minimum of two to a maximum of four classes per school will be able to complete the questionnaires. The students will be in their normal science classes in grades 9 or 10. Yes ❐ No ❐ ❐
14. When teachers are required to assist with the administration of instruments, describe what they will be asked to do and the amount of time required.	Instruments will be administered by the researcher as described in the summary of the research proposal. Each questionnaire takes about 15 minutes to complete.

15 Where consent is sought from students and/or parents how is it to be obtained? **Attach copies of materials used to inform parents and/or students and relevant consent forms.**	
16. Instruments and other forms of data collection. **Where these are well known and commonly used (eg. those listed in the ACER Catalogue) list the name(s) of the instruments. Otherwise enclose a copy of each instrument and its accompanying covering letter and instructions. For all instruments you intend using, clearly indicate the group to whom it is to be administered (eg. parents, teachers, students). Describe how each is to be administered and give an estimate of the time required.**	

17. If people other than the investigator(s) indicated above are to administer tests, or conduct interviews, please indicate their names and qualifications.	
18. **(a)** Outline your plans for disseminating the results of these investigations.	The results of the study will be distributed to each of the participating school. Papers will be published in science education journals. The instrument developed for this study will be available for the evaluation of science education programs, the professional learning of science teachers and the renewal of science programs.
(b) Expected date of dissemination.	2005

I agree to abide by the conditions set out in the Guidelines for Conducting Research in Tasmanian Government Schools.

Signature of Applicant: **Duncan Bradley** --

Signature of Supervisor(s): **Bevis Yaxley** --

Date: 29.5.01 --

Tasmania

DEPARTMENT *of* EDUCATION

18 June 2002

Mr Duncan Bradley
66A Forest Road
WEST HOBART TAS 7000

Dear Duncan

RE: PRACTICALS IN SCIENCE EDUCATION – A STUDY OF THE THEORETICAL BASES, RATIONALE, AND IMPLEMENTATION OF PRACTICALS IN JUNIOR SECONDARY SCIENCE EDUCATION

I have been advised by the Departmental Consultative Research Committee that the above research study adheres to the guidelines established and that there is no objection to the study proceeding.

Please note that you have been given permission to proceed at a general level, and not at individual school level. You must still seek approval from the principals of the selected schools before you can proceed in those schools.

A copy of your final report should be forwarded to the Director, Office for Educational Review, Department of Education, GPO Box 169, Hobart 7001 at your earliest convenience within six months of the completion of the research phase in Department of Education schools.

Yours sincerely

Alison Jacob
DEPUTY SECRETARY
(EDUCATION STRATEGIES)

116 Bathurst Street, Hobart GPO Box 169B, Hobart, 7001, Tasmania, Australia
Telephone: (03) 6233 8011 *Facsimile:* (03) 6231 1576

A-3 Request to High School Principals to carry out research

Dear Wendy,
I am seeking approval to approach Paul Steossiger to arrange for me to administer a questionnaire to two classes of senior OHS students sometime this week. No work would be required by the teachers. I would introduce and administer the questionnaires.This would be part of the validation process for the science program evaluation instrument referred to in the attachment to this email. The research is part of a PhD program at Curtin University, supervised by Bevis Yaxley. Approval has been applied for from the OER and I believe I have satisfied their requirements.
A reply by email would be most convenient for both of us.
Thank you in anticipation at this busy time.
Regards
Duncan

Everything OK for Mon. 8/12, 11.45 onwards. You can survey 2 classes. Regards Paul S.

-----Original Message-----
From: Duncan Bradley [mailto:bradleyd1@bigpond.com]
Sent: Friday, 21 November 2003 11:38 AM
To: paul.stoessiger@education.tas.gov.au
Subject: Stedent Questionnaire Responses

Dear Paul,
Thank you for agreeing to OHS students participating in the science practicals research project. The data collected on the two previous occasions has been analysed and the results have enabled us to develop the third and final version of the questionannaire. Currently I am about 100 student responses short for the validation of the SPI Version 3.
Would it be possible for me to administer the single questionnaire to individual students in two Grade 9 science classes.
I need 2 classes of students to complete individual questionnaires relating to science practicals and how often various activities occur in their science practical programs. Validation of the questionnaire is the aim of the research. There have been two pilot studies. This is the final version of the questionnaire. OHS students are part of a sample of about 1000 students from Tas and WA.
The students should be your more able science or maths classesin G9. However, if only mixed ability classes are available that is OK. I will come to school at the appropriate time on the time table to administer the questionnaires. There is no admin work for you to do. Each class will take about 20 minutes to complete the responses. It would be good to do it on one visit to OHS but if necessary I will come out more times. I am not available on Thursdays at any time, or Mondays after 11am.
Would you please let me know when it would be most convenient for you and your students for me to administer the questionnaires by return email.

Thank you for your assistance with this research project.

Yours sincerely,

Duncan Bradley

A-4 Invitation to science teachers to be part of the research study

66A Forest Road
West Hobart
Tasmania 7000

Email address bradleyd1@bigpond.com
Telephone (03) 62348243

21 October 2003

An Invitation to Participate in a Research Project to Improve Science Practical Programs

Science Teachers and Science Students in junior secondary high schools are invited to participate in a research project designed to improve science practical programs. You are asked to respond to a questionnaire which contains statements about practices which could take place in science practicals. Following procedures used in studies of school learning environments the questionnaire has actual and preferred (or ideal) forms. The responses will be used to validate the questionnaire for use as;

- an evaluation instrument for science programs,
- a resource to assist with the professional learning of science teachers and
- a basis for the renewal of science practical programs.

The study does not involve personal or sensitive issues. It is not considered necessary to obtain parental permission for students to participate in the study. The Tasmanian Education Department has given permission for the study to be conducted in schools.

Schools and individuals will not be identified in the study. Responses will be anonymous and confidential. Data collected will be quantitative in nature and will be stored on computer while analyses are completed. The data files will be kept for five years. Then they will be destroyed. Completed questionnaires will be destroyed at the end of the study.

Participation in this research project is not compulsory.
Thank you for agreeing to assist with this research project.

Yours sincerely,

DUNCAN BRADLEY

A-5 Example of mailed requests for survey completion

66A Forest Road
West Hobart
Tasmania 7000

Email address bradleyd1@bigpond.com
Telephone (03) 62348243

29 October 2002

Dear Science Teacher,

Thank you for agreeing to assist with this research. Please find enclosed the following;

- An invitation to participate in the research project,
- 50 copies of the SPSPI Actual and Preferred forms,
- A postage paid, addressed envelope for the return of the completed surveys.

I have included sufficient surveys for two of your best classes of grade 10 or/and grade 9 students. Please ask the students to complete the surveys carefully. We do value their responses. The purpose is to consult them in our efforts to improve science programs. We are interested in individual responses rather than group efforts. On the Actual Form students are asked to indicate how they think their experience actually is. On the Preferred Form students are to indicate how they would like it to be. They are asked to answer all questions. Although it is not essential for students to write their full names at the top of the sheet they are asked to give some of their name as we may want to follow up the responses with interviews. Students are asked to indicate their grade/class and their gender either directly or by their name.
Please thank the students again for their help with this research project.

Place the completed surveys in the return envelope and mail it to me as soon as possible.

Thank you again, for your assistance.

Yours sincerely,

Duncan Bradley

A-5 Example of mailed requests for survey completion

66A Forest Road
West Hobart
Tasmania 7000

Email address bradleyd1@bigpond.com
Telephone (03) 62348243

Alex Downes
Ulverstone High School
Leven Street
ULVERSTONE
Tasmania 7315

29 October 2002

Dear Alex,

Thank you for agreeing to assist with this research. Please find enclosed the following;

- An invitation to participate in the research project,
- 50 copies of the SPSPI Actual and Preferred forms,
- A chocolate frog for each student who completes two surveys,
- A postage paid addressed envelope for the return of the completed surveys.

I have included sufficient surveys for two of your best classes of grade 10 or/and grade 9 students. Please ask the students to complete the surveys carefully. We do value their responses. The purpose is to consult them in our efforts to improve science programs. We are interested in individual responses rather than group efforts. On the Actual Form students are asked to indicate how they think their experience actually is. On the Preferred Form students are to indicate how they would like it to be. They are asked to answer all questions. Although it is not essential for students to write their full names at the top of the sheet they are asked to give some of their name as we may want to follow up the responses with interviews. Students are asked to indicate their grade/class and their gender either directly or by their name.
Please thank the students again for their help with this research project.

Place the completed surveys in the return envelope and mail it to me as soon as possible.

Thank you again, Alex, for your assistance.

Yours sincerely,

Duncan Bradley

A-5 Example of mailed requests for survey completion

Dr David Henderson
Rossmoyne Senior High School

Keith Road
ROSSMOYNE
W.A. 6148

8 November 2002

Dear David,

Greetings from Hobart!
I am writing to request your assistance with my research project into the purpose and value of practicals in science programs. I appreciated the help you gave me with the collection of student survey data when I visited Curtin University in June last year. That data has been processed and analised. About thirty percent of the items were considered unsuitable for various reasons. I am sure you remember all of the arguments. I have prepared a second version of the survey with new questions to replace the unsuitable ones. I believe the survey is a much better instrument with less repetition and which addresses the scales more precisely. I am now engaged in the validation process of this second version of the SPSPI.

In anticipation I thank you for agreeing to assist with this research project. Please find enclosed the following;

- An invitation to participate in the research project,
- 50 copies of the SPSPI Actual and Preferred forms,
- A chocolate frog for each student who completes two surveys,
- A postage paid addressed envelope for the return of the completed surveys.

I have included sufficient surveys for two of your best classes of grade 10 or/and grade 9 students. Please ask the students to complete the surveys carefully. We do value their responses. The purpose is to consult them in our efforts to improve science programs. We are interested in individual responses rather than group efforts. On the Actual Form students are asked to indicate how they think their experience actually is. On the Preferred Form students are to indicate how they would like it to be. They are asked to answer all questions. Although it is not essential for students to write their full names at the top of the sheet they are asked to give some of their name as we may want to follow up the responses with interviews. Students are asked to indicate their grade/class and their gender either directly or by their name.
Please thank the students again for their help with this research project.
Place the completed surveys in the return envelope and mail it to me at your earliest convenience.
Thank you again, David, for your assistance.

Yours sincerely,
Duncan Bradley

Appendix B: Coding of Student Responses to Open Items

STUDENT PERCEPTIONS OF SCIENCE PRACTICALS INVENTORY (SPSPI) - QUALITATIVE DATA

Class	Student ID	Grade	Gender M=1 F=2	**BEST Actual**	**SPSPI Actual**	UDACT **DM**	OIPS **MD**	DIPS **DR'**	CRFB **MR**	DEM **RR'**	SKLD **R'R**	LABX **R'D**	DACT **RM**	NR
1	1	7	1	I don't understand										1
1	2	7	1	expt involving bunsen burner							1			
1	3	7	1	evaporating water with bunsen burner							1			
1	4	7	1	separating colours of texta ink using blotting paper and water							1			
1	5	7	1	bridge building to see how much weight a straw b				1						
1	6	7	2	I like experiments best								1		
1	7	7	1	anything with a bunsen burner							1			
1	8	7	1	purifying water							1			
1	9	7	2	nr										
1	10	7	2	evaporating seawater							1			
1	11	7	2	playing with the bunsen burner		1								
1	12	7	1	playing with bunsen burners		1								
1	13	7	1	nr										
1	14	7	1	bunsen burners							1			
1	15	7	2	I can't think of one I like										1
1	16	7	2	evaporation,matter,atoms,experiments							1	1		
1	17	7	1	nr										1
1	18	7	1	I don'tlike any science practicals										1
1	19	7	2	filtering							1			
1	20	7	1	I don't like science very much										1
1	21	7	1	using magnets to separate dusts			1				1			
1	22	7	2	all kinds of experiments								1		
2	1	9	1	using mta electronic boards with making decisions workbook									1	
2	2	9	2	making bridges out of squewersand testing their s				1						
2	3	9	2	nr										1
2	4	9	2	nr										1
2	5	9	2	active metals in water to make a bang and flames						1				
2	6	9	1	I have not enjoyed any other practicals than makii				1						
2	7	9	2	nr										1
2	8	9	2	nr										1
2	9	9	2	I don't have one										1
2	10	9	1	mixing two or more chemicals together									1	
2	11	9	2	mixing chemicals and noting the reaction									1	
2	12	9	2	making concrete slabs and testing them				1						
2	13	9	1	nr										1
2	14	9	1	alkaline/acidity where we tested different household substances								1		
2	15	9	2	watched teacher put stuff in water, it exploded						1				
2	16	9	2	oxygen and hydrogen bombs									1	
2	17	9	1	I don't have a favourite										1
2	18	9	1	nr										1
2	19	9	1	mixing chemicals and noting the reaction									1	
2	20	9	2	lithium and berylium reaction with water						1				
3	1	10	1	nr										1
3	2	10	1	making small explosions with chemicals									1	
3	3	10	1	dissecting a heart							1		1	
3	4	10	2	cool stuff like dissecting cows' eyes and sheep's heart							1		1	
3	5	10	1	heart dissection							1			
3	6	10	2	cutting up cows' eyes							1			
3	7	10	2	cutting up cows' eyes							1			
3	8	10	1	elctronics and chemistry									1	
3	9	10	1	dissecting cows' eye, noy real scientific but loads of fun							1			
3	10	10	1	exploding hydrogen and oxygen									1	
3	11	10	1	nr										1
3	12	10	1	making explosions with chemicals									1	
3	13	10	2	dissecting carcases							1			
3	14	10	1	combustion of hydrogen									1	
3	15	10	1	combustion of hydrogen and oxygen									1	
3	16	10	1	blowing up hydrogen									1	
3	17	10	2	dissecting fish							1			
3	18	10	1	electronic boards									1	
3	19	10	1	exploding hydrogen and oxygen									1	
3	20	10	2	nr										1
4	1	10	2	dissection of male rat							1			
4	2	10	2	rat dissection							1			
4	3	10	2	rat dissection							1			
4	4	10	1	rat dissection							1			
4	5	10	1	none of the science practicals has been really memorable										1
4	6	10	1	trying yto make copper with mini blow torches, copper oxide and charcoal.3									1	
4	7	10	2	nr										1
4	8	10	1	boiled water and added salt									1	
4	9	10	1	rat dissection							1			
4	10	10	1	design our own investigations in groups,			1							
4	11	10	1	burn magnesium									1	
4	12	10	1	rolling balls to investigate motion								1		
4	13	10	2	rat dissection							1			
4	14	10	2	rat dissection							1			
4	15	10	2	rat dissection (interesting) making and launching rockets (fun)							1			
4	16	10	1	all have been fun and interesting pracs										1
4	17	10	1	air track motion study								1		
4	18	10	1	hydrogen explosions									1	
4	19	10	1	evaporation of salt solution, crystallisation									1	
5	1	10	2	noneare realy interesting, they are too complicated and difficult										1

Class	Student ID	Grade	Gender M=1 F=2	BEST Actual	SPSPI Actual	UDACT DM	OIPS MD	DIPS DR'	CRFB MR	DEM RR'	SKLD R'R	LABX R'D	DACT RM	NR
5	2	10	1	diffusion of various substances									1	
5	3	10	1	learn something new or strange										1
5	4	10	2	different sugars in dough mixture fermenting with yeast								1		
5	5	10	2	burning peanuts to determine the energy content								1		
5	6	10	1	burning nuts to measure kj								1		
5	7	10	2	rat dissection								1		
5	8	10	1	washing powder								1		
5	9	10	1	related to teenager interests										1
5	10	10	2	rat dissection							1			
5	11	10	2	fun and enjoyable science in G7										1
5	12	10	1	growing plants									1	
5	13	10	1	rat dissection							1			
5	14	10	1	acids and bases									1	
5	15	10	2	rat dissection							1			
5	16	10	2	rat dissection							1			
5	17	10	2	boiling water in a paper cup									1	
5	18	10	2	making glue out of cornflour									1	
5	19	10	1	boiling water in a paper cup									1	
5	20	10	1	?										1
6	1	10	2	investigate on own not on a sheet			1							
6	2	9	1	experiments on plants outside,not boring, outside								1		
6	3	10	2	building acid rain chamber, noting effecton plants				1						
6	4	10	2	making lipstick and moisturiser									1	
6	5	9	1	measuring wave speed at the beach								1		
6	6	10	1	electrolisis									1	
6	7	10	1	solar energy									1	
6	8	9	1	burning magnesium									1	
6	9	9	1	experiment I designed myself, traffic ligh			1							
6	10	9	1	competition, who could keep an ice cube longest				1						
6	11	9	2	no best prac, enjoy cells & microscopes							1			1
6	12	10	2	worm dissection							1			
6	13	9	1	no favourite prac										1
7	1	9	1	dissect heart,fun							1			1
7	2	9	2	food testing,proteins								1		
7	3	9	1	sling shot,friction									1	
7	4	9	2	parachutes and balloon rockets									1	
7	5	9	2	dissect heart,fun							1			
7	6	9	1	studies of paper plane flight				1						
7	7	9	1	dissecting kidneys							1			
7	8	9	1	lemon battery									1	
7	9	9	1	no favourite prac										1
7	10	9	2	dissect pig's heart							1			
7	11	9	2	kidney dissection							1			
7	12	9	1	kidney&liver dissection							1			
7	13	9	1	heart&kidney dissection							1			
7	14	9	2	kidney dissection							1			
7	15	9	1	heart dissection							1			
7	16	9	1	nr										1
7	17	9	1	heating liquids with bunsen burner							1			
7	18	9	1	heart dissection							1			
7	19	9	1	heart,lung dissection							1			
7	20	9	2	I like them all really										1
7	21	9	2	food testing,proteins								1		
7	22	9	1	I like them all really										1
7	23	9	1	bunsen burners to evaporate water							1			
8	2	10	1	explosions,smoke									1	
8	3	10	2	plasticene model of plate tectonics					1					
8	4	10	1	exploding volcano						1				
8	5	10	1	contact puzzles									1	
8	6	10	1	contact puzzles									1	
8	7	10	2	heart&kidney dissection							1			
8	8	10	2	heart dissection							1			
8	9	10	2	heart dissection							1			
8	10	10	1	nr										1
8	11	10	1	expts on petroleum fuels								1		
8	12	10	1	investigating electricity				1						
8	13	10	2	electrostatic expts										
8	14	10	2	nr										1
8	15	10	2	expts growing bacteria from different sites,								1		
8	16	10	2	heart&kidney dissection							1			
8	18	10	1	turning copper nitrate to silver nitrate									1	
8	17	10	1	touched an electrostatic machine									1	

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9	1	9	1	static electricity test									1	
9	2	9	1	test metals for conductivity								1		
9	3	9	1	compound bar completes circuit									1	
9	4	9	2	dissection of heart and gut							1			
9	5	9	1	static electricity test									1	
9	6	9	2	heat conductivity of metals								1		
9	7	9	1	compound bar completes circuit									1	
9	8	9	1	dissecting animals							1			
9	9	9	1	fire alarm									1	
9	10	9	1	heart dissection							1			
9	11	9	2	dissection, how heat travels							1			
9	12	9	1	making light from heat									1	
9	13	9	2	making and shooting a rocket									1	
9	14	9	1	heat conductivity of metals								1		
9	15	9	2	dissection of pig							1			
9	16	9	1	dissection of heart							1			
9	17	9	2	work with energy,interesting and fun									1	
9	18	9	2	I like any biology prac										1
9	19	9	2	I like dissection of organs most							1			
9	20	9	1	using a centrifuge							1			
9	21	9	2	heart dissection, bunsens, heat transfer							1			
9	22	9	1	Leibig condenser to distil water							1			
9	23	9	1	using the electroscope									1	
9	24	9	2	dissection of digestive system							1			
9	25	9	1	dissection of a pig gut							1			
9	26	9	1	elements burning in oxygen								1		
9	27	9	2	I like all science pracs										1
9	28	9	1	hydrogen pop test							1			
9	29	9	1	electrical charges									1	
9	30	9	1	use generators,lights,batteries and bunsens, it was lots of fun									1	
10	1	10	2	hydrogen 'pop' test							1			
10	2	10	2	invesigating a creek				1						
10	3	10	1	metals and acids								1		
10	4	10	1	nr										1
10	5	10	1	hydrogen 'pop' test							1			
10	6	10	2	instructions clear, own conclusions, dicussion								1		
10	7	10	2	hydrogen pop test							1			
10	8	10	2	at the creek, fun ,out of class				1						
10	9	10	2	at the creek,different plants and animals				1						
10	10	10	2	hydrogen pop test							1			
10	11	10	1	chemical reactions, exlosives								1		
10	12	10	2	something big happens						1				
10	13	10	2	hydrogen 'pop' test							1			
10	14	10	1	levers and pulleys move 4WD				1						
10	15	10	2	indicators from flowers								1		
10	16	10	2	hydrogen 'pop' test							1			
10	17	10	1	I like all practicals										1
10	18	10	2	nr										1
10	19	10	1	nr										1
10	20	10	1	acids and metals reactions								1		
10	21	10	1	nr										1
10	22	10	2	hydrogen 'pop' test							1			
10	23	10	2	making sherbert									1	
10	24	10	2	chemical reactions, bunsens								1		
10	25	10	2	I do not enjoy Sc pracs										1
10	26	10	2	hydrogen 'pop' test							1			
10	27	10	1	making sherbert,honeycomb									1	
11	1	9	2	filtered muddy water							1			
11	2	9	2	analysed river algal bloom				1						
11	3	9	2	electricity									1	
11	4	9	2	excursions, dry ice									1	
11	5	9	2	chemistry								1		
11	6	9	2	batteries									1	
11	7	9	2	battery investigations				1						
11	8	9	2	owls pellet analysis				1						
11	9	9	2	bunsens,hands on expts									1	
11	10	9	2	food testing								1		
11	11	9	2	battery investigations				1						
11	12	9	2	food testing								1		
11	13	9	2	making popcorn									1	
11	14	9	2	making battery holders									1	
11	15	9	2	food testing								1		
11	16	9	2	using bunsen burner and chemicals									1	
11	17	9	2	astronomy pracs,enjoyable									1	
11	18	9	2	smoke from dry ice									1	
11	19	9	2	electric circuit problems				1						
11	20	9	2	dissecting digestive and respiratory organs				1			1			
11	21	9	2	food testing								1		
11	22	9	2	battery investigations				1						
11	23	9	2	make a car to go as far as possible				1						
11	24	9	2	food testing								1		
11	25	9	2	building strongest bridge				1						
12	1	10	1	plaster cast of shoe in foren.sc									1	

Class	Student ID	Grade	Gender M=1 F=2	BEST Actual	SPSPI Actual	UDACT DM	OIPS MD	DIPS DR'	CRFB MR	DEM RR'	SKLD R'R	LABX R'D	DACT RM	NR
12	2	10	2	fingerprinting									1	
12	3	10	2	I haven't- don't enjoy sc										1
12	4	10	2	making our own things			1							
12	5	10	2	making crystals&bunsen									1	
12	6	10	1	nr										1
12	7	10	2	bunsen burner licence							1			
12	8	10	1	going on computers										1
12	9	10	1	nr										1
12	10	10	2	planting,pruning trees									1	
12	11	10	2	making things with few supplies				1						
12	12	10	2	fingerprints									1	
12	13	10	1	designing rollercoasters				1						
12	14	10	1	we don't do much prac										1
12	15	10	1	nr										1
12	16	10	2	finger prints									1	
12	17	10	2	bunsenburner licence							1			
12	18	10	2	making rollercoaster				1						
13	1	10	2	human body									1	
13	2	10	1	nr										1
13	3	10	2	chemical reactions								1		
13	4	10	1	cutting up sheep's organs							1			
13	5	10	1	nr										1
13	6	10	2	heart dissection							1			
13	7	10	1	chemical reactions								1		
13	8	10	1	dissections							1			
13	9	10	2	making crystals&bunsen									1	
13	10	10	2	dissections							1			
13	11	10	1	dissections							1			
13	12	10	1	dissections							1			
13	13	10	2	nr										1
13	14	10	1	dissections							1			
13	15	10	2	chemical reactions								1		
13	16	10	2	dissections							1			
13	17	10	2	making rollercoaster				1						
13	18	10	1	dissections							1			
13	19	10	2	making crystals&bunsen									1	
14	1	10	1	separating salt from water				1			1			
14	2	10	1	observing bar breaker						1				
14	3	10	1	burning metals over bunsen										
14	4	10	1	separating salt from water				1			1			
14	5	10	1	dissections							1			
14	6	10	1	steam distillation lavender							1			
14	7	10	1	potassium in water						1				
14	8	10	1	glass blowing,dissecting							1			
14	9	10	1	dissections							1			
14	10	10	1	dissections							1			
14	11	10	1	dissections							1			
14	12	10	1	nr										
14	13	10	1	metals in acids,sodium								1		
14	14	10	1	observing bar breaker						1				
14	15	10	1	metals in acids,sodium								1		
14	16	10	1	blood,cells using microscope									1	
14	17	10	1	burning metals over bunsen								1		
14	18	10	1	dissections							1			
14	19	10	1	dissections							1			
14	20	10	1	dissections							1			
14	21	10	1	shooting dowl into air									1	
14	22	10	1	dissections							1			
14	23	10	1	physics,angles & distance								1		
14	24	10	1	dissections							1			
14	25	10	1	dissections							1			
14	26	10	1	potassium in water						1				
14	27	10	1	dissections							1			
14	28	10	1	dissections							1			
15	1	10	2	genetics surveys								1		
15	2	10	2	moulds,bacteria in env								1		
15	3	10	2	dissections							1			
15	4	10	2	titration expts								1		
15	5	10	2	dissections							1			
15	6	10	2	dissections							1			
15	7	10	2	botany								1		
15	8	10	2	chemical reactions										
15	9	10	2	dissections							1			
15	10	10	2	enjoyed all pracs										1
15	11	10	2	enjoyed all pracs										1
15	12	10	2	making honeycomb in chem									1	
15	13	10	2	dissections							1			
15	14	10	2	design a boat					1					
15	17	10	2	gravity expt circuit								1		
15	18	10	2	titration expts								1		
15	19	10	2	making cell&animal models					1					
15	20	10	2	making cell&animal models					1					
15	21	10	2	design a boat				1						

Class	Student ID	Grade	Gender M=1 F=2	BEST Actual	SPSPI Actual	UDACT DM	OIPS MD	DIPS DR'	CRFB MR	DEM RR'	SKLD R'R	LABX R'D	DACT RM	NR
15	22	10	2	making honeycomb in chem									1	
15	23	10	2	making cell&animal models					1					
16	1	10	2	enjoyed all pracs										1
16	2	10	2	nr										1
16	3	10	2	enjoyed all pracs										1
16	4	10	2	metals in water,sodium						1				
16	5	10	2	chemical reactions								1		
16	6	10	2	slater investigations			1							
16	7	10	2	chemical reactions								1		
16	8	10	2	dissections							1			
16	9	10	2	dissections							1			
16	10	10	2	dissections							1			
16	11	10	2	dissections							1			
16	12	10	2	dissections							1			
16	13	10	2	expts relevant to real life								1		
16	14	10	2	cells under microscope									1	
16	15	10	2	motion epts with toy cars								1		
16	16	10	2	chemical reactions								1		
16	17	10	2	exciting chemical reactions									1	
16	18	10	2	build a tower out of tape				1						
16	19	10	2	exciting chemical reactions									1	
16	20	10	2	dissections							1			
16	21	10	2	metals in water,potassium						1				
17	1	10	1	metals in water						1		1		
17	2	10	2	insulation expts										
17	3	10	1	eye catching,good time										1
17	4	10	2	metal testing							1			
17	5	10	2	electric circuits,electronics								1		
17	6	10	2	cooling expts							1			
17	7	10	2	steamboat making								1		
17	8	10	1	fun,chemistry,dissecting							1			
17	9	10	2	metal testing							1			
17	10	10	2	chemical reactions							1			
17	11	10	1	properties of metals							1			
17	12	10	1	metals in acids,H2 test							1			
17	13	10	1	nr										1
17	14	10	2	metal testing								1		
17	15	10	1	env investigations				1						
17	16	10	2	dissections							1			
17	17	10	1	metal testing								1		
17	18	10	1	metal testing								1		
17	19	10	1	bunsen,chemical reactions								1		
17	20	10	2	energy investigations				1						
18	1	10	2	burning chemicals over bunsen										
18	2	10	1	nr										1
18	3	10	2	animal studies									1	
18	4	10	1	chemical reactions								1		
18	5	10	2	env investigations				1						
18	6	10	1	energy investigations				1						
18	9	10	1	chemical reactions								1		
18	10	10	1	dissections							1			
18	11	10	1	nr										
18	12	10	1	energy investigations										1
18	13	10	1	metals in water,potassium						1				
18	14	10	1	metals in acids,H2 test								1		
18	15	10	1	dissections							1			
18	16	10	1	fun,chemistry				1						
18	17	10	1	chemical reactions								1		
18	18	10	1	metals in acids,H2 test								1		
18	19	10	1	chemical reactions								1		
18	20	10	2	env investigations			1							
18	21	10	2	making crystals									1	
18	22	10	2	making crystals									1	
18	23	10	2	chemical reactions								1		
18	24	10	2	chemical reactions								1		
Class	**Student ID**	Grade	Gender **M=1 F=2**	**BEST Actual**	**SPSPI Actual**	UDACT **DM**	OIPS **MD**	DIPS **DR'**	CRFB **MR**	DEM **RR'**	SKLD **R'R**	LABX **R'D**	DACT **RM**	NR
				TOTALS		2	905	34	5	13	120	66	80	59

SAMPLE				
	22	7	M14F8	TAS
	105	9	M48F57	
	259	10	M125F134	
Totals	386	7,9,10	M187F199	

ESSENTIAL	UDACT	OIPS	DIPS	CRFB	DEM	SKLD	LABX	DACT	NR	STUDEN	EX/F/I/NI	NOT TCI	CHEM	ENV
Preferred	**DM**	**MD**	**DR'**	**MR**	**RR'**	**R'R**	**R'D**	**RM**						
No understand									1					
some things									1					
chemistry									1				1	
learning fun things											1			
experiments							1							
evaporating and separating things						1								
learn about different substances and metals								1						
nr									1					
gravityand do experiments on space							1							
nr									1					
nr									1					
nr									1					
nr									1					
I don't know									1					
nr									1					
nr									1					
nr									1					
?									1					
nr									1					
chemistry								1					1	
doing experiments							1							
making and experiencing lots of chemical reactions							1						1	
nr									1					
nr									1					
nr									1					
fun and not boring, big bang for example											1			
nr									1					
nr									1					
nr									1					
nr									1					
nr									1					
nr									1					
nr									1					
nr									1					
nr									1					
something with a bunsen burner						1								
nr									1					
I don't know														
nr									1					
nr									1					
nr									1					
nr									1					
not sure									1					
electrolysis of water to hydrogen and oxygen							1							
cutting up stuff						1								
electrolysis of water to hydrogen and oxygen							1							
simple investigations of com		1												
chemical changes and dissecting							1						1	
ways to help the environment														1
something fun,with an element of danger,or excitement, purely to learn from the experiment,not to write report														
I don't know									1					
I don't know or care what happens in an ideal science class									1					
I don't know														
relevant and hands onsuch as dissecting								1						
thermonuclear explosions with G9 close by									1					
dissection						1								
dissecting fish						1								
not sure									1					
electronics								1						
environmental investigations		1												1
how things work and reactions							1						1	
dissection of human						1								
biology, chemistry, more dissection						1								
science that relates to the w		1												1
making safe transistor explosions								1			1			
science practicals are important in all science ares, that does not mean that we enjoy it									1					
nr									1					
nr									1					
chemical reactions,explosior		1											1	
dissections						1								
how our body functions						1								
under standing what we are doingand how to d				1										
explosions, chemical reactions with colous and bubbles, more group projec							1						1	
animals and plants									1					
find out about the world									1					
current program									1					
current program									1					
physics and biology pracs							1							
making explosives								1					1	
air track work, motion							1							
not sure									1					

ESSENTIAL	UDACT	OIPS	DIPS	CRFB	DEM	SKLD	LABX	DACT	NR	STUDEN	EX/F/I/NI	NOT TCI	CHEM	ENV
Preferred	**DM**	**MD**	**DR'**	**MR**	**RR'**	**R'R**	**R'D**	**RM**						
enjoyable and related to everyday life											1			
how to disolve substances like oil and water							1						1	
experiment involving springs, Hook's Law							1							
cells and atoms which make up our body									1					
something well explained with theory									1					
more interesting ,everyday things											1			
burning,bombs,explosives											1		1	
more to do with what matters to me,different every year									1					
nr									1					
fun,enjoyable,exciting									1		1			
more fun									1		1			
nr									1					
more experiments							1							
study human body									1					
based on everyday life									1					
I am not sure									1					
nr									1					
burning something or making explosions							1						1	
don't know									1					
experiments outdoorswith marine plants or animals							1							1
the one at end of year									1					
titration							1						1	
nr									1					
nr									1					
metals and acids							1						1	
titration							1						1	
explosions and stuff								1					1	
nr									1					
sound experiments							1							
nr									1					
rat dissection						1								
don't know									1					
fun,chemicals, doing not listening							1				1		1	
fun, lots of equipment							1				1			
one where we learn a lot about science									1					
more expts of why, not it just happens							1							
human body, how it works									1					
bombs,chemical meltdown,burn stuff							1				1		1	
nr									1					
electricity								1						
biology									1					1
humans,animals,earth														1
more hands on								1						
cloning									1					
biology dissections						1								
more hands on								1						
nr									1					
nr									1					
hands on, in groups								1						
nuclear reactors,chemicals									1				1	
biology, electricity									1					
really easy to understand									1					
fun, with equipment								1			1			
more independence		1												
use new equipment									1					
explosions								1					1	
watching cell mutation under microscope								1						
nr									1					
contact puzzles									1					
making contact puzzles									1					
human biology									1					
birth of animals									1					
birth									1					
nr									1					
learning about disease									1					
nr									1					
nr									1					
nr									1					
growing bacteria from various sites							1							
human biology									1					
safety glasses									1					
make gunpowder and explosives								1					1	

ESSENTIAL	UDACT	OIPS	DIPS	CRFB	DEM	SKLD	LABX	DACT	NR	STUDEN	EX/F/I/NI	NOT TCI	CHEM	ENV
Preferred	**DM**	**MD**	**DR'**	**MR**	**RR'**	**R'R**	**R'D**	**RM**						
convection,conduction, radiation								1						
bunsen burners more						1								
nr									1					
dissection						1								
solids into gases								1						
dissecting animals														
we have input into what we do									1					
making rockets,using bunsens,robotics								1					1	
less written, more prac									1					
using microscopes						1								
dissection of animals						1								
more bunsen burners, more fun						1					1			
prac every lesson									1					
environmental stuff														1
work alone and in groups									1					
what we would like to find ou		1												
energy,everyday life									1					
every thing we learn is essential									1					
dissection of organs						1								
practicals we can do ourselv		1								1		1		
more fun practicals									1		1			
pracs showing main points to be learnt					1									
friction									1					
rockets and bombs								1					1	
dissecting animals						1								
chemistry experiments							1						1	
science pracs are essential									1					
nr									1					
nr									1					
lots of equpment, working th		1								1				
hydrogen 'pop' test						1							1	
not sure									1					
hydrogen 'pop' test						1								
nr									1				1	
working with animals									1					
clear instructions, ideas discussed afterwards				1				1						
making our own experiment:		1								1				
making sherbert, fun								1			1		1	
real nature, own experience		1												1
hydrogen 'pop' test						1							1	
expts with elements							1						1	
interesting,relevant									1		1			
hydrogen 'pop' test						1							1	
use equipment, more pracs								1						
biology pracs							1							
hydrogen 'pop' test with a rocket						1							1	
not sure									1					
nr									1					
nr									1					
acids and bases								1					1	
nr									1					
not sure									1					
learning about the environment									1					1
nr									1					
new things, not those done last year									1					
hydrogen 'pop' test						1							1	
making soaps,everyday things								1					1	
fun, fun excursions									1		1			
acids, alcohol, energy drinks							1						1	
electricity									1					
excursions									1					
discovering new things		1												
fun building bridges			1											
nr									1					
dissecting things,hands on,understand more						1								
not sure									1					
how to use all the different eqpmt						1								
food tests							1							
learning to use epuipment						1								
human biology									1					
hands on expts we can do on our owr								1						
nr									1					
nr									1					
vetinary sc, astronomy interests me									1					
food tests								1						
need for life, further study, fun									1		1			
bunsun burners						1								
nr									1					
electricity, human body									1					
all pracs have equal importance									1					
nature,human biology									1					1
excursions									1					
human body parts									1					

ESSENTIAL	UDACT	OIPS	DIPS	CRFB	DEM	SKLD	LABX	DACT	NR	STUDEN	EX/F/I/NI	NOT TCI	CHEM	ENV
Preferred	**DM**	**MD**	**DR'**	**MR**	**RR'**	**R'R**	**R'D**	**RM**						
genetics in the family									1					
I still don't enjoy sc									1					
nr									1					
nr									1					
nr									1					
using eqpt,doing expts						1	1							
going on computers									1					
nr									1					
nr									1					
nr									1					
using microscope						1								
nr									1					
cut up animals						1								
nr									1					
microscopes,dissecting						1								
nr									1					
using microscope						1								
nr									1					
nr									1					
making models				1										
more hands on expts								1						
nr									1					
nr									1					
more chemistry pracs													1	
dissections						1								
dissections						1								
chemical reactions							1						1	
more hands on expts								1						
make things we could keep								1						
nr									1					
more hands on expts								1						
chemicalexplosions								1					1	
more hands on expts								1						
explosions								1					1	
something really interesting											1			
nr									1					
using fancy equipmt						1								
violent,exciting reactions								1					1	
learning to make explosives properly								1					1	
more about sex									1					
blowing stuff up,burning things								1					1	
exciting chem reactions								1			1		1	
dissections						1								
experimenting with CO_2							1						1	
more exploration of chemistry							1						1	
studs suggest expts		1								1				
dissections						1								
making rockets								1						
metals in acids							1						1	
metals in water,eg francium							1						1	
biology									1					
dangerous stuff									1					
metals in water,eg potassium							1						1	
making explosions								1					1	
dissections						1								
female anatomy									1					
blowing stuff up,burning things								1					1	
blowing stuff up,burning things								1					1	
physics									1					
dissections						1								
dissections						1								
dissections						1								
dissections						1								
metals in water,acids							1						1	
learning by doing								1						
unsure									1					
dissections						1								
chemical reactions								1					1	
relevant,interesting									1		1			
chemical reactions								1					1	
relevant expts on real life							1							
chemical reactions								1					1	
dissections						1								
unsure									1					
unsure									1					
dissections						1								
chemical reactions								1					1	
dissections						1								
gravity&motion expts							1							
gravity&motion expts							1							
dissections						1								
making cell&animal models				1										
relevant expts on real life							1							

ESSENTIAL	UDACT	OIPS	DIPS	CRFB	DEM	SKLD	LABX	DACT	NR	STUDEN	EX/F/I/NI	NOT TCI	CHEM	ENV
Preferred	**DM**	**MD**	**DR'**	**MR**	**RR'**	**R'R**	**R'D**	**RM**						
dissections						1								
model making				1										
nr									1					
nr									1					
relevant expts on real life							1							
think for ourselves& relevant										1				
think for ourselves& relevant										1				
relevant expts on real life							1							
chemical reactions								1					1	
all pracs are important									1					
titrations							1						1	
expts about health&body							1							
relevant expts on real life							1							
relevant expts on real life							1							
exciting,relevant to life							1				1			
exciting expts, explosions							1							
nr									1					
interesting expts to understand the boring sc							1				1			
chemical reactions								1					1	
new exps, not repeated							1							
all pracs are important									1					
biology pracs									1					
chemical reactions								1					1	
chemical reactions								1					1	
relevant expts on real life							1							
exciting,interesting,memorable											1			
env investigations		1												1
metal investigations		1											1	
env investigations														
energy pracs									1					
nr									1					
using essetial eqmt						1								
chemistry,dissecting													1	
chemical reactions								1					1	
chemical reactions								1						
env investigations		1												1
relevant expts on real life							1							
env investigations		1												1
dissections						1								
energy pracs								1						
chemical reactions								1					1	
nr									1					
env investigations		1												1
nr									1					
nr									1					
chemical reactions								1					1	
chemical reactions								1					1	
biology pracs														
describing rocks						1								
chemical reactions								1					1	
big chemical reactions								1					1	
nr									1					
space travel									1					
dissections						1								
metals in acids,H2 test							1						1	
rocks and fossils						1								
chemical reactions								1					1	
chemical reactions								1					1	
env investigations		1												1
chemical reactions								1					1	
env investigations		1												1
dissections						1								
making crystals								1					1	
chemistry&physical sc														
chemical reactions								1					1	
ESSENTIAL	UDACT	OIPS	DIPS	CRFB	DEM	SKLD	LABX	DACT	NR	STUDEN	EX/F/I/NI	NOT TCI	CHEM	ENV
Preferred	**DM**	**MD**	**DR'**	**MR**	**RR'**	**R'R**	**R'D**	**RM**						
TOTALS		19	1	5	1	55	973	63	166	6	24	1	74	16

DISSEC	GEOLO	PHYSIC	BIOLOG
		1	
1			
1			
1			
1			
		1	
1			
1			1
		1	
1			
1			1
			1
		1	1
		1	

DISSEC	GEOLO	PHYSIC	BIOLOG
		1	
			1
			1
			1
		1	
1			
			1
		1	
			1
	1		1
			1
1			1
		1	
			1
			1
			1
			1
			1
			1
			1
			1

DISSEC	GEOLO	PHYSIC	BIOLOG
		1	
1			
1			
			1
1			
		1	
1			
1			
			1
		1	
1			
			1
			1
		1	1
			1

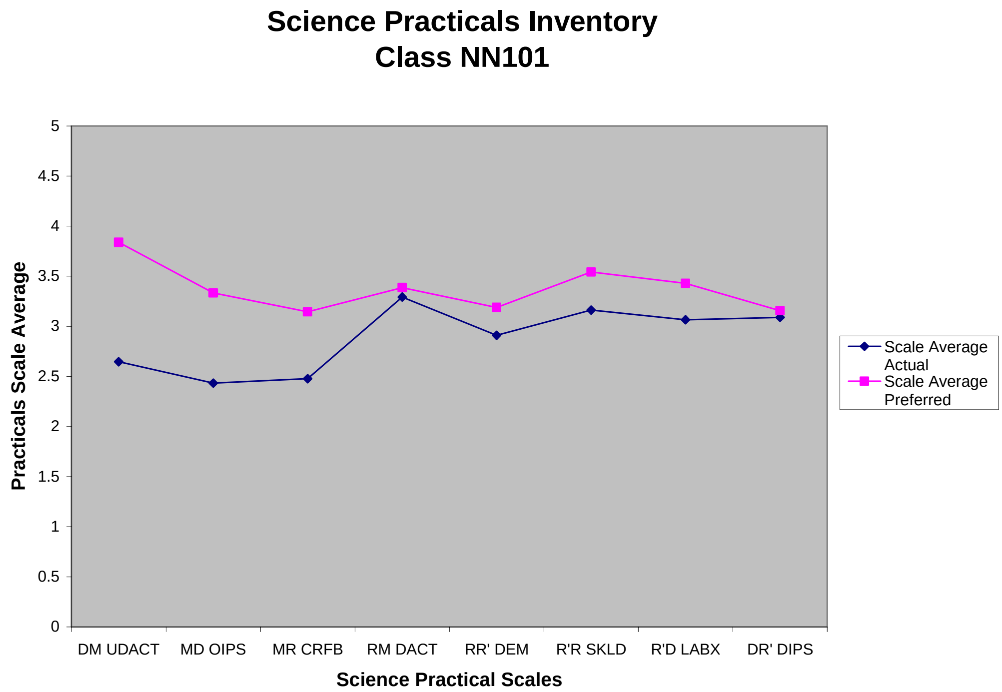
DISSEC	GEOLO	PHYSIC	BIOLOG
			1
			1
1			
1			1
			1
1			
1			
1			
1			
1			
1			
1			
1			
1			
1			
1			
1			
1			
1			

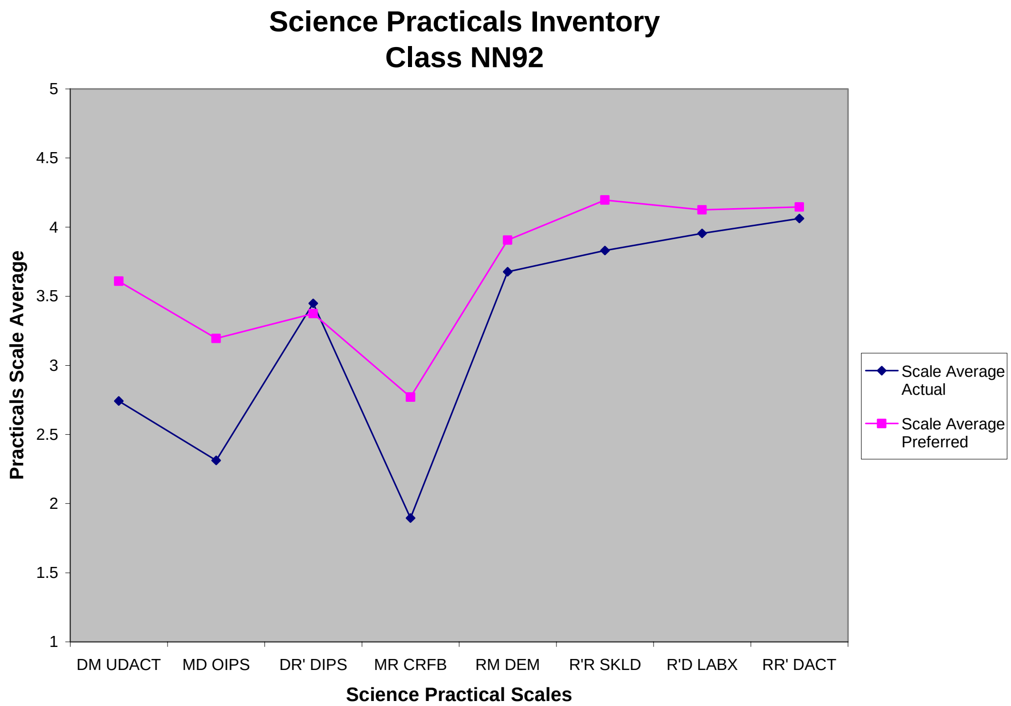
DISSEC	GEOLO(	PHYSIC:	BIOLOG
1			
			1
		1	
1			
		1	
			1
	1		
		1	
1			
	1		
1			

DISSEC	GEOLO(	PHYSIC:	BIOLOG
36	3	16	32

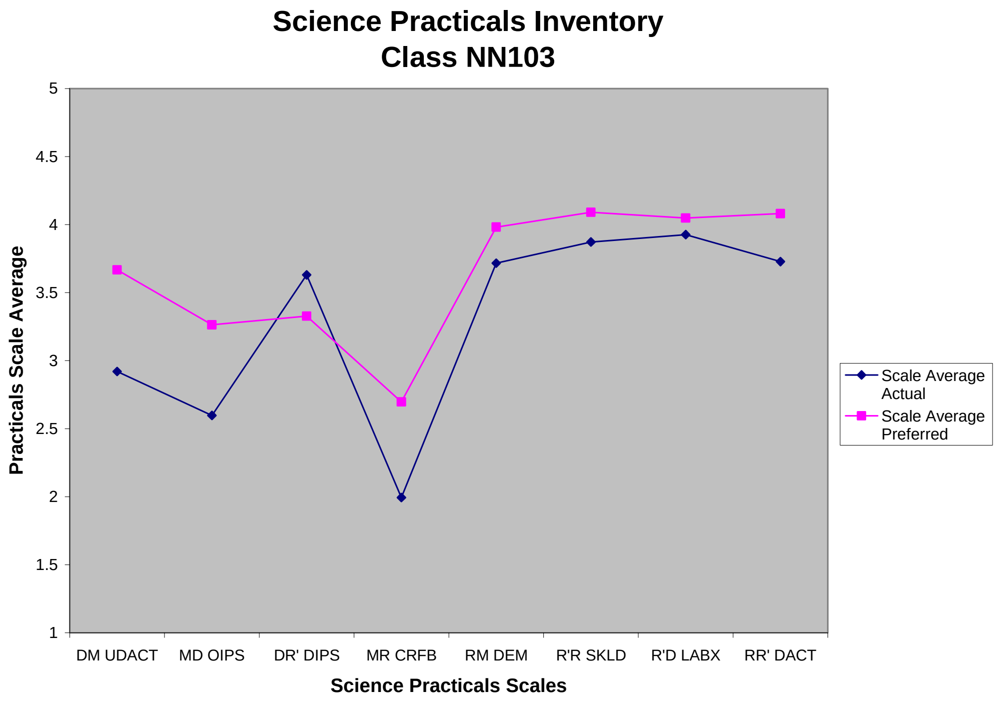
Appendix C: Examples of Class Students’ SPI Response Charts

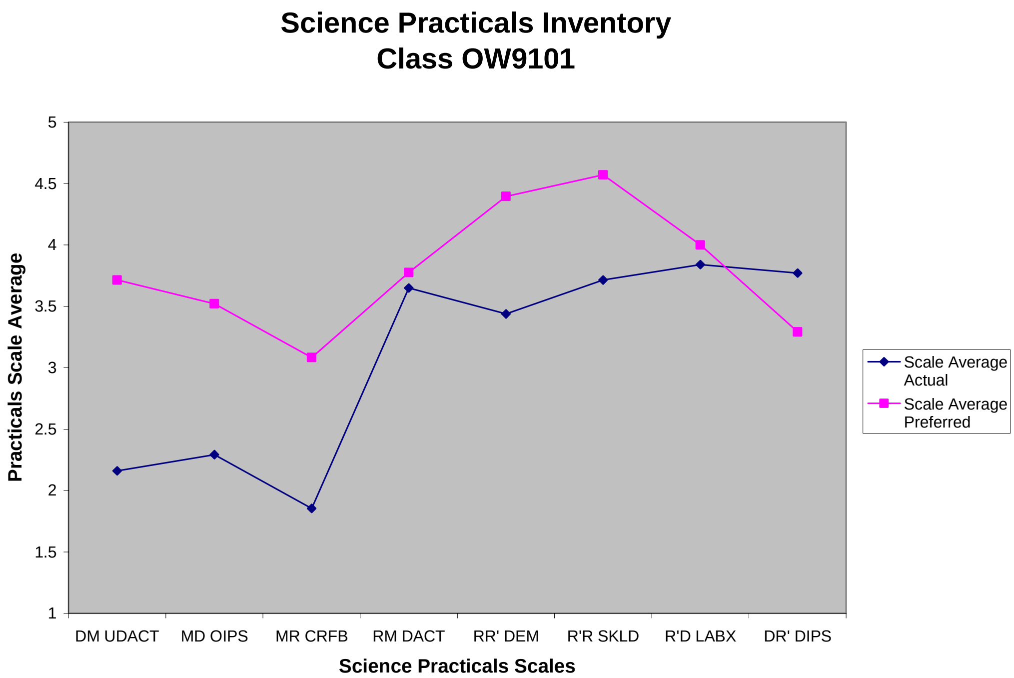
Appendix C: Examples of Class Students' SPI Response Charts





Appendix C: Examples of Class Students' SPI Response Charts





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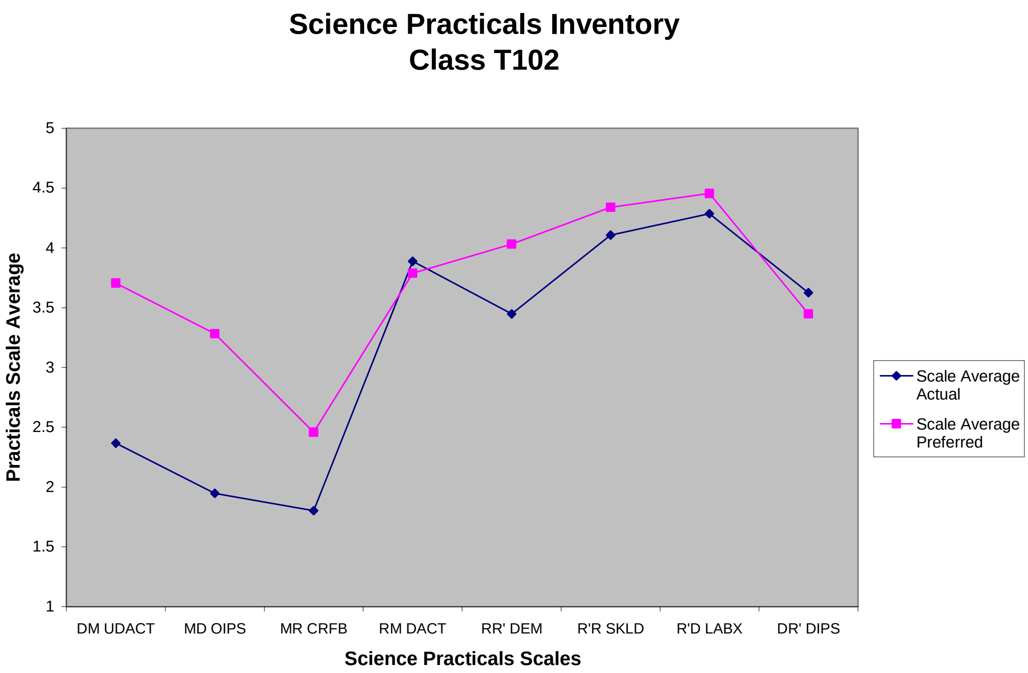
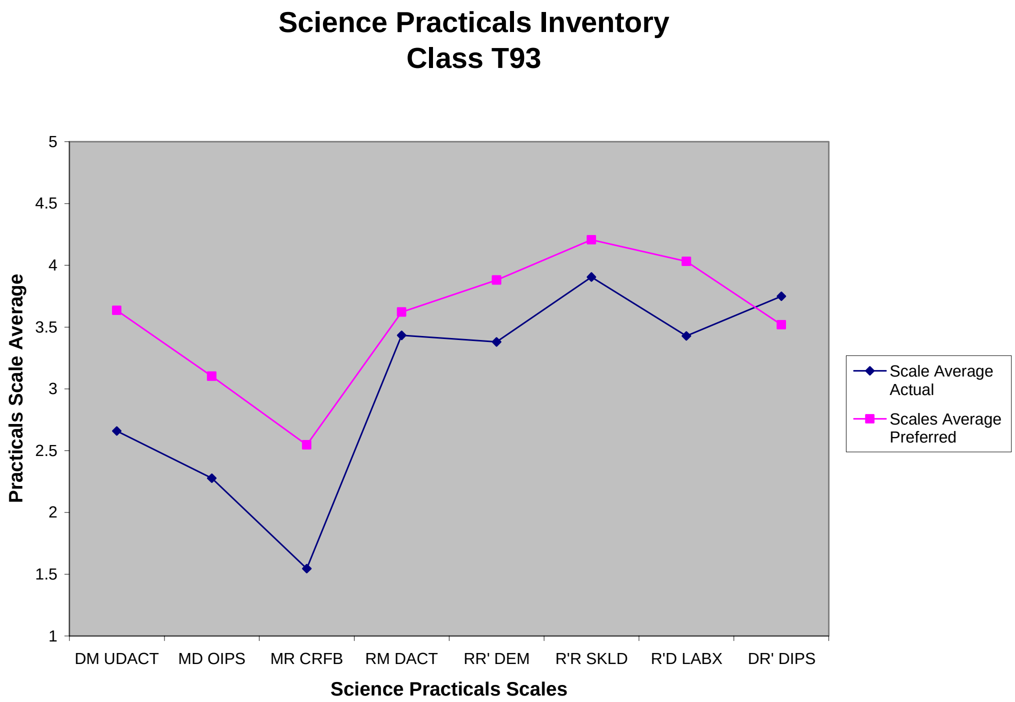
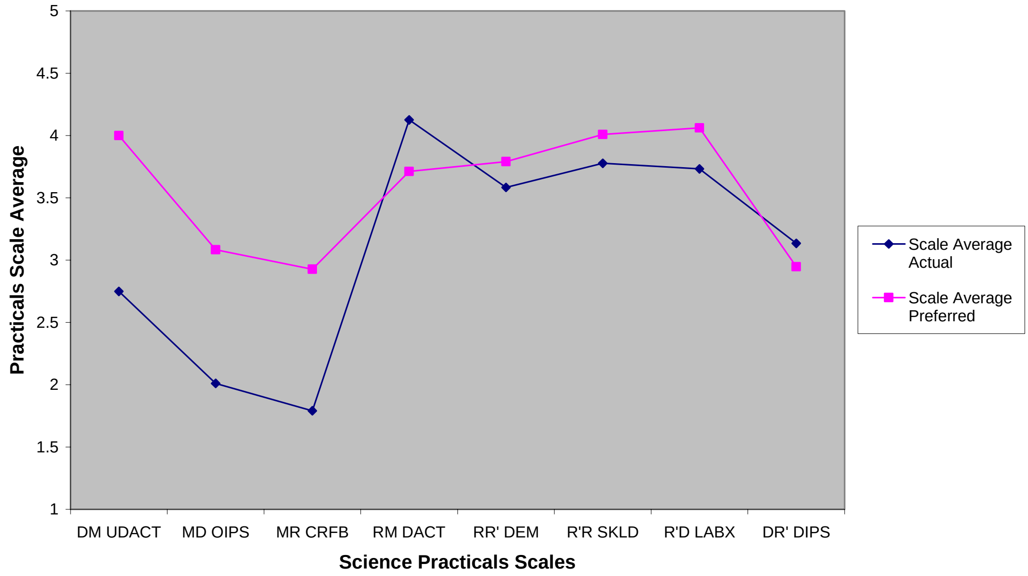


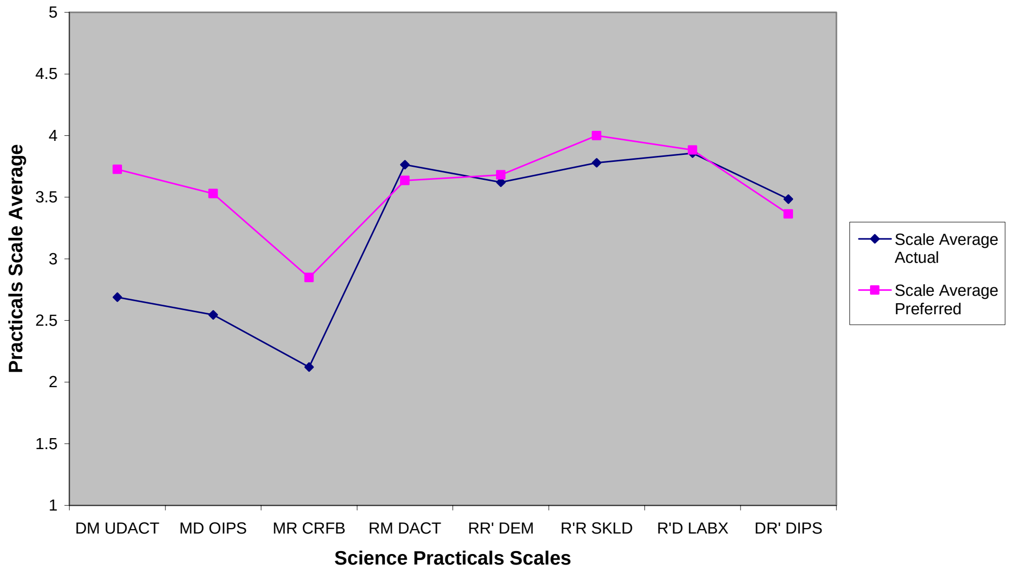


Appendix B: Examples of Class Students' SPI Response Charts

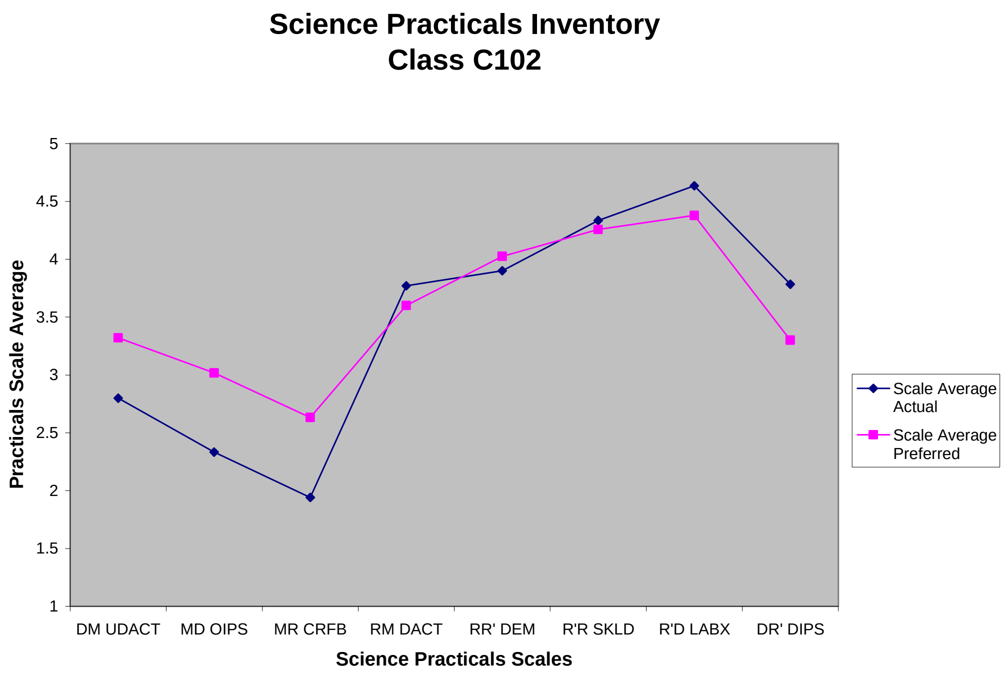
Science Practicals Inventory
Class T94

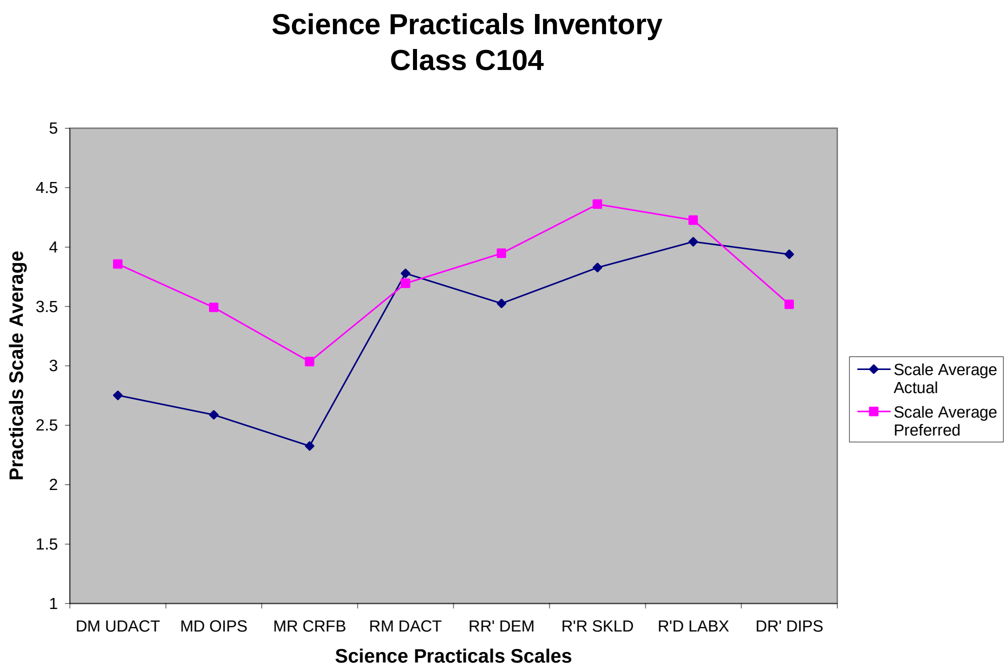


Science Practicals Inventory
Class C101

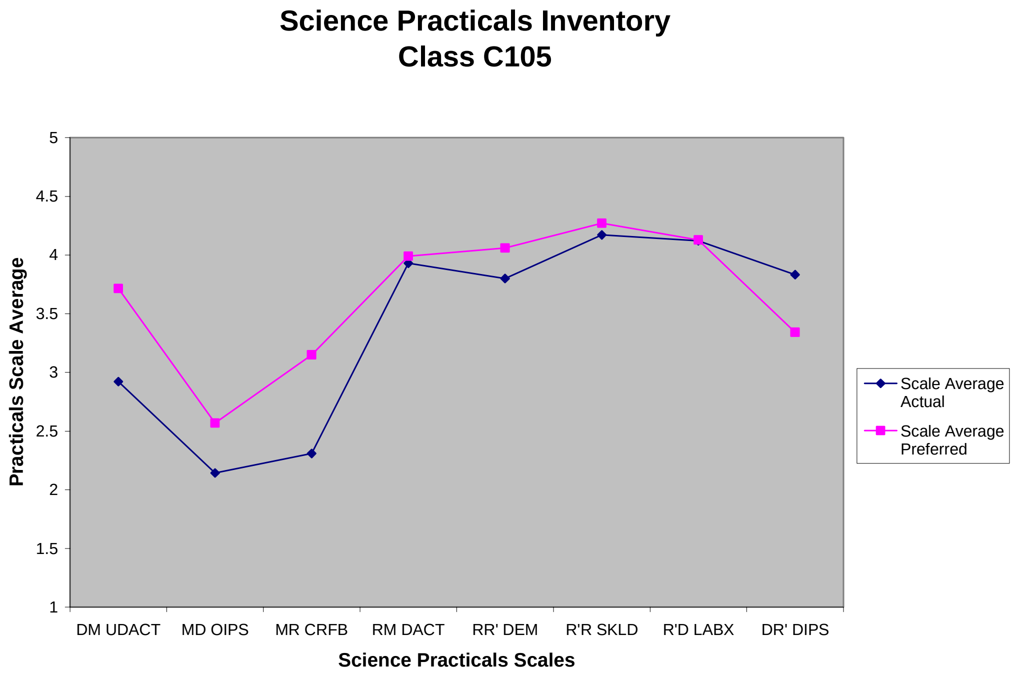


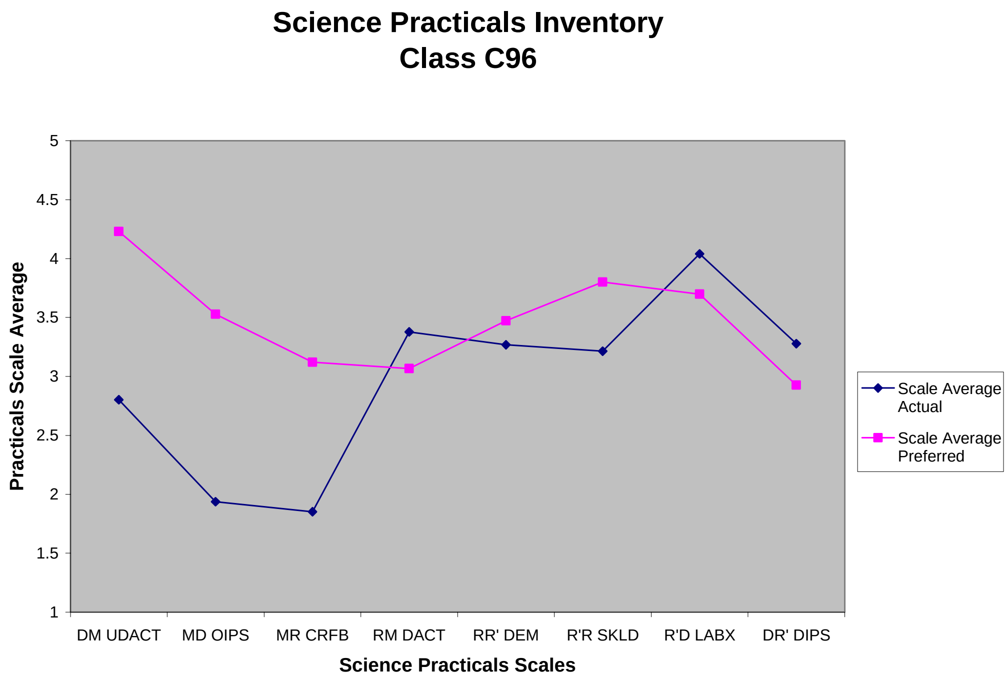
Appendix B: Examples of Class Students' SPI Response Charts



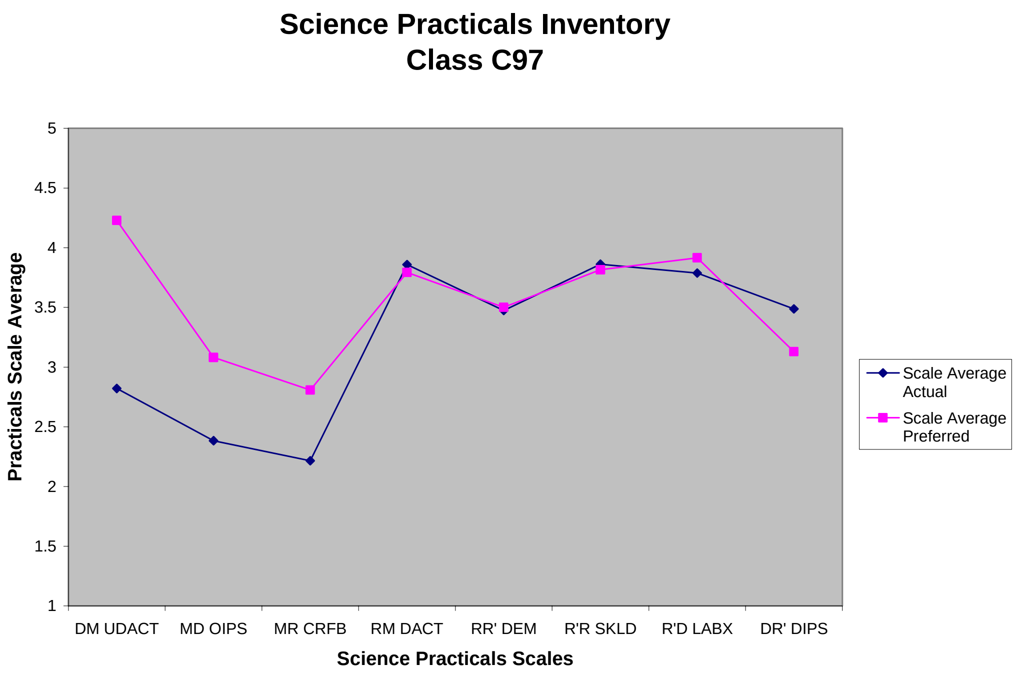


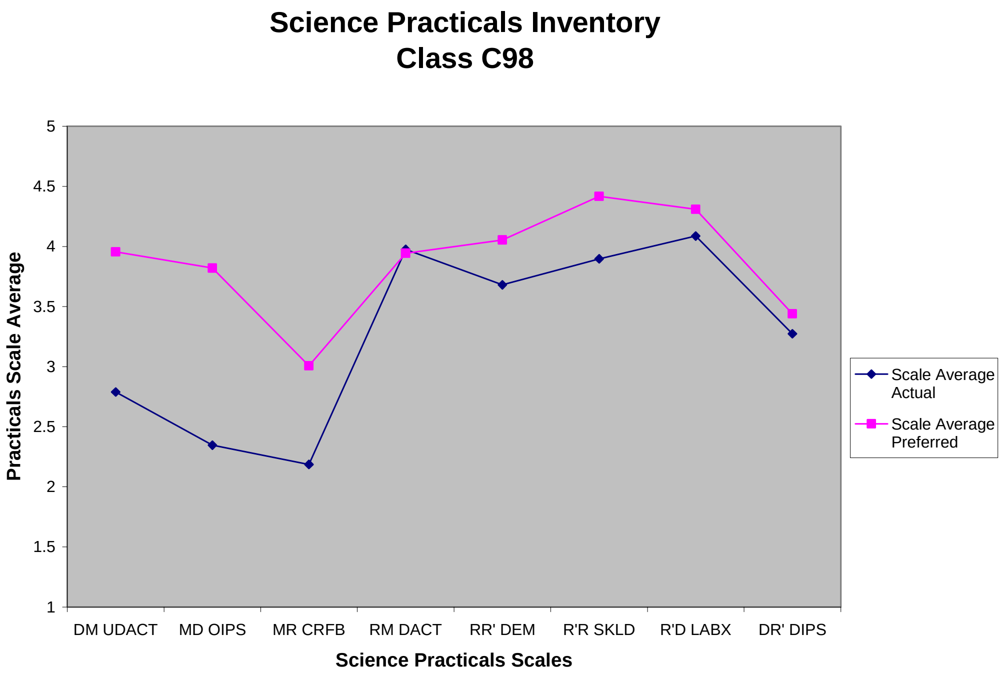
Appendix B: Examples of Class Students' SPI Response Charts



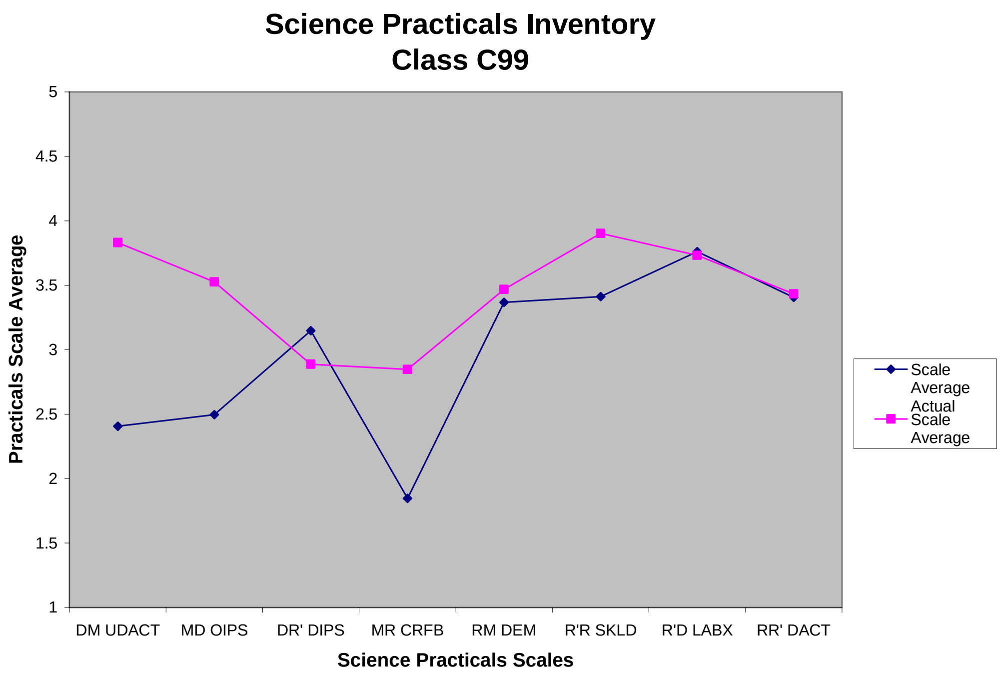


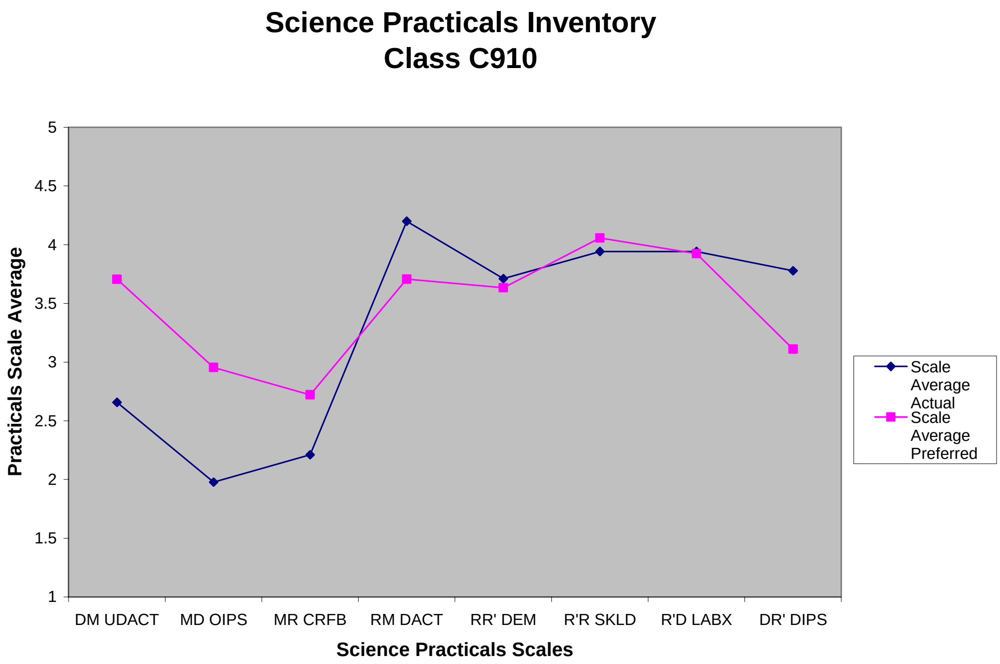
Appendix B: Examples of Class Students' SPI Response Charts



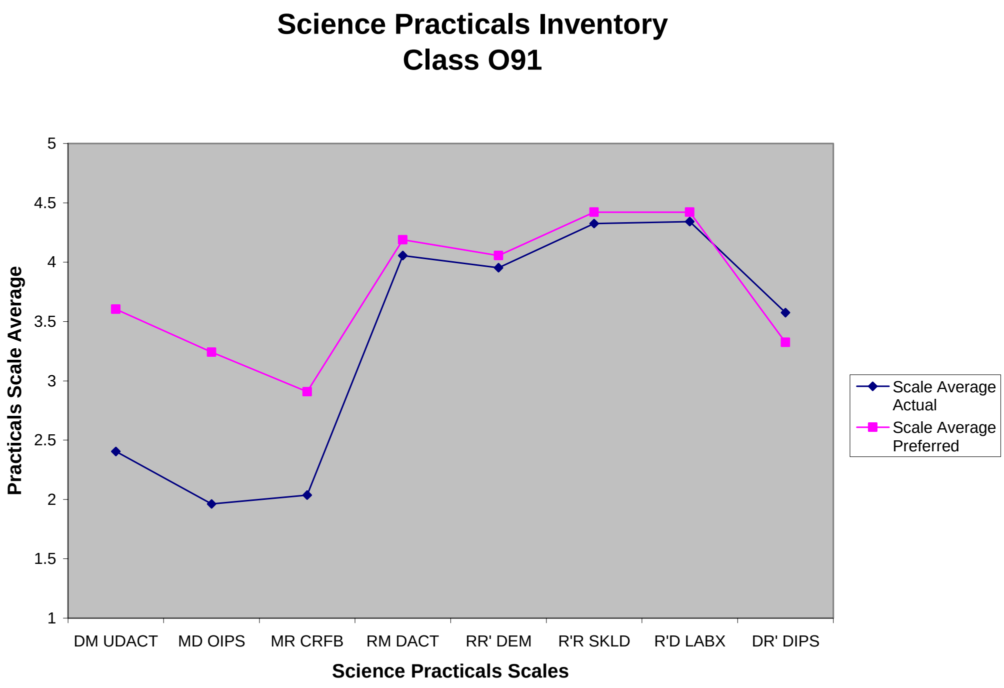


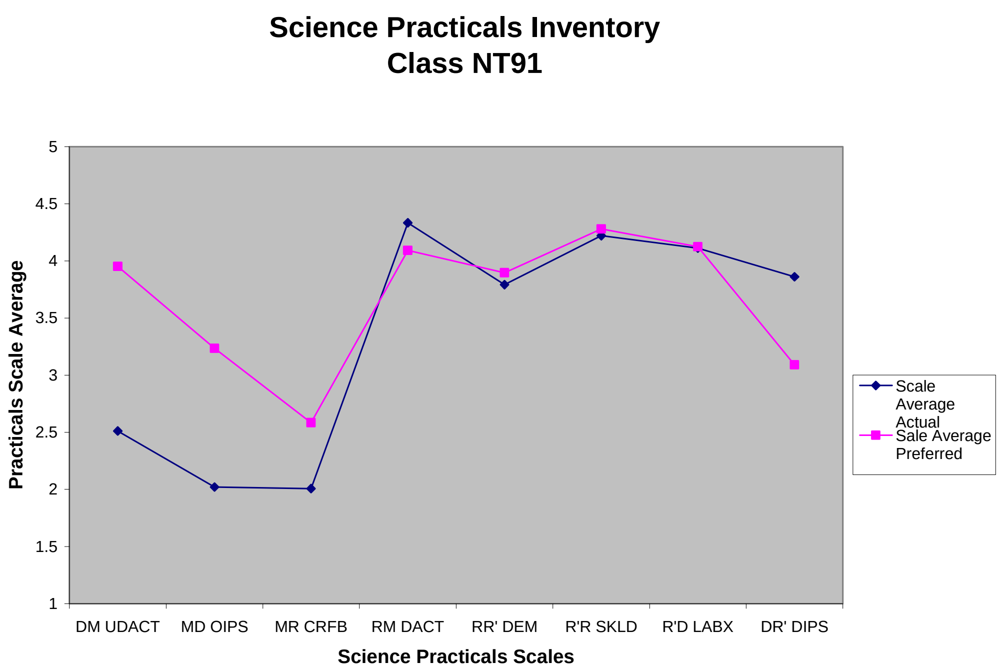
Appendix B: Examples of Class Students' SPI Response Charts





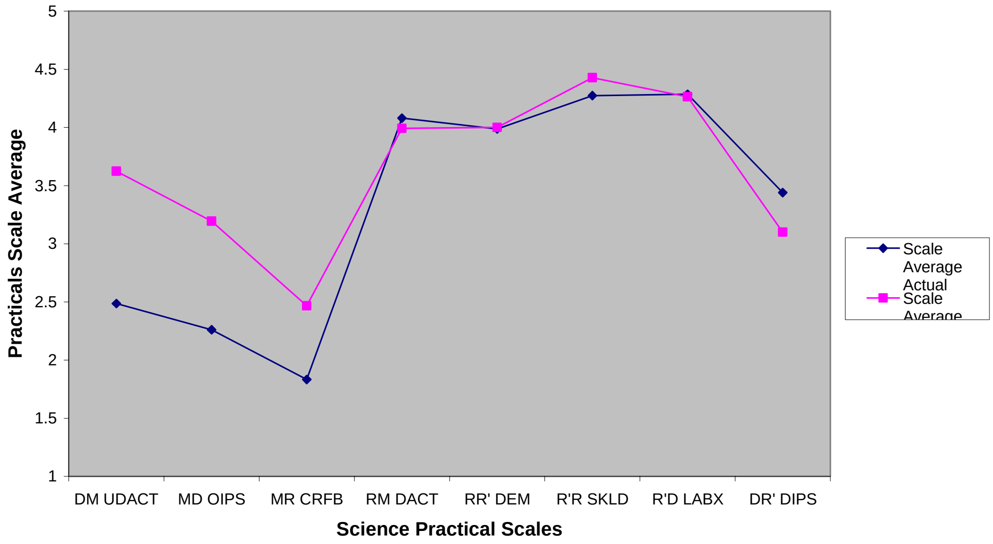
Appendix B: Examples of Class Students' SPI Response Charts



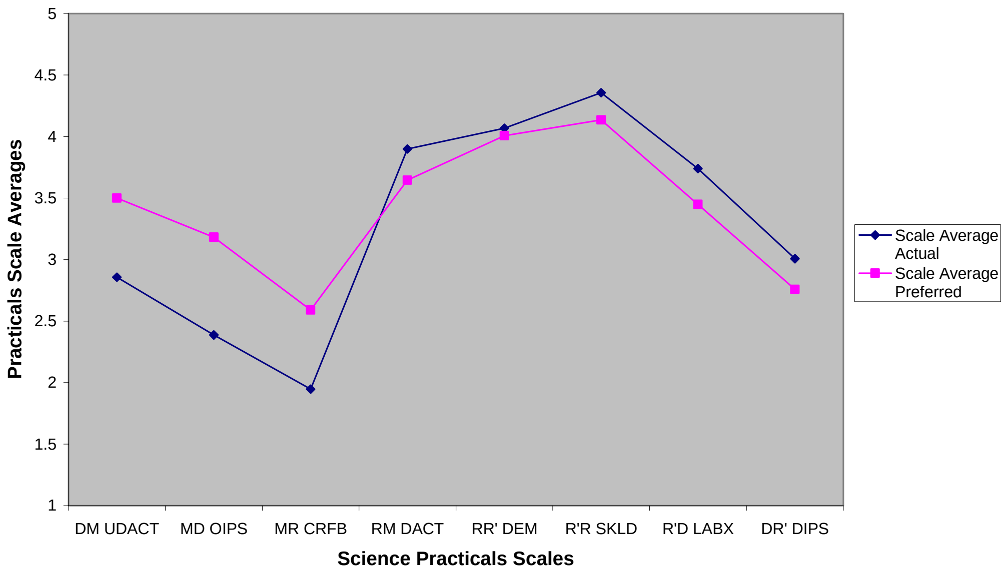


Appendix C: Examples of Class Students' SPI Response Charts

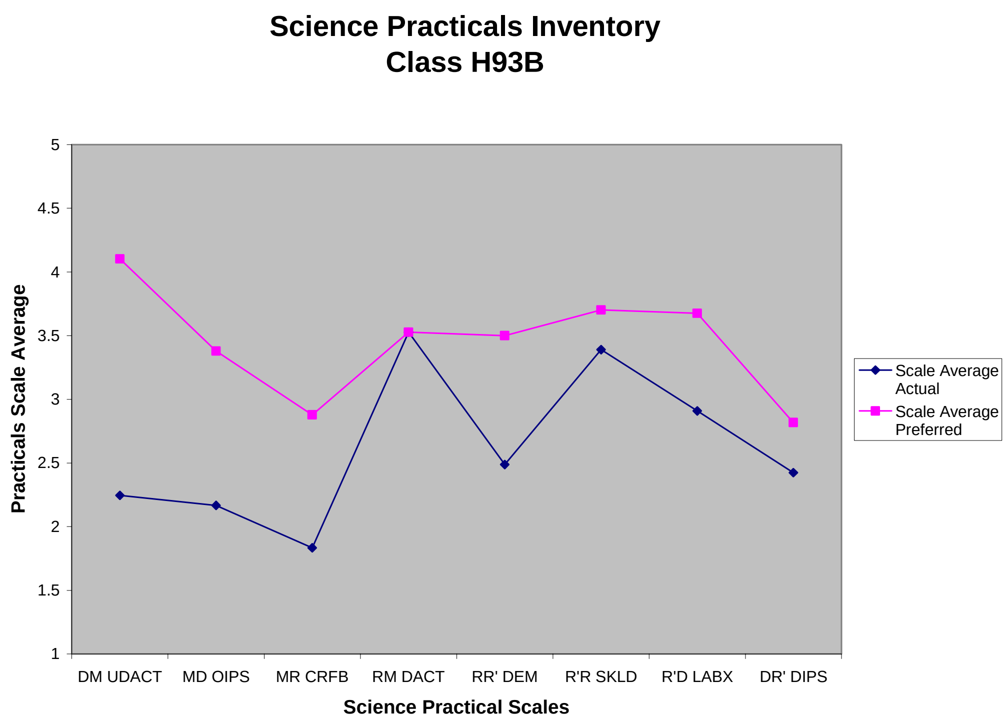
Science Practicals Inventory
Class NT92

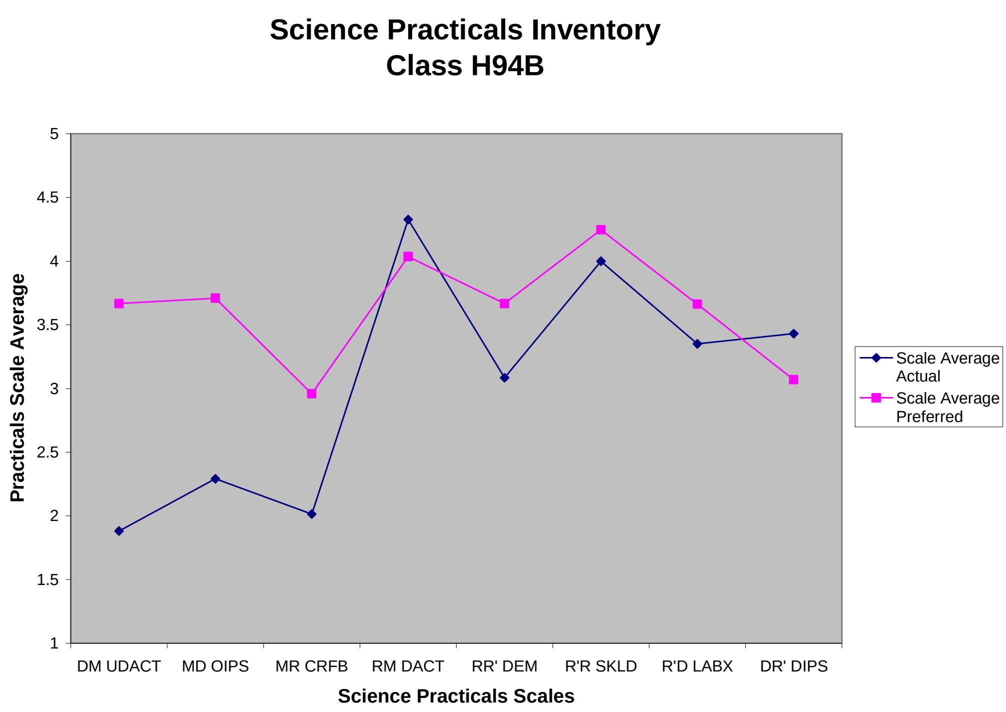


Science Practicals Inventory
Class H92A



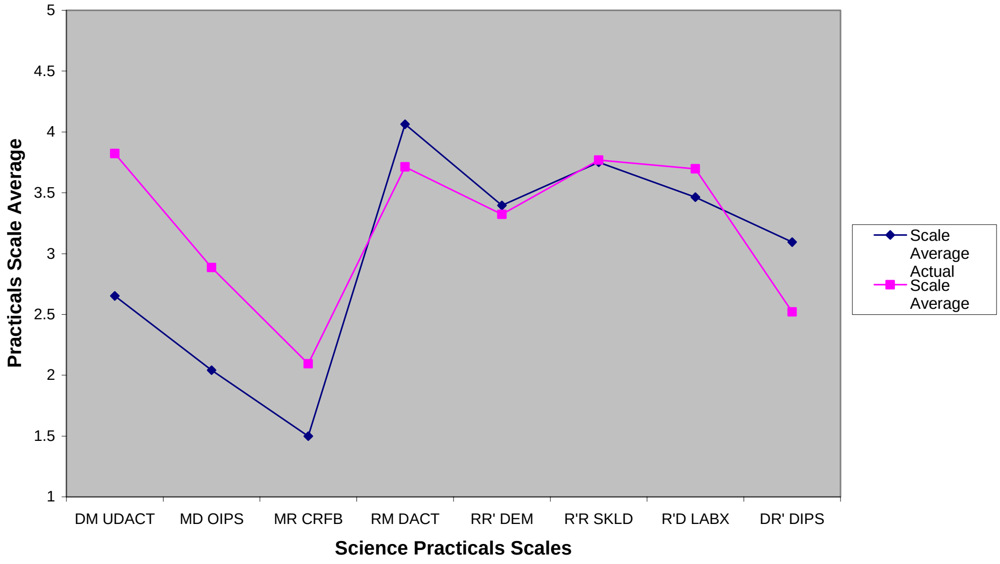
Appendix C: Examples of Class Students' SPI Response Charts



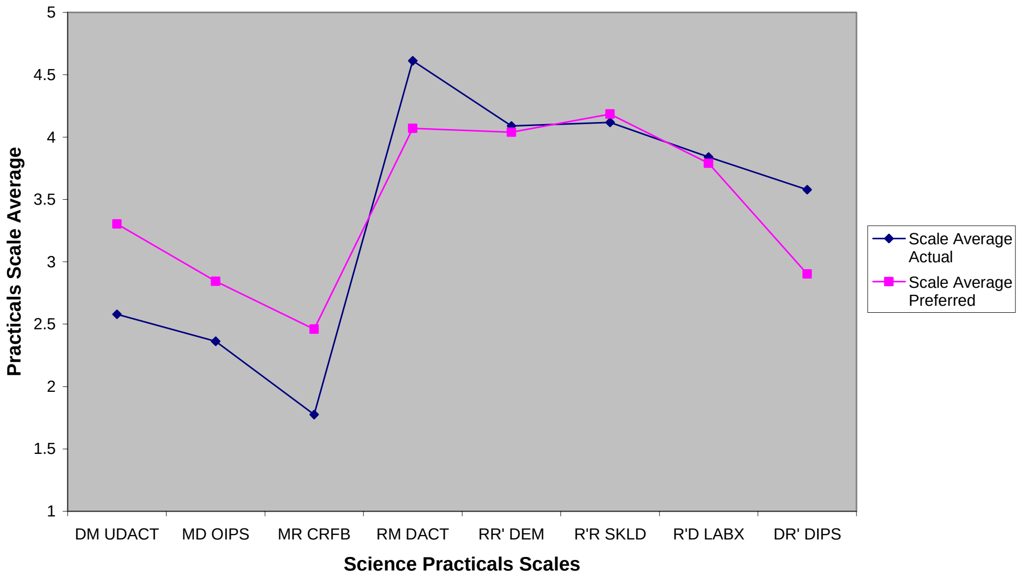


Appendix C: Examples of Class Students' SPI Response Charts

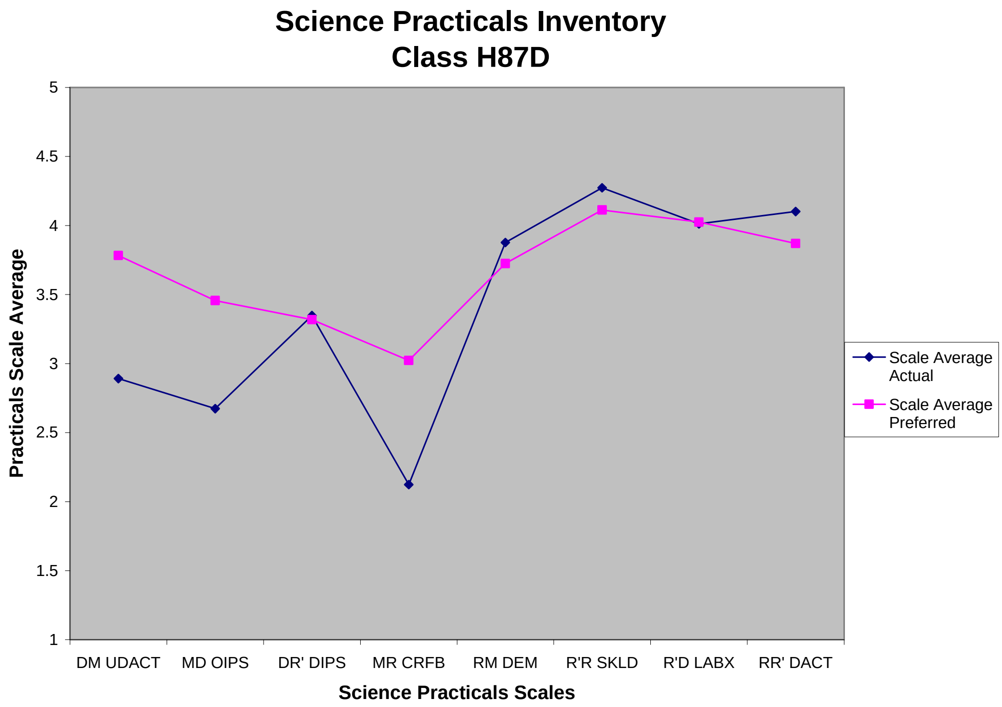
Science Practicals Inventory
Class H95C

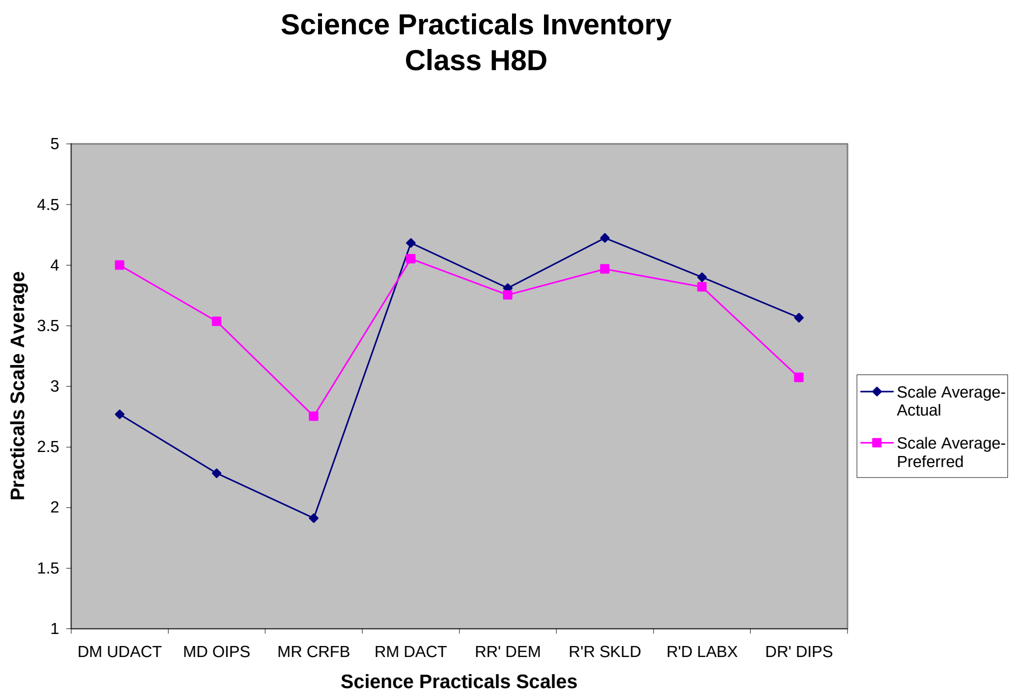


Science Practicals Inventory
Class H96C



Appendix C: Examples of Class Students' SPI Response Charts





Appendix D: Science Teachers Group Interviews Field Text

Appendix D: Science Teachers Group Interviews Field Text

Reference : Science focus group discussing the purpose and value of Science Practicals. The group consists of 5 Science teachers of C High School; B, M, T, K and S. The discussion is led by the researcher Duncan Bradley.
Date of interview: 15 October 2002

Note from transcriber : Voices of male participants may not be entirely correct due to lack of reference to specific individuals during the interview.

Duncan – Could I ask....could we go round the table if that's a formal way, if that's not too intimidating, and ask people to address the question generally about what is the purpose or the value of practical work, what are your perceptions, would anybody like to..?

B(?) – I'll make a start if you like Duncan. I think there is a number of purposes for prac work and I think it kind of varies. I think there are a number of things. I'd say it helps reinforce their theory, the work they do, their understanding of scientific theories. I think also it gives them some hands on experience of working scientifically. I think it sometimes gives an opportunity to solve a problem, a real problem and they see or the teacher sees, I suppose, as well as the kids, or hopefully both, as something which is worth solving, worth looking at, and so they undergo some methods if you like to try and get answers. I think there's also a number of other smaller side benefits like, helps kids understand the different way, actually hands on stuff rather than just looking at books, reading things and similar information like that, so I think there's a number of purposes.

Duncan – Thankyou. Would anybody like to pick that up?

M(?) - In our development of essential learning's we've been looking carefully at different modes of thinking and scientific inquiry is certainly a specialised way of thinking and, it's definitely a process, it's not easily taught just didactically, so you really need the experience of getting involved in the steps and going through them, for people to have a fair chance of understanding what's involved in the process of scientific inquiry

K – I just could reiterate what Barry's saying, its really good for kinaesthetic learners, they need to pick up things and handle them. Stuff in books doesn't mean anything to them so it's a different way of learning as Barry said, I think it adds interest and I think you need to learn the skills in really basic types of experiments before you can do open-ended ones, because there's no academic rigour, like we were talking this afternoon, we had kids doing experiments on water quality out in the Derwent River, and some of them had no idea that the fact that they left a little bit in the bottom, like 20 mls, in the bottom of their measuring cylinder was significant for their comparability to other peoples samples, so unless you go through those basic experiments first, there's no academic rigour in the open-ended investigations that they do. So, I think that those little, funny little things we do when we start them off in grade 7, separating mixtures and stuff like that are actually really valuable and they need to get the skills and learn how to handle the equipment properly before they can be turned loose to do their own investigations. Open-ended investigations make science real for them so that's your end point. You want to get to the point when they can actually conduct valid investigations.

Duncan – Thankyou for that

T – Must be my turn. I like doing lots of prac work in my classes after I started off with a certain amount of theory, I like them to use that theory to build something like catapults we did with our under grade 7's, and then they can use that theory, put it into practice, find that it doesn't always work, nice and neat and tidy, and try other options, and maybe even develop some more, some more learning from what they're actually doing.

Duncan – Thankyou

K – Plus I think it teaches them persistence, doesn't it? Which is a really important part of learning to investigate.

T – We're doing catapults at the moment and you can talk all you like about catapults, and when you actually come to build one you find that you have to fine tune it, they can use the practical work to do that. A number of my kids said they find out little things they've never even thought of before, you've never even thought of when talking about the theory, they then have to learn how to use as well.

Duncan – So what, what do you see in the relationship between building catapults and science?

T - Play around with hooks more and things like that, various aspects of that sort of thing and they've got to use that.

Duncan – So you're saying that there is a relationship between the practical work, should be a relationship between the practical work and the theoretical science.

T- Yeah. Steam boats are probably a better example. They learn all about different types of metals, conduction, convection, all those sorts of things and they can put it all together to build their final product. It's like..........?

B – That's an interesting way of going about it T, because I know you do it that way, I tend to approach it more from a different point of view, I tend to approach it when I can, and when it's in place and you know for example, levers and motors(?), throw the stuff to them and get the kids to fiddle around with it and try and find something themselves and then come back and do the theory later and say, well, this is what you saw here and this illustrates a bit of the theory, but I know you do it the other way around, like going through bits of theory first and then getting them to use it .

K – Sometimes though that playing around, if it hasn't got a direction to go in then its really hard for people to make sense, you know I reckon things are mixed, it just depends on what you're doing like, if you gave them some steamboat material and told them to build it, they wouldn't know. I mean they instinctively probably make the boilers out of......... but they wouldn't know why they were doing it, would they?

T – They've got to have a starting point and a finishing point. They usually know they're going to build a steamboat at the beginning, they need to know how they're going to go about it to start with, as experts you don't go and get someone else to build a steamboat, you hire a professional

Duncan – So, who decides on the steamboat, the teacher or the......? S, do you have anything to add or.....?

S– I basically support what everyone said, I think, with some sorts of practical work where children are actually designing things themselves I think it adds some novel things to it, to keep their interest as well, I mean, I don't know, just like the rubber band powered insects we built last year, I think some of the children got really involved in it and it also helped them. I mean some of my children went away and actually did a lot of work at home with their parents and got their parents involved and I thought that sort of adds a dimension too which you don't always get in a formal practical class.

K - The thing that happened with my steamboats that was surprising, was very non-academic kids, excelled in the practical skills in making the steamboat so it gave them an area to really excel whereas when we do a test on conduction, convection, radiation they'd be lucky to pass, but they were really good at practical things, so it was good from that point of view too. My kids loved the steamboat and I was really............

T - Scares you at first doesn't it?

K - I was really reluctant to do it, oh, this..........works and I don't know what they're going to get out of it, but it actually, they loved it and when they gave me feedback it was very positive. The only thing they didn't like was being made to work without their friends

Duncan – But what did they, did they learn?

K – Well they,... I can show you their comments there were things like "it made me realise that I don't have to work with my friends to get work done, in fact I probably got more done without them and" , they had to produce posters and say all the science parts that were applied, so it was a pretty good activity and those who, as I say, are often not the stars of the class in academic performance were recognised by the others in the group as "gee you did a great job building the ......or whatever, " so they had another area they could excel.

Duncan – So the feedback to the class was through charts saying.......

K – part of the assessment was the science stuff, so being able to apply ....and the other part was cooperative group work skills and they had to assess themselves and each other and talk about their skills as a team and rank each person in the team for their contribution, identify what the other persons strengths were, identify what their weaknesses were and what they needed to work on to improve their skills as a team member and then they were just asked for a comment, "did you like doing it?" and they were all very, very positive.

S – How much background did you have to have?

K – well I did that basic stuff like conduction, convection and radiation, the energy trolley, the community trolley, all that stuff you include, insulators and conductors before, and then I did the boat.

S – What, you personally, what, did you have to make a boat first and work it out - you didn't? – you actually just went and did it in the class room?

K – No, but we did have models that previous kids had made in previous years and I also said "this is the equipment, you can have anything here on this trolley, or you can have anything you've brought from home but it's got to be a steamboat and it's got to have the jet thing out the back, and you've got to have a fire safety consideration, apart from that, go for it". So, some built little catamarans, and they....you know it was good fun.

Duncan – So there was a place in there for you as a teacher in providing the basic science knowledge and some demonstration, before you started.

K – yep

Duncan – What grade is that we're talking?

K – seven (7)

Duncan – seven (7). Oh right, okay.

T - Grade nines in forensic, they started off doing a course on basic forensic science, finger prints and the rest of that stuff, then they go out and do it, use it all to find out who did it, with a scenario, and when they've done that bit and they've arrested somebody, they still have to do the same thing again at the trial. So they become lawyers, and ,judges .....different way again

Duncan - So there's a feedback

T - Double-barrelled one really.

Duncan – Well thankyou. I thought that was really useful. I'd like to just actually go through this questionnaire now, and the questions are actually designed, they really just refer to different situations which may occur, or different practices which may occur in your class. This is just a discussion guide really, I'm not, I've no other purpose for this, this afternoon. I won't be taking it in and marking it and there are no right and wrong answers, it's, I'm really interested in your comments as to the appropriateness of the item, or how, what are the pros and cons of a particular approach. This is, these items are actually designed and directed to students so, they're not directed to teachers. But they are trying to describe a, an approach to practical science that may go on in your class.
First one, would anyone like to comment on " I am encouraged to follow my views with the equipment provided" ?

M - I'd say, I'd try to make that a high priority, so I would at least be saying often, if not very often. Just thinking back to the most recent major prac I did with my grade 8 class which was making model electric motors. They had an opportunity to do some research and find out what are some of the simple basic designs, but at least 2 groups went off on significant tangents and tried to come up with a novel design of their own. Unsuccessfully, but at least they, they were encouraged to pursue it as far as they were able, and they were fairly clued in kids, so, they had a chance of succeeding, they just weren't able to quite get it to come together.

S – What grade were they?

M – grade 8

S – grade 8. I don't, I mean, I don't think, I think in my class I'm a lot more structured. I mean I don't think they had a lot of opportunity to actually follow their own ideas. Unless we're doing something open-ended like the rubber band insect, machines, things like that, but I think generally I tend to direct my kids into doing particular activities.

K – You've got some constraints on you haven't you? First of all you've got a certain body of work to get through, a lot of it can't just produce magically equipment for you, you've got to book things ahead and so forth, so you have to use certain amounts of equipment sometimes. Sometimes when you're doing open-ended investigations it's fair enough, but in other times you want them to do such and such at such and such a time because of content constraints, so, I think it's something that adds an ideal to be pursued but constraints mean I have to do sometimes or often, I couldn't do very often because sometimes it doesn't suit me.

B - Often constraints are class size and the type of kids.

M - but if kids come up with novel ideas it's a little bit off the line of what you were intending to do, as long as they go about things in an appropriate way and ask, and discuss with you, I'd encourage them to pursue their own ideas. Sometimes experiments where you might have a specific train in which to follow through and they're not going to see the sorts of things that you wanted if they don't follow your set down method, I suppose it would prevent you from being too generous in giving them latitude, but, that's only, I'd only cut off those avenues if you are concerned that they might not see some significant things that you wanted them to see. You don't want to have to guide them too much, if you don't have to.

Duncan – How about your response to " My investigation is discovering new knowledge"

M - That's a difficult question

Duncan – These are all mixed up, they're very difficult to achieve

B - Depends on what you mean by new knowledge. I mean, new knowledge to them or new knowledge to the scientific world?

M - It's probably unrealistic to think that isn't it? I mean it would be serendipidous you'd think. If they discovered something completely new.......

K - You'd be more likely to think that they'd made a mistake

B - So, you really mean for the kids?

M - That's the intention isn't it?

Duncan – It really means knowledge that's not already known by the teacher.

M- by the teacher?

K – by the teacher?

Duncan – By the teacher or by the .....

M - Not by the student?

K – I'd have to say 'seldom' or 'never'

T - yes. So this is the student's investigations discover new knowledge that's not known by the teacher.

S – I'd say the only place where I've actually seen it, where you do it consistently is when you used to have advanced science and the children did their own investigations, where they picked their own topic and investigated it through the term, and I mean that was very time-consuming and not always successful. I mean you did get some really good results out of some of the students, but, it got a lot of stress on the teacher because you're actually sitting there with some children doing very little and others are doing quite a lot of work. So, there's a big variety in the class.

M - If it was researching information, I would be more inclined to say 'sometimes' but certainly not in practical investigations. I'd be surprised.

T - You've also got new approaches and things you've never thought of doing, does that count?

Duncan – Oh, well, that's a good reason for doing, having that approach really.

T - Sometimes they copy other peoples ideas a lot too.

Duncan – Yes. Okay, well how about number 3 " I'm encouraged to investigate my teacher study questions"

M - Not solely. "very often". The ones that we set up, we do that with a purpose in mind, we want them to find some key relationship or key piece of, or verify often some key piece of knowledge. Along with that, if they're on top of what they're doing and they've got the get up and go to want to investigate further then encourage that to. So I would say encourage to investigate the teacher study question 'very often', but take them further if you're able. Or investigate you own as well.

Duncan – any comments?

B - I think its a good question. It depends again on the group of kids you've got and the size of the class you've got. I mean, my lower tens as you well know, if I didn't encourage them to do the questions like I set them, to investigate those things then they wouldn't do anything or they'd just muck around. They've got to be directed, kids like that have got to be directed. Another classic example, we did some CASP(?) work, which is a project throughout Australia and which was meant to be a student centred project to try and retain their interest and many of those groups over 6 weeks did next to nothing. It's up to them to use their initiative, to investigate the things set in the book in front of them, the teacher became an adviser and there were many, many groups who did next to nothing. Some of the very good groups got a tremendous amount out of it, so I think it depends so much on the group size and your group type, but I think it's a good question to have in there.

Duncan – Okay. Thanks. "I'm shown how to use measuring instruments to measure different quantities. For example, mass, length, time, temperature"

M - It's an age or skill level sensitive question. The younger less experienced students 'often', more experienced, more able students, 'less often'.

T - Grade seven's I do it all the time.

B - Grade nine's I went through it with them because they needed to do it for what they're investigating so, yes, it's mainly in the junior grades and I think here most of us would probably ensure that the kids are shown how to do those things because we regard them as basic skills for investigation as they get older.

K – Sadly many of them think they know how to use it, but they don't actually have a lot of rigour in the way they use it.

M - Most of them need a little bit of sharpening up in skill, in technique, and I think we can all think of different situations, where you keep observing kids to see where they'd introduce parallax error and they're pretty poor at that.

K – They just need to be reminded just about every 10 minutes.

M - Just techniques stuff, like the meniscus in measuring in, well we don't usually look at pipettes and burettes too much these days, but measuring cylinders we certainly do. So just telling the difference between reading the top or the bottom of the meniscus. Senior kids pretty often fall foul of that. What else would there be?

K – Centigram balances they often don't know how to zero them or don't bother to zero them before they've started. Put them on any sort of surface to use.....

B and M - yes

M - Just even.......things with the centigram balance like stabilising it while you're adjusting your mass....

K – and not going six across, three left, 2 across, 2 left

M - Logically stepping up or guessing in half, and in half again. But I think just the one stabilising where you slide the slide, so it doesn't wobble for 2 minutes before it settles.

Duncan – "My teacher shows me how to use equipment correctly"

T - That's again a grade seven thing. Keep an eye on them in the higher grades.

Duncan – There's a role for teaching, for the demonstration of equipment?

T - Oh, yeah.

Duncan – You say it's related to the age of the kid?

T - grade seven

M - The level of intervention is. I would say I always show how to 'often' at least, because it's a function sometimes of how many kids you've got to service, so you might miss some in a period, but, I'm always on the lookout for bad technique, and it doesn't matter what age, I'll step in if I can see bad technique. It's just a fact that have to step in more often for the junior kids because they're more likely to not have developed a technique.

K – But you also have to explicitly teach it in grade seven, in the older grades you'd probably expect that most people would have some idea

M – You explicitly intervene in the older grades, but I guess I wouldn't do an up front lesson, or demo in front of the class and say "Well this is how you read a measuring cylinder or....."

K – I would basically say "if there's anyone who's not quite sure they're doing this the right way you come out the front and have a tutorial with me and everybody else get on with it"

M- Got to be a bit more careful. I do that too but you've got to be careful because you'll get the ones that won't own up and you've still got to keep an eye out for them because they're using incorrectly.

K – Oh, yeah. Which is why you have practice runs.

M - yeah, true

Duncan – What about the writing of reports? “I must write reports about my science practical”

K – ‘often’, not always.

M – yeah, often.

S - I tend to do it most of the time unless it’s something like ‘design your own animal that lives in the Arctic and feeds on nuts under rocks’.

K - I don’t expect a full conclusion like a 5 paragraph talking about patterns and trends and then talking about errors. I don’t expect that for every single prac they do because it takes them .... I mean some of them are writing 3 and 4 page conclusions now, and if you expected that on every prac.......

T - With the catapult one, I just expect them to sort of write down a little note – what went wrong, why they went wrong, what worked, what didn’t, just to keep them ......

Duncan – That’s really good if you’re getting 4 and 5 page conclusions.

K – You should see (Monica H), she’s really at level of a first year university student, already.

S – But you’re teaching mainly the senior grades this year, aren’t you?

K – Oh I am. I’m teaching, well, I’ve got 2 grade 10 classes and they’re very good kids in there, I still get ones that are ....though, in the same class.

T – I like those ones.

Duncan – Now, this questionnaire is designed to have about 6 items addressing the science sort of area, and so we can, although we’ve taken some time over the first section there, and I know they’re all mixed up, we will be able to move on a bit more quickly. Question 8 – “I’m encouraged to do my own experiments with substances provided”

K – You’ve got to put a rider on that. You can’t just give them chemicals and say ‘go for it’ can you, for example? It wouldn’t be safe. Depends on what materials you’re talking about.

Duncan – okay

S – I think when I first started teaching I didn’t have a physics background and I can remember being told by the Head of Science in the States, you know, “Give them the electrical equipment and let them investigate” which was all very well except they blew up all the equipment as well, so, I mean .....

K – flatten all the batteries ....

S – Well, I mean, there’s got to be limits I think.

M - I’d answer ‘sometimes’ to that, because I often encourage covertly, I would only encourage the students that I rate as reliable and sensible, in fact I would actively discourage for the whole group, but then say if someone has a conversation with me and you can see that they’re thinking, and they’ve got, they might be on to something, I’ll say “Why don’t you try that out?”, so, covert encouragement is........

Duncan – I like that link to a conversation that’s going on, that’s really good. “I work scientifically”.

B - I think you’d have to probably, have to decide the, have to explain to the kids what scientifically meant as a lot of them wouldn’t know. So, for the kid to answer that I think you’d really need to outline a little bit more what you mean by scientifically.

M- I'd be, I reckon you'd find because of that thing more kids would answer back down the scale than actually would tend to work scientifically.

Duncan – What's the perception, one of the rationales for practical work is they have experience of acting like a scientist. Perhaps "I work as a scientist" might be the better wording of that, it's a new one I've just put in. Is that an important, is that an important factor for you? Rationale for prac work?

Chorus – yes's.

M - interesting difference between the perception and the actual there. I would like to think if I'm doing a good job the students will work scientifically. Whether they understand that they are, that's probably an added bonus, I guess I'd like them to think they are too but it would be more important for me if they are doing it, rather than they think they're doing it. If they're doing it not knowing it then that's probably quite good really because it's a way of functioning. I mean the cleverer kids should know that they're doing it.

K – Being able to label it as scientific method or just realising that I've got to have results that mean something, so, I've got to work in a particular way, yeah, I think a lot of kids would say 'I've got to work in a particular way to get reasonable results' but they might not realise that it's called, you know, scientific method. That's why we do this, this and this, so it's really, I suppose we don't spend a lot of time teaching scientific method per se.....

M - Not theoretically, but we teach them the steps or process to go through and you hope they pick that up.

K – Yes. We don't actually say 'This is scientific method' and come up with a hypothesis, mainly we do that probably with my better grade 10 kids, when they're doing their planning stuff.

B - So it's not formally

K – not any more, we used to when I first started.

T - Yeah, I'd say we would have done it more

Duncan – Number 10. "I'm encouraged to solve my teacher science problems"

K – encourage to solve financial problems, relationship problem? All my problems?

Duncan – well it comes back to........

All males - interesting question

B - I think with the very good kids you perhaps, you can say that you know 'this is our problem, how do we go about doing it and, you have a go at trying to solve it'. I think with low ability kids, with kids who are not switched on, then they might see it that way, which is a bit of a worry.

Duncan – So if it's the teachers problem they don't need to worry about it?

M - Things just through time constraints we tend to set up the teachers problems for the class to solve more often than we set up the kids problem or we encourage them to figure out the problem and then the solution for themselves, but, I would be sad if there wasn't a bit of an opportunity at least sometimes for the students to pose the problem. I think we should be encouraging that.

K – Though in order to get to the point of posing problems you've got to have a bit of background information, haven't you, and really I think the kids start in grade seven, they don't know much about anything.

S - They don't have much of a background in science.

K - I mean, they know lots about the world but being able to crystallise that into formulating your own problems is a very difficult task. It's quite advanced I'd say, and to think about how they would actually go about making some sort of valid test or experiment to test.

M - but there can be at different entry levels I would think. Say if you're just doing work with magnets say, you can just give the students the stuff and say you know, 'What do these things do?', and they can propose things to investigate and test so, they do. You can probably predict what they're going to test, but, they're given the opportunity to state it themselves. It doesn't have to be terribly rigorous.

K – No. My only frustration with that is I'm obsessive about good use of time I suppose and that can be really time consuming taking that approach, but it is important to take it at times. Like I find it really, constantly trying to overcome time constraints.

Duncan – "My teachers demonstrations are linked to science classwork"

K – I hope I answer 'always'. Sometimes Elaine (?) won't let me do it with the kids because the chemicals or whatever aren't allowed to be, we have to get around it like that.

B - I find I don't do too much demonstrating these days. The Hoffmanns voltameter is one of the few I've done this year.

M - I think the point about it is though that you wouldn't demonstrate something that you're not covering soon or just finished at the time. Like, they're usually matched in time to what they're investigating.

T - with the forensic stuff I demonstrate some of the fingerprinting on the iodide paper and I don't like the iodine paper floating around the lab.

K – Some of the reactivity of metals stuff you can't let them touch it so you have to do some demonstration. It would be really sad if you couldn't do it any more. It's cutting out everything. Alana told me yesterday they weren't allowed to make slides of their cheek cells, and I said 'Well, crikey, what are we going to do?". They've to do it.

Duncan – "I learn how to do Science procedures like heating, dissolving, filtering and evaporating", back on to skills, teaching of skills.

S – Well that's just basic grade 7 skills. I think we'd all do that.

K – I think that's our big emphasis in grade 7. A little bit of background knowledge....

B - When you interpret that understand that we're talking about the junior kids, not the seniors if we say 'very often'. Well, we wouldn't do it very often past grade 7.

Duncan – "I must follow set guidelines for writing experimental reports".

K - Sometimes.

S - I would in most of my classes when we're doing a formal little experiment in class. I would expect them to have an Aim, Equipment, method.

K – Actually when I did the boats, I didn't do that at all. I had them keep a diary and produce a poster as a group and the arrows going to all the different science applications, so it just depends on what experiment it is and whether you want a group analysis or individual.

Duncan – So there's a role for a journal? Is that what you're saying?

K – In some experiments it's more valuable than writing it up like that I think.

S - Especially design sort of process ones, isn't it?

M - I hammer away at set guidelines, but my set guidelines aren't the old formal report writing guidelines. I insist that students always have diagrams that are labelled and with captions or descriptions. I insist that they always write paragraphs about what they've done and I insist that they write paragraphs about what they have learned, discovered, or what new things that they can talk about, but, that's the level of my guidelines that every report has to have, sometimes I'll extend them into the more formal but that's a minimum, and I always insist on that at least.

T - Forensic science is just a diary. During their investigation you can't write a prac like that. Keep an accurate diary and get a conclusion from the information they've got in the diary, then they've succeeded.

K – I wonder how many scientists actually write aim, method, results, conclusion anyway. It's only when you present information. You more often keep a diary of your experiments as you are working on it. I mean, I assume you do but since I'm not a scientist I don't know.

T - They must do. Grade 7 definitely........

K – It's really about who you're communicating to isn't it?

Duncan – "I do hands on science activities to help my understanding of science".

K – Hopefully they're going to put 5.

B - yeah, I think that's important. It mightn't be one of the ideals of scientific investigation and working scientifically but I think it's important. If the kids engage, it keeps them interested, gives them variety in their learning processes.

Duncan – "I do research like real scientists".

T – often

S – I don't think my children do.

T- My grade 7's now are the engineers corp for Alexander the Great, ...working as scientists to.......

M - who are they working for?

T - Alexander the Great, ... occupy time at the moment so they are engineers and not students anymore...

K – I don't really know if I understand what the questions getting at. Do you mean research which is where you have the other thing about new knowledge and knowledge new to who, that stuff?

Duncan – It's asking "are we trying to give the kids a feeling that they're operating like scientists"

K – well I hope I don't......

M - I yeah, if I analyse the time spent in classes and the time spent in research, and be honest, I'll have to say I probably only do that 'sometimes'.

S – I don't think I do it very often.

K - So, do you mean, like, say you were researching on a, like we did that thing on the periodic table, going off and doing that kind of research or, do you mean research by experimentation. I'm not sure what you mean there.

M - I was interpreting it more as investigating

Duncan – investigating. Being like scientists.

K – so, if you mean trying to discover new knowledge through experimentation I would hope they would answer 'often'.

Duncan - or the kids think that they're acting like scientists

B - Your steamboat design..........

S – Do you mean things like using controls and things like that? Is that, I mean that's how I would interpret that.

Duncan – Yeah. I wasn't really trying to get down to it, I'm really trying to get whether the kids feel that they're operating like scientists. "My teachers demonstration", oh, sorry, "I am required to describe my practicals to other students in the class".

S – Sometimes.

K - It's a time constraint thing isn't it? Seldom for me

M - Good question, sort of

Duncan – You've been talking about the charts and the feedback from the kids.

K – Yeah, they...

Duncan – particularly in group activity..

K– and sometimes they have to do an oral presentation to the class too, but, it doesn't happen heaps. It happens like steamboats and open ended investigations. Don't happen heaps because they're very time consuming, maybe do 2 or 3 with the lower grades a year. Senior grades do more designing their own pracs. I'd often report back to the class.

M - It would be good, try to get the prac thing done.

K – It's that time thing again. It's always the time thing.

Duncan – Yeah. This is a repeat question, number 17, "My teachers demonstrations help me understand the theory covered in science classes". We've really dealt with that one I think. "Science practicals help improve my science skills".

B - What do you mean by science skills? Working scientifically?

K – or, basic skills like handling equipment. I'm not sure what you mean, or both? Often, very often.

Duncan – number 19 "Results of my experiments are already known to my teacher".

K – I'd have to say 'often'. Sadly.

Duncan – Number 20, "If I finish the laboratory experiment I'm allowed to do some of my own experimenting".

S –I'd say seldom.

T - I'd say seldom. Maybe, because it makes me nervous.

S – I think there are just too many kids in a class room. I mean when you've got 30 odd kids in a classroom I'd be too worried about kids doing their own experiments.

Duncan – It comes back to your conversation doesn't it?

M - the covert encouragement

K – Usually you're trying to get them to do a lot. I mean, I think kids are going flat out to get everything done.

Duncan – and you've got time constraints.

K – because you're always trying to push them faster than they want to go sadly, and so its a time constraint thing again. As well as a safety issue.

S – I think it's a safety issue really. I mean I, encourage my children once they're finished to pack up and clean up and you know, all those sort of things, in preference to actually doing their own little experiments, because I'm just too worried about what might happen if I'm not actually observing them.

K – It kind of depends on what they're doing, doesn't it?

S – It does.

K – I mean, chemicals and things where they could hurt themselves, you wouldn't allow it, but, if it was magnets you'd say "Oh yeah, play with it for awhile". Just depends on what it was.

T - ....you can do, sometimes

K - to nearly had a fire in her lab. You know that thing where they make their own fuse? Tony C (?) had flames coming up from the steel wool. I nearly killed him.

M - got to use one strand only.

K – Pardon.

M - one strand only.

K – Oh, I know, but of course you've got those students who don't listen to instructions.

B - but they do when they realise that you can

M – Yeah, some of them do and they don't ....

Duncan – "I research questions that my teacher doesn't know the answer to". Well we've dealt with that one.

Chorus – yes's

Duncan – "I make science posters to show what I've found out".

Chorus - lots of time, 'often', 'very often'.

S – 'Often', particularly in junior classes.

T - even higher classes.

Duncan – and in group work?

K – I was actually going to say to you, I'm interested that not very many of the questions so far have dealt with group work skills. There might be some further down, but, yeah, often I'll use posters as a way of several kids working on the same piece of work.

Duncan – "My teacher.........", well that may be related to the model that I'm using...

K – okay.

Duncan – I'll just show you that at the end.

K – alright.

Duncan – "My teacher shows me how to use a microscope correctly when required". Well, that comes down to the skill teaching. "Science practicals help me practice my science skills". Well, that's a repeat question.
"I have instructions to follow when I do laboratory experiments".

K – Hopefully

Duncan – "I play with equipment and substances".

Chorus from all – 'seldom'

Duncan – "My teacher gives me study questions to be investigated". Sounds to me pretty close.
"I make models to explain the work done in science lessons".

K & S – 'sometimes' or 'often'.

Duncan – That's more just feedback isn't it? "My teacher asks students questions about science demonstrations".

S – I very rarely do.

K – I'm not sure what you're asking there. I want that clarified, what does that mean?

Duncan – Well, it's, the teachers actually ask questions to the kids about the demonstration.

K – So I'm doing the demonstration and then I say 'What do you think's going to .....?'

Duncan – yeah.

Chorus – yes's

K – Socratic method, is it called?

Duncan – Yes, you're saying, the questions not good, I need to look at that. "I learn how to use instruments to measure quantities such as length, weight, time and temperature". Well, that's another one of the residual ones. "I do hands on activities in science pracs".

K – That's a repeat as well isn't it?

Duncan – Yep. Well, I've got about 6 for each......

K – and that's to do with statistic validity isn't it?

Duncan – That's right.

K – It's a deliberate thing.

Duncan – Yep. "When I'm allowed to find out for myself I work better at science practicals".

K – Can't answer what the kids will say.

Duncan – You can't answer that. That's really, you don't think that they do perform better if you do have practicals?

K – some might, some will get really engaged.

Duncan - it gets back to the .....

S – It depends very much on the........

Duncan – type of class really

B - When we did the CASP stuff 50% of the class worked quite happily on their own and half decided to have a holiday, so....

Duncan – "My teacher gives me science problems to be solved". Well, that's a repeat. "I make charts to explain the work done". 'I'm encouraged to ask questions about science demonstrations". Hmmm, there's a lot of repeats here. "Equipment I use in experiments is listed as apparatus".

B - No, don't use that word at all any more.

S – I do.

M - I do sometimes, just so they're exposed to it. I tend to use equipment, but I will use it sometimes.

K – Somebody once told me you have individual pieces of equipment and you put them together as apparatus to perform a specific function. So if you've got your filtration stand and your filter funnel and your filter paper then its apparatus but each individual bit is equipment. Is that correct?

Chorus - No.

K – That's how it was explained to me, because I said "What's the difference?".

B - Well, I've tried to minimise the amount of scientific language as a deliberate decision particularly with the kind of classes that I've got. So I try and use common every place words for science words whenever possible, so, for me, it's near enough to say equipment is apparatus and therefore always use the word equipment.

M - I consciously work on vocabulary at times and I tend to go slightly the other way. I think we need to expose people to synonyms all the time, so that they can expand their vocabulary as well. You tend to use one more than others but, I'm of the opinion, try to encourage expansion and more knowledge as well.

K – You've got to give people the language to understand, don't you?

M – Don't labour it but give them exposure, because at some time you might send them to a book and say, you know, "Go and investigate this experiment", and if they come across it and they've never seen it before it slows them down.

T - I take the opposite point of view, I suppose because of the type of kids I've been teaching. They'll say they really don't know what it means they'll switch off. So give them a word they do know what it means and keep them engaged.

M - Yeah, when I use a word that I know is new I'll purposefully say it in conjunction with its more familiar form, and talk about the fact that these 2 words mean the same thing. This one's a more old fashioned or more formal and this one, that we use in common language. If you come across it just know what it's about.

Duncan – "I'm given instructions for hands on science activities". Well, we've addressed that. "I'm encouraged to suggest study questions for investigations". Well, we've been there really haven't we. "I plan investigations to answer questions provided".

Chorus – yes's

K – Yep, it’s an age thing too though. The older kids I tend to do more than the younger ones.

S – More fits in with the grade 9 and 10 syllabus, doesn’t it, then the 7and 8’s?

K – yep.

Duncan – “I use mind maps to explain the work done in science”.

K – yep. ‘often’

T - Should use them more

B / M - sometimes

K – I use them as a study tool as well.

B / M - It’s a good idea.

K – and a starting point.

T - When you do separations and stuff like that.

Duncan – “My teacher outlines safety rules to use”.

SIDE B

S - or tables where they’re actually filling in, if they’ve been done, so I, like my acids and bases unit I actually for each experiment, I actually wrote a sheet and they had a whole series of basically what were their results that they filled in as they did their experiment.

T - I can remember a few they should recall as they go along, so that fit’s that description, but not many.

Duncan – “I’m encouraged to suggest practical problems to be solved”, I suppose we’ve discussed that.
“I’m encouraged to design solutions to my teachers problems”, we’ve covered that.
“I use drama to role play or represent science activities or ideas or processes”.

S – Never in my class. I don’t feel comfortable.

K – seldom

M – It’s one I wish I did more

T – I’ve tried it and it didn’t go down very .....

S – Same here and I’m not comfortable with it at all.

K – There are certain things that I always use role play for, like, The models of matter you have people jumping around being atoms, I always do it every year and I might do role play for chemical reactions or the water cycle. Henry great water cycle, remember that? Just depends on what specific topic we’re doing.

S – I don’t feel I’ve got enough background. I mean I have never been exposed to it and I don’t feel confident to do it myself. The only times I’ve ever done it was with machines where they had to role play a, I don’t know what it was now, a or a toaster, and it didn’t go very successfully so I steer clear of it.

S – I just found it was like organised chaos.

T - Got all the benches around the room one time and I got the grade 7’s, and I gave them a scenario to act out and see...., it didn’t go very well.

K – You know that football thing they do for heat transfer, we did that this year, and the kids just went .... but they actually remembered, it went very well.

B / T - What was it?

K – You know, it’s in some really old book like Windridge, where they have this football analogy to explain the difference between conduction, convection and radiation. So we’re running around the lab with a football and doing models of conduction, convection and radiation and surprisingly many of them actually retain ....

B / T - No accidents

K – No. I had to put (Bradford) out but then I had to put him out every lesson anyway, so that’s alright.

Duncan – “I do hands on science activities to increase my experience of science”.

K – same as been asked twice before

B - What about the results, experiments and results?

Duncan – “I describe what happens in experiments as results”.

Chorus – yes, often

S – and the one about “I learn how to use measuring instruments such as stopwatch, thermometer, metre rule”. Basically, I can’t say that I’ve actually taught how to use a stopwatch.

K – Because they use them so badly

Duncan – It’s one thing that’s come out of this interview, these discussions, is that you think that teaching the skills is really important, whereas you say that you don’t do it very often.

S– Well, I mean, I do the thermometer and the metre rule but the stopwatch I don’t think I specifically teach that. I just assumed

K – People not doing it properly......

S – I don’t think I spend a lot of time on the stopwatch, not as much as I should spend on the stopwatchs in comparison with, things like thermometers and metre rules. I mean I make a real emphasis with thermometers and metre rules and things, but, I don’t think I do with stopwatches. I think when I’ve used them in 9 and 10 I’ve assumed they can use a stopwatch.

K – I had really good students yesterday they managed to screw up the stopwatch. Elaine was ready to kill me because they all think they know how to do it and they don’t.

T - What damaged it?

K – pressing buttons..................

Duncan – “I learn how to use computers to collect and process data”.

K – Say that again.

Duncan – “I learn how to use computers to collect and process data”.

K – Collect data, no, process data, yeah, a bit.

Duncan – "I prepare power point presentations to explain my science work".

K / S – sometimes

Duncan – This is more in that category of that feedback, you know, charts......

S – My 7's are very good at power point presentations. They've done quite a few this year where, but I usually don't say "everyone has to do a power point presentation", I say "you can pick the format of how you're going to present your work", and a number of the children who feel confident with power point will actually present it as a power point presentation, rather than a chart or poster.

K – Yeah, with the numbers so you can read it. (other conversation)

M - Got plenty of space there, you can push it down a bit (also another conversation)

Duncan – (joining Kim and Mark conversation) Oh this box. On the last one – Conclusions. "I describe what I've learnt from experiments as conclusions"

Chorus - often

Duncan – and "The conclusions of my experiments confirm science theory work". That's really related to the fact that the practical work is used to confirm and it's one of the boring things that people already know about the answers, this is what's being said that they already know the answers so it's not very exciting.

T - I would argue that most of the students wouldn't necessarily know the science theory. We would you'd hope. But you'd certainly find some of the kids that already know.

T - If we designed

K – it depends on the type of investigation.

B / M - Sometimes they don't though, do they, and they've got to analyse why not.

Duncan – Well thankyou. I'm not going to worry about the attitude thing at the bottom. You may be interested to know that hardly any kids of the 500 who have answered want more science or want to talk about science with their friends.

K – An interesting thing to know would be how many of them think they could leave science out all together because I think most kids even though they don't like science, I'm constantly confronted by kids saying "I hate science", and I say well, "Why did you choose it then?" "Oh, because you need it." It's important. So they value it.

Duncan – yes

K – But they don't enjoy it necessarily.

B- When you say attitude, that means in this school or just across schools?

(Background conversation going on, not heard properly.)

Duncan – Across schools. This is a standard attitude test used by Curtin plus all their other science research

B - Right

Duncan – But I was just commenting on my, on what I see the kids are doing. I just thought I'd just explain what I was doing, in the last 5 minutes. The hour is up.

S – The kids with the attitude, like I reckon if you asked them the question like, "I'd like to do more science practicals" or something like that, I mean, most of the kids would say that.

Duncan – Oh, they want more science practical

K – Or open ended investigations, my own experiments, most of them would say yes.

Duncan – Yeah, I am actually asking the kids on the front, "What's their favourite", and on the, on the preferred sheet, the second one, I'm asking what they think would be most important, what should be included and you're right, the bright kids are actually saying "We want to answer more of our own questions and do more of our own investigations and less of the teachers work." But then there's the other group who are not confident enough to do that. They want security, so there's almost a, a need for 2 different types of science.

K – That's good because we're offering 2 different courses next year aren't we?

Duncan – Okay, I just thought that I'd... ( ) was really the educational psychologist who's behind the discovery learning method and hands on, he was an educational psychologist not a science teacher and he said that there were 2 continua in curricula; rote learning and meaningful learning, or the other continuum was received learning or discovered learning, and the people behind the discovery science movement put these 2 together, which is not what (......) said. They said that rote learning was received learning and that discovered learning was meaningful. And (.....) actually specifically in some of his work, writings says that isn't a way of thinking about it and since then some people have actually rather than putting them together have put them at 2 dimensions. This is the first attempt about 1982 where they produced this, sort of, 2 – dimensional graph and that was a fellow called (Head), and another one, bloke called (Elton) in 1987 produced this sort of cross here, where discovery and rote reception are, one continuing at right angles to meaningful and rote, and then inside that you get the scientific research here, trial and error solutions play here. He says textbooks are multiplication tables, but I don't, I think he's just filled in ... . I don't agree with that.

(?) - The other one wasn't it, multiplication tables.

Duncan – Yes. I don't agree with the terms they've used there but I, so I've actually found 8 scales to correspond to these. 8 types of practical work to fit on that sort of grid, and this is, these are the 8 things that I'm saying, play is random activity and trial and error, inquiry and problem solving where the students identify a question or problems, students plan an inquiry, students carry out an inquiry or trial their solutions, students answer questions and solve the problems. Directed inquiry is where the teacher provides, or the teacher identifies the question and does all the various parts of the inquiry and the students answer the question and solve the problem. The creative feedback I'm thinking is that meaningful, the top of the meaningful bit which includes the describing, reporting, the discussion, the model making, chart and poster making, role play, simulation, power point, drama, all those sorts of things. Demonstrations where the teacher demonstrates science phenomena, supports science theory and directs students attention, discussion and so on. Practical skill development which is teaching the skills, which you're supposed to be doing, and then the laboratory experiments, the laboratory experiments where you give the kids experiments to do and they follow the instructions, they conduct their experiments safely, they collect data, recognise and correct errors, write reports, draw conclusion, follow guidelines. And then the directed activity at the bottom which is really hands on science activity with work sheets, which are not really....... enough. So, really what I'm, what I'm saying is that when teachers design their prac courses they need to consider all of these consciously.

K – So, are you acknowledging there, that there is value in things like play and rote learning? Because I basically think there is.

Duncan – It depends, yes.

K– But I don't think you should have an over abundance of them.

Duncan – No, depends what you....

B - They shouldn’t be completely absent either.

K – No, because what you, for example, my daughter is sitting her year 12 exams this year and if she can’t learn some things by rote, she’s not going to pass her exams.

Duncan – No, that’s right. But then she’s being asked to as well. And I just wanted to show you some of these, those scales and the codes by the questions I’ve got along here are coded according to the position on those models and the idea is to give the actual questionnaire, is what actually happens in the classroom and the second line is the preferred questionnaire, where what the kids want to happen, and you can actually then....

K – What are the big gaps? What’s that big gap in the first one?

END OF RECORDING

Appendix E: Final Version of SCIENCE PRACTICALS INVENTORY (SPI)

Appendix E: Final Version of SCIENCE PRACTICALS INVENTORY (SPI)

Science Practicals Inventory Final Version (SPI).

SCIENCE PRACTICALS INVENTORY (SPI)

Directions

This questionnaire contains statements about practices that could take place in science practicals.
You will be asked **how often** each practice **actually** takes place.
You will also be asked **how often** you would **prefer** the practice to take place.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted.

Think about how well each statement describes what the science practical is **actually** like for you. Draw a circle around

1	if the practice **actually** takes place	ALMOST NEVER
2	if the practice **actually** takes place	SELDOM
3	if the practice **actually** takes place	SOMETIMES
4	if the practice **actually** takes place	OFTEN
5	if the practice **actually** takes place	VERY OFTEN

Think about how often you would **prefer** each practice to take place. Draw a circle around

Be sure you give an answer to all questions. If you change your mind about an answer, just cross it out and circle another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Practical Example. Suppose that you were given the statement: "Students work on their own when doing science practicals." You would need to decide whether you thought that you **actually** work on your own *Almost Never, Seldom, Sometimes, Often* or *Very Often.* For example, if you selected *Almost Never*, you would circle the **actual** number **1** on your Answer Sheet. If you would prefer to work on your own *Often*, you would also circle the **preferred** number **4.**

Please write your name and other details below.

THANK YOU FOR ASSISTING WITH THIS RESEARCH PROJECT

NAME______________________SCHOOL___________________CLASS ______Male/Female

Remember that you are describing your **actual** *science practicals and then your* **preferred** *science practicals.*		Almost Never / Seldom / Sometimes / Often / Very Often
DM UNDIRECTED ACTIVITY / PLAY		
1. I am given freedom to find out for myself in science.	actual preferred	1 2 3 4 5 1 2 3 4 5
2. I am allowed free activity in science practicals.	actual preferred	1 2 3 4 5 1 2 3 4 5
3. I am allowed free activity which makes science practicals fun.	actual preferred	1 2 3 4 5 1 2 3 4 5
4. I play with equipment and substances.	actual preferred	1 2 3 4 5 1 2 3 4 5
5. I am allowed to find out for myself.	actual preferred	1 2 3 4 5 1 2 3 4 5
6. Freedom to do what I like in science practicals is part of my science learning.	actual preferred	1 2 3 4 5 1 2 3 4 5
7. I am allowed free activity making science practicals more interesting.	actual preferred	1 2 3 4 5 1 2 3 4 5
MD OPEN INQUIRY / PROBLEM SOLVING		
8. I am encouraged to do my own experiments with substances given.	actual preferred	1 2 3 4 5 1 2 3 4 5
9. I do practical work like scientists do.	actual preferred	1 2 3 4 5 1 2 3 4 5
10. If I finish the laboratory experiment I am allowed to do my own experimenting	actual preferred	1 2 3 4 5 1 2 3 4 5
11. I research questions that my teacher does not know the answers to.	actual preferred	1 2 3 4 5 1 2 3 4 5
12. I am encouraged to suggest study questions for investigations.	actual preferred	1 2 3 4 5 1 2 3 4 5
13. I am encouraged to suggest practical problems to be solved.	actual preferred	1 2 3 4 5 1 2 3 4 5
DR' DIRECTED INQUIRY/ PROB SOLVING		
14. I am encouraged to investigate my teacher's study questions.	actual preferred	1 2 3 4 5 1 2 3 4 5
15. I must write reports about my science practicals.	actual preferred	1 2 3 4 5 1 2 3 4 5
16. I am encouraged to solve my teacher's science problems.	actual preferred	1 2 3 4 5 1 2 3 4 5
17. I must follow set guidelines for writing experiment reports.	actual preferred	1 2 3 4 5 1 2 3 4 5
18. My teacher gives me study questions to investigate.	actual preferred	1 2 3 4 5 1 2 3 4 5
19. My teacher gives me science problems to be solved.	actual preferred	1 2 3 4 5 1 2 3 4 5

MR CREATIVE FEEDBACK		
20. I make science posters to show what I have found out.	actual preferred	1 2 3 4 5 1 2 3 4 5
21. I make models to explain the work done in science lessons.	actual preferred	1 2 3 4 5 1 2 3 4 5
22. I make charts to explain the work done in science lessons.	actual preferred	1 2 3 4 5 1 2 3 4 5
23. I use mind maps to explain the work done in science. .	actual preferred	1 2 3 4 5 1 2 3 4 5
24. I use drama to role-play or represent science ideas or processes.	actual preferred	1 2 3 4 5 1 2 3 4 5
25. I prepare POWERPOINT presentations to explain my science work.	actual preferred	1 2 3 4 5 1 2 3 4 5
RR' DEMONSTRATIONS		
26. My teacher's demonstrations are linked to science class work.	actual preferred	1 2 3 4 5 1 2 3 4 5
27. My teacher demonstrates how to use a microscope before I use it.	actual preferred	1 2 3 4 5 1 2 3 4 5
28. My teacher's demonstrations help me understand the theory covered in science classes.	actual preferred	1 2 3 4 5 1 2 3 4 5
29. My teacher questions students while doing science demonstrations.	actual preferred	1 2 3 4 5 1 2 3 4 5
30. I am encouraged to ask questions during my teacher's science demonstrations	actual preferred	1 2 3 4 5 1 2 3 4 5
31. My teacher's demonstrations are important to my science learning.	actual preferred	1 2 3 4 5 1 2 3 4 5
R'R SKILLS DEVELOPMENT		
32. I learn how to use measuring instruments to measure different quantities, for example; mass, length, time, temperature.	actual preferred	1 2 3 4 5 1 2 3 4 5
33. I learn how to use equipment correctly, filtering, evaporating.	actual preferred	1 2 3 4 5 1 2 3 4 5
34. I learn how to do science procedures like heating, dissolving,	actual preferred	1 2 3 4 5 1 2 3 4 5
35. I learn how to use a microscope correctly when required.	actual preferred	1 2 3 4 5 1 2 3 4 5
36. I learn how to use instruments to measure quantities, such as; length, weight, time and temperature.	actual preferred	1 2 3 4 5 1 2 3 4 5
37. I learn safety rules for using science equipment.	actual preferred	1 2 3 4 5 1 2 3 4 5
38. I learn how to use measuring instruments, such as; stop watch, thermometer, metre rule.	actual preferred	1 2 3 4 5 1 2 3 4 5
PLEASE TURN THE PAGE TO ANSWER THE QUESTIONS ON THE BACK		

R'D LABORATORY EXPERIMENTS		
39. The AIM of each experiment is clearly stated.	actual preferred	1 2 3 4 5 1 2 3 4 5
40. Equipment I use in experiments is listed as APPARATUS.	actual preferred	1 2 3 4 5 1 2 3 4 5
41. I draw diagrams of equipment used in experiments.	actual preferred	1 2 3 4 5 1 2 3 4 5
42. In experiments I follow instructions listed as METHOD.	actual preferred	1 2 3 4 5 1 2 3 4 5
43. I describe what happens in experiments as RESULTS.	actual preferred	1 2 3 4 5 1 2 3 4 5
44. I describe what I have learned from experiments as CONCLUSIONS.	actual preferred	1 2 3 4 5 1 2 3 4 5
45. Conclusions of my experiments confirm science theory work.	actual preferred	1 2 3 4 5 1 2 3 4 5
RM DIRECTED ACTIVITY		
46. I have instructions to follow when I do laboratory experiments.	actual preferred	1 2 3 4 5 1 2 3 4 5
47. I am told what to do when I do experiments.	actual preferred	1 2 3 4 5 1 2 3 4 5
48. I am given instructions for hands on science activities.	actual preferred	1 2 3 4 5 1 2 3 4 5
49. I have worksheet questions to answer as I do hands on science activities.	actual preferred	1 2 3 4 5 1 2 3 4 5
50. I am told what to do to help me learn science.	actual preferred	1 2 3 4 5 1 2 3 4 5

THANK YOU FOR ASSISTING WITH THIS PROJECT