Science and Mathematics Education Centre

AN EVALUATION OF THE LEARNING OUTCOMES IN ENVIRONMENTAL SCIENCE FROM A FIELD-BASED WATER QUALITY ENVIRONMENTAL UNIT

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ABSTRACT

This thesis validates the Science Laboratory Environment Inventory for the first time in a field based environmental setting using a water quality-monitoring program within a girls' high school and compares the cognitive achievement of students in the water quality-monitoring school with those in non-water quality-monitoring schools. The psychosocial learning dimensions of the water quality-monitoring program are assessed using a modified form of the Science Laboratory Environment Inventory.

The results indicate that students involved in the water quality-monitoring school were more homogenous and ranked higher in their cognitive achievement and transferability of concepts than students in the non-water quality-monitoring schools. Pre and post testing together with anecdotal information affirmed that there was a direct association between the quantitative results and qualitative information in relation to the learning dimension scales of the Science Laboratory Environment Inventory.

Comparisons were made between similar water environmental programs in different countries and the water quality-monitoring school program results. The use of skills and constructivist techniques indicates that the water quality-monitoring program together with real life problem solving work is an effective method for improving science learning.

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CHAPTER 1

INTRODUCTION

1. 0 Introduction

It has been observed that students are more capable of assimilating concepts and processes when out in the field, than when working in the laboratory or classroom situation (Michie, 1998; Pohl, 1996). The capacity of students to assimilate and transfer information quickly becomes significant although various teachers, both here and overseas, use different methodologies to teach outdoors in the field. These methodologies include discovery learning, constructivism and combinations of different methods. Nonetheless, it is the author's experience, using an environmentally based water quality-monitoring program, that the students seem to assimilate information faster and are able to transfer information better in the field compared with working in a laboratory or classroom situation.

There are many schools in Australia that operate water quality-monitoring testing programs such as Streamwatch (Waterwatch, 1995). These programs have been devised by the various water corporations in each State and are under the umbrella of Waterwatch, Australia. Although there are anecdotal comments that the program 'works' because of its hands-on nature and the perceived student enjoyment of the program, there is no evidence as to why or how the enjoyment of learning is achieved within the program. Therefore, there could be some factors or processes that stimulate students to achieve and transfer information better while working out of doors. Whatever these are, their identification might assist in the development of better teaching techniques and thus improved learning for science students.

There is a paucity of research in field-based learning other than what is anecdotal. The literature indicates that there are associations between student perceptions of their psychosocial environment and their cognitive achievement but there has been little research in environmental studies specifically in an outdoor field program. Investigating this will require a brief review of learning styles and patterns, methodologies and the use of an instrument that assesses the learning dimensions within a science outdoor setting.

Arising from the research on psychosocial learning environments of Fraser (1982), Fraser and Fisher (1983a), and Fisher and Fraser (1990), the *Science Laboratory Environment Inventory* (Fraser, Giddings, & McRobbie, 1991) has been chosen as an appropriate instrument for this study as it has been specifically developed to assess the learning dimensions within school and university laboratories and has been validated by many researchers (e.g., Fraser, 1998; Fraser, Giddings, & McRobbie, 1991; Giddings & Waldrip, 1993; Henderson & Fisher, 1998; Wong & Fraser, 1995). As the water quality-monitoring program is a science unit, it is perceived that using and validating the Science Laboratory Environment Inventory in an outdoor science learning program will benefit researchers and teachers by providing them with an instrument that may be used in the field.

1. 1 Historical Background

In 1987 Dr William Stapp from the University of Michigan launched an environmental program that was to become the basis of water quality-monitoring programs in educational institutions. The program utilised computers and scientific method to improve environmental programs in community based water quality-monitoring programs. The program was brought to Australia in 1989 by the New South Wales Government, as there were major concerns about improving the water quality of rivers. The program in NSW was called Streamwatch. Sydney Water, the water authority of NSW, initiated Streamwatch as a program in 1990. The intention was to encourage schools, through their curriculum, and community groups to become involved in monitoring and restoring the quality of Sydney's waterways.

In 1993, the Australian Federal Government launched a national community based water quality-monitoring initiative called 'Waterwatch'. This is a project within the Australian Nature Conservation Agency that provides national coordination and financial support for water quality programs in all states and territories.

Streamwatch is an international program and there are similar programs that operate overseas. However, to date no formal evaluation of these programs with regard to their effectiveness has been completed.

The main components of Streamwatch are:

- Quality data gathering by regular monitoring of a local waterway.
- Establishment of good links in the local community to ensure that other stakeholders in the water quality issue are actively engaged in the Streamwatch project.
- Regular communication of test results and information about resultant action between participants via email.
- Strategic questioning used to empower the participants to find local solutions for the improvement of their local waterways.

In each of the above components, students work in the field and in the laboratory classroom and learn a variety of skills, concepts and knowledge, as a result of their direct involvement in environmental work.

1. 2 The School Situation

In 1994, at the request of the Roads and Traffic Authority in Sydney, the Streamwatch water quality-monitoring program commenced at the school where the researcher works. The water quality-monitoring program was incorporated into the school's science syllabus; each class is rotated through the program with their own teacher. In all the Year 10 classes observed, the majority of the students are competent in the fieldwork that they do. From direct observation and formal assessment tasks in the author's school, it appears that students who have been involved in water quality-monitoring have applied the concepts learned in the field readily and more effectively than if they were in a normal laboratory situation (Pohl, 1996).

Within the author's school, the water quality-monitoring program is incorporated into the Year 10 science program. Each year 10 class is rotated through the program to provide the students with an integrated and applied approach to environmental matters that are the direct consequences of natural and human impacts on the environment.

Prior to going to a local creek, the students are trained in the use of water testing equipment and the theoretical aspects of the various parameters, for example dissolved oxygen, nitrate and phosphate, as well as habitat auditing. In the field, students are taught to relate the parameters they are measuring to their observations and make informed decisions about their discoveries. They are encouraged to question and act on what they have done as well as plan for remediation and who or what authority should implement the desired remediation. Often the students implement their own ideas in consultation with their teachers and the local government authority. The measurements together with details of actions the students have taken, are sent to Sydney Water Streamwatch and the local government authority. The authorities provide feedback as appropriate.

The students are also encouraged to utilise what they have learned in other subject areas. Their other subject teachers also encourage this. As a consequence the students develop their own specific talents in an integrated manner, allowing them to maximise their learning about the environment. For example, one student developed her botanical drawings and integrated these with her science course by classifying the plants that she had drawn. Another student wrote a musical composition about the local creek which was played publicly at a Streamwatch Open Day. The students are also encouraged to publicise their findings of the water quality of the creek in the local newspaper and share their experiences with other students in other schools using the Internet.

1. 3 Background to the Study

The past 30 years has seen international research efforts involving the conceptualisation, assessment and investigation of aspects of classroom learning environments as an important field of study (Fraser, 1994; Fraser, 1998b; Fraser & Walberg, 1991). Anderson and Walberg (1968) developed the *Learning Environment Inventory* that focussed research on the quality of learning environments from the perspective of the student. As the science laboratory is a major facet in the teaching of science, the *Science Laboratory Environment Inventory* (SLEI) was developed and used by Fraser, McRobbie, and Giddings (1993) in cross-national validation studies which showed it was a reliable and valid instrument. More recently, Wong and Fraser (1995) provided further cross-cultural validation information on the SLEI using actual and preferred forms of the instrument. The 'actual' version asks students to rate their current laboratory environment and in the 'preferred' version, students are asked to rate the laboratory environment ideally liked or preferred. Items in each version of the questionnaire refer to similar aspects of the laboratory environment but, whereas an item in the actual form is "Students in this laboratory class get on well as a group", the corresponding item in the preferred form is "Students in this laboratory class would get on well as a group" (Henderson & Fisher, 1998). Furthermore, students' perceptions on the SLEI scales were correlated positively with their attitudinal outcomes (Fisher, Henderson, & Fraser, 1997). Henderson and Fisher (1998) assert that the SLEI can be used to assess student perceptions within the laboratory environment, and by assessing the differences between actual and preferred on a particular scale, the teaching and learning process can be optimised to bring about improved learning outcomes. While there are cross-validation data available on the SLEI (Fraser, McRobbie, & Giddings, 1993; Wong & Fraser, 1995) this study aimed to modify and use the SLEI in an environmental outdoor setting for the first time and to validate it for use in such situations. Comparisons are also made with students who are not involved in a field based science program.

1. 4 Rationale

Environmental education in high schools is usually taught theoretically either in an elective such as environmental chemistry in the New South Wales senior chemistry syllabus or through informal situations such as excursions in junior high school (Michie, 1998; Price & Hein, 1991). By way of example, the author's school has excursions to the Botanical Gardens to examine plant diversity, a Beach Science excursion to examine the relationships of fauna and flora in a tidal zone and a zoological excursion. These excursions highlight curriculum requirements but do not consider in context the human impacts on the fauna and flora and their ecological relationship to humans or the need for conservation of fauna and flora. Such excursions may be largely an exercise in taxonomy. The theoretical applications in junior high school often amplify concepts without examining real world problems in a real world situation (Disinger, 1984). Students, through theoretical considerations and problem solving within the classroom, become aware of the issues but they often appear not to be able to relate this learning to the real world (Michie, 1998; Orion & Hofstein, 1994). As a result, students often obtain a narrow view of the world around them and do not conceptualise the significance of environmental issues that directly or indirectly confront them (Lisowski & Disinger, 1987).

The water quality-monitoring program however, allows students to become involved in authentic situations through the monitoring of a local stream or river and to use the data collected to assess the problems involved. The students then have to find relevant solutions to the problems that they encountered. This often provokes students to find their own solutions and develop critical thinking that has arisen from their findings, and this helps the students to develop a social awareness of the world in which they live. Students who have been involved in the water quality-monitoring program gain confidence in science and other subjects and appear to be able to find solutions and transfer ideas better than if the work was theoretically based (Moreira, 1980; Pohl, 1996).

At a practical level, teachers are often not equipped to deal with authentic situations due to lack of expertise, timetable constraints, and other external pressures placed on them. For example, students are often pressured to succeed in examinations. These pressures come from parents, teachers, educational administrators, and often from the students themselves. Students may be affected to the extent that they feel they must achieve the best possible outcome. The result is that they often achieve high marks because of the mechanistic approach that they use and as a consequence may have little real understanding of the concepts and issues involved (Disinger, 1984; Roth, 1992).

Because of its in-field and authentic approach, the water quality-monitoring program provides an avenue where students may use their individual capacities while building on specific constructs to develop their thinking and translating their thoughts into actions that are positive and meaningful in a real world situation. The water quality-monitoring program has components of equipment usage training and theory that are taught in the classroom, for example the physics needed to correctly use a turbidity tube or how a photometer uses light to measure specific ions in solution. Theory and equipment usage are developed further through practical involvement in the field. The authenticity of the field situation ensures that students can use their knowledge and skills to develop further constructs in a very real and practical manner.

1. 5 Aim and Objectives

The overall aim of this thesis is to evaluate the effectiveness of a water quality-monitoring program with particular emphasis on students' fieldwork. The specific objectives are as follows.

1. To modify the existing Science Laboratory Environment Inventory and validate it for use in outdoor learning situations.
2. To use the Science Laboratory Environment Inventory to determine differences in the actual and preferred perceptions of students of their learning environment when they are working in the field on a water quality-monitoring program.
3. To determine the effectiveness of the water quality-monitoring program on students' reporting on fieldwork, concept learning, and academic achievement.
4. To investigate associations between qualitative anecdotal evaluative aspects of the program and the quantitative data gathered by the Science Laboratory Environment Inventory.
5. To compare the effectiveness of the field based water quality-monitoring program in other countries that have different environmental education settings.

1.6 Significance

Most schools, irrespective of whether they are primary or secondary, do little in the way of regular fieldwork in the sciences (Michie, 1998). Fieldwork is usually practised as excursions. Excursion material is usually well prepared before-hand, commonly as worksheets that demand a tick or a simple fill in answer (Griffin, 1994; 1996). These worksheets do not demand the use of higher cognitive processes or involvement with real life activities. The water quality-monitoring school's worksheets provide this higher level by giving an avenue of guidance into discovery and better assimilation and transferability of concepts and knowledge.

As reported by teachers, fieldwork is often considered as just another 'hands-on' experience and happens infrequently and is not considered as a major teaching tool as the time taken to do it properly is apparently disproportionate to teacher preparation time and curriculum flexibility (Michie, 1998). A consequence of this is that the evaluation of the 'hands-on' approach outside the laboratory in high schools is minimal. However, there is abundant qualitative literature based on anecdotal evidence (Cantrell & Barron, 1994; Disinger, 1984; Doherty, 1992; Doran & Hejaily, 1992; Duckworth, 1978; Falk & Balling, 1982; Ignatiuk, 1978).

However, there is paucity of literature when considering fieldwork in high schools and whether students learn to apply acquired information and perform other relevant tasks better while doing fieldwork. This study provides additional information in this area by investigating the associations between students' perceptions of their psychosocial environment and student achievement.

This study contributes to the research through the evaluation of a water quality-monitoring program. Studies consistently have shown evidence of associations between student perceptions of their classroom learning environment and student outcomes, even when other variables such as ability have been controlled (Fraser, 1994; Fraser, Walberg, Welch, & Hattie, 1987; Haertel, Walberg, & Haertel, 1981). Research studies (Fraser, 1994; Fraser & Fisher, 1983b) have noted that a closer conformity between actual and preferred environments enhances student learning. Furthermore this study is unique, as it is the first time that the Science Laboratory Environment Inventory has been used in a field based program. Previous research has been focussed on science students involved in physics, chemistry or integrated science classes (Henderson, 1995).

1. 7 Limitations

The limitations imposed on this thesis have arisen from the lack of school involvement in the research due to school policy decisions. Fifteen schools were invited to participate. Only five schools were willing to participate. A total of 580 students were drawn from water quality and non-water quality-monitoring schools. The water quality-monitoring school was constrained to 209 students. This was due to timetabling and the necessity to cycle the students through other topics in year 10. The data were collected from all year 10 classes that were involved in the water quality-monitoring program as part of their science program. Three hundred and seventy one students from four non-water quality-monitoring schools were involved to obtain a comparison of student achievement between the two programs and validate the Science Laboratory Environment Inventory. Data on student achievement from non-water quality-monitoring schools were based on the results of an end-of-year moderator examination in science, whereas in the water quality-monitoring school student achievement was based on a water quality-monitoring common test as well as the end-of-year science moderator examination.

Gender is considered as a limitation as individual schools imposed various restrictions based on the policies of the NSW Department of Education and Training's child protection regulations.

1. 8 Thesis Overview

Included in Chapter 1 has been an introduction to the thesis, together with the historical background of the water quality-monitoring program and a description of the school situation in which the water quality program is conducted.

Chapter 2 examines the literature that is pertinent to the water quality-monitoring program. It examines learning models and environments. Learning patterns and styles in the light of student outcomes and the use of the Science Laboratory Environment Inventory as an instrument for measuring dimensions within the field and the normal classroom is addressed. Fieldwork and its relationship to constructivism, learning and cognitive achievement is considered.

The research design and the quantitative and qualitative methodology are outlined in Chapter 3 together with the objectives that this thesis addresses. Previous research using the Science Laboratory Environment Inventory is also considered. The population sample, data collection and treatment are outlined. The chapter includes a description of the methodology used in the pre and post topic testing, cognitive achievement and other qualitative information. Procedural processes used for handling the data are also described.

Chapter 4 presents the results concerning the use of the modified form of the SLEI. Statistical tests are used to assess the validity of the modified SLEI and associations between students' cognitive achievement and their perceptions according to the SLEI. Differences with regard to cognitive achievement between the water and non-water quality-monitoring groups are given. The SLEI is shown to be valid and may be used to quantify the learning dimensions in the field. Through statistical analysis of the data, cognitive achievement and the transferability of concepts are discussed.

Chapter 5 examines quantitative and qualitative testing with regard to knowledge and understanding and the ability to transfer concepts. The pre and post topic testing is supportive of the statistical analysis of the SLEI. Qualitative data obtained during pre and post topic testing are also given. The results of 100 summarised vignettes from the students in the water quality-monitoring program are a component of supporting anecdotal evidence. The findings from the vignettes and the pre and post topic testing are indicative of the effectiveness of the water quality-monitoring program and reinforce the findings from the use of the SLEI.

Chapter 6 considers the evaluation of water quality-monitoring programs in both developing and developed countries. The chapter considers the types of programs and curricula as related directly to the water quality-monitoring school in order to place it in context with local and global environmental education programs. The purpose of this chapter is to provide an insight into the type of curricula offered and to demonstrate the need to utilise constructivist programs such as the water quality-monitoring program as means of achieving more effective teaching and learning.

Consideration is made of extra-curricular and excursion activities that are being used in various countries. The considerations arose from discussions with schools and Ministries of Education in other countries. The main issues are related to fieldwork, assessment and methods in relation to the water quality-monitoring school in

Australia. The chapter focuses on constructions, cognitive achievement, skills and knowledge within teaching strategies used and the need for real life problem solving to enhance student learning.

In Chapter 7 the conclusions from the study are drawn together with reference to the research questions. The chapter also includes the recommendations and limitations of the research together with suggestions for future studies.

Appendix 1 of this thesis contains the background needed for both students and teachers together with the environmental, chemical and biological aspects needed to implement the program. It serves to provide background information for teachers as an example of a program that is effective within a high school. This information is included to demonstrate the various aspects of implementing a water quality program and the information needed for both students and teachers.

Appendix 2 contains both the actual and preferred forms of the SLEI together with modified version used in this study. Appendix 3 contains relevant letters required by the NSW Department of Education and Training.

CHAPTER 2

LITERATURE REVIEW

2. 0 Introduction

This literature review describes previous research on classroom environments with a specific focus on the Science Laboratory Environment Inventory as an instrument to assess learning environments, learning models, and methodology. Fieldwork is considered within the context of existing teaching, learning and cognitive theories. The review also relates some of the historical aspects to the cognitive processes involved in environmental education specifically within the water quality-monitoring program. The review indicates the paucity of empirical research on assessment and learning in subjects conducted outside of the classroom or laboratory. Hence the significance of this thesis.

2. 1 Learning Environments

An optimal learning environment is essential for the development of learning patterns if nurturing and construction of intellectual development is to be fostered in the student. This requires that the learning patterns and importantly the real world learning situation of field based activities can be mapped in relation to learning environment dimensions. Such mapping is vital in the development of learning environments and the development of conceptual understanding (Kaput, 1987).

Science teachers, according to Wiggins (1989), are role models of the methodology of thinking and acting for students and provide the stimulus inherent in a given learning dimension. The literature suggests that the research into learning environments needs to be effectively modelled to determine which learning environments lend themselves effectively to the teaching of mathematics and science. There is a need to do this particularly in environmental science education, as there is little research in this area.

In regard to modelling and measurement of the learning environment, the focus has been primarily based on student perceptions of the quality of the learning environment within a class context rather than within the framework of the individual's view of the world, and the specific learning experiences that the individual experiences. That is, a measuring instrument needs to be developed to measure the constructivist and hypothetical deductive outcomes in relation to the student and the learning environment.

Bobbett and French (1991), and McBride and Carifio (1995), indicate that sensitive instruments are necessary for assessing learning dimensions. The SLEI is such an instrument as it sensitively obtains students' perceptions about learning environment dimensions that are directly related to laboratory settings (Fraser & McRobbie, 1995). Hunt (1975) and Fraser and Fisher (1983b), have demonstrated that student achievement is closely related to the students' preferred environment and importantly that achieving a closer match between students' actual and preferred environments is likely to lead to better student outcomes. That is, the closer the match between the actual and the preferred environment, the better the student outcomes. Logically the use of the SLEI could provide data about learning environment dimensions that if altered appropriately would bring about increased gains in student achievement (Henderson & Fisher, 1998).

Teachers, although they would like their students to gain better outcomes, often do not administer instruments such as the SLEI as they are either unaware of such an instrument or may be constrained by time or faculty policy. Consequently, they often do not use instruments that are available to them. As a result, there appears to be little evidence originating from the classroom that relates to learning environments other than that completed by researchers.

Learning in the field is dynamic and provides challenges for students to solve real life problems, making learning meaningful within the student's own particular context. While this notion is constructivist, the assessment of the learning environment dimensions that are operative in the field may be similar to that of laboratory settings. The work of Giddings and Fraser (1990), Moreira (1980), Scott and Heller (1991), and Ross (1995), suggest that the learning environment dimensions reinforce learning patterns. If scientific, practical and thinking skills are undertaken in a field based situation the learning environment dimensions may be more closely linked and may well be more constructivist than in a laboratory setting.

Teachers may well find that the field setting is more relevant to teaching in a constructivist manner than in the laboratory, as there may be greater opportunity to develop sense making processes that involve active negotiation and consensus building (Fraser, 1998a). This is because of the greater demand placed on the students to make sense of what they are learning in a dynamic authentic situation.

Within the normal laboratory this is not always possible because there are demands on teachers that place them in a situation where they may not be able to implement constructivist techniques. This is because they may need to take on a variety of roles, such as laboratory technician, counsellor and administrator. Time constraints such as having to deal with different groups of students using the same laboratory six or seven times a day in 40 minute periods is another factor that limit teaching strategies (Deutsch, 1949; Lave, 1988; Pohl, 1996). Consequently, learning environment dimensions and teaching strategies suffer. However, much of what happens in the learning environment and its dimensions is dependent on what Fraser and Tobin (1989) claim are exemplary management techniques and the personality of the teacher in providing the motivation within a specific setting (Berryman, 1991; Rosenthal and Jacobson, 1968).

Teachers may assess learning dimensions but in an unstructured manner as they reflect on their own teaching. In the classroom laboratory setting, the SLEI is available for assessing learning environments and this could be more widely used to provide feedback to teachers. It would be useful to extend this potential feedback situation to field based situations. However, there is a gap in the literature in assessing learning dimensions in an environmental science field based situation.

What is available is either anecdotal or a series of observations from which a series of assumptions have been made to fit a particular model. Much of the research is based on classroom or laboratory situations and may not be applicable to out-door environmental education. The work to date on learning environment dimensions that may be utilised and related by way of inference to outdoor environmental programs is that of Fraser (1981, 1982, 1989), Fraser and Fisher (1983a), Fraser and Treagust (1986), Fisher and Fraser (1990), Giddings and Fraser (1990), Giddings and Waldrip (1993), and Henderson and Fisher (1998).

Giddings and Fraser (1990), and Giddings and Waldrip (1993), have indicated that constructivism in the relevant learning environment is measurable and valid given current perceptions and parameters. The work of Fraser and Deer (1983), Fraser and O'Brien, (1985) and Taylor, Fraser, and Fisher (1997), has successfully used quantifying constructivist instruments as well as the SLEI in schools to determine the various aspects of the learning environment and their association with student outcomes.

As the scales of the SLEI measure high school learning environments, and as the water quality-monitoring program is operant in a high school setting, the SLEI may be considered as an instrument with some modifications for assessing field-based programs. Further work in this area is required within different schooling contexts and specifically with environmental education. Specific research on learning environments is considered next.

2.2 Research on Learning Environments

There has been a considerable amount of work on the assessment of psychosocial perceptions in learning environments within the classroom. Trickett and Moos (1973) and Moos (1974, 1980), conceptualised the classroom environment as a framework that described social and psychological dimensions within the psychosocial context of learning environments. These dimensions are the Relationship, Personal Development, System Maintenance and System Change.

Moos (1974) developed a scheme for classifying social environments. In the scheme were three types of dimension. The Relationship Dimension identifies the nature and intensity of personal relationships within the environment and assesses the extent to which people are involved in the environment and support each other. The Personal Development Dimension assesses the directions along which personal growth and self-enhancement tend to occur and the System Maintenance and System Change Dimension involves the extent to which the environment is orderly, controlled and responsive to change. The outcomes of Moos's (1974) work included the studies by Moos (1979), Walberg (1979), and Moos and Trickett (1986), involving the *Classroom Environment Scale* (CES), the *Learning Environment Inventory* (LEI) (Fraser, Anderson, & Walberg, 1982), and the *My Class Inventory* (MCI) (Chavez 1984; Fisher & Fraser 1981). Haertel, Walberg, and Haertel (1981) established associations between student perceptions and achievement. Person environment fit studies (Fraser, 1982; Fraser & Fisher, 1983) confirmed the notion that students work better in their preferred environments. The preferred or ideal environments are those that are concerned with goals and value orientations and measure perceptions of the preferred classroom environment.

Scales and dimensions, such as the Relationship and System Maintenance and System Change dimensions of Moos (1974), have been synthesised and streamlined since they were first used in evaluation aspects of the Harvard Project Physics. The scales used in the SLEI as a result of this previous work have proven to be reliable in assessing the learning environments of a classroom. Associated research with the *College and University Classroom Environment Inventory* (CUCEI) (Fraser & Treagust, 1986), the Learning Environment Inventory (LEI) and the Classroom Environment Scale (CES) all demonstrate the validity of such instruments in assessing the psychosocial learning environment.

Instruments were developed further to assess qualities of the classroom learning environment from the perspective of the student, undertook classroom environment research which focussed on student outcomes (e.g., Fraser 1998; Fraser & Walberg 1991; Henderson & Fisher, 1998). Wubbels, Creton, Levy, & Hooymayers (1993). The SLEI associates student perceptions with the nature of the classroom. Other research on constructivist learning environments has been carried out by Taylor, Fraser, and Fisher (1997). Other instruments that have been used in assessing laboratory dimensions and attitudes include the *Science Laboratory Activity Questionnaire* (Ost & Swanson, 1968), and the *Test of Science Related Attitudes* (Fraser 1981). The next section deals with the SLEI and its development.

2. 2. 1 Science Laboratory Environment Inventory

As science education has unique components of practice and theory, the Science Laboratory Environment Inventory (SLEI) was developed specifically for use in science laboratory classes at senior high school and tertiary levels. Fraser, McRobbie, and Giddings (1993) developed the Science Laboratory Environment Inventory specifically for science laboratory use and McRobbie and Fraser (1993) initially used the SLEI to investigate the associations between learning environments and student achievement. This study is using the SLEI in a field based situation and using it for comparing field activities with normal classroom laboratory perceptions for what is understood to be the first time.

According to Fraser, Giddings & McRobbie (1995) the initial development of the SLEI, was guided by five criteria. First a literature review (Hegarty-Hazel, 1990b; Hofstein & Lunetta, 1982; Tobin, 1990; Walberg, 1991; Woolnough, 1991), second, an examination of all scales contained in all existing classroom environment instruments for non laboratory settings (Fraser, 1986). Third, the scales of the instrument needed to cover the categories espoused by Moos (1974) for conceptualizing all human environments (see p. 21).

Fourth, science teachers and students at the upper secondary and university levels were asked to comment on the relevance of the dimensions and items. Fifth, the instrument needed to be time efficient in answering and scoring.

The initial SLEI contained eight scales but only five survived field-testing and these are Student Cohesiveness, Open-Endedness, Integration, Rule Clarity, and Material Environment. Further revision and the writing of new items eventually resulted in 35 items, with seven items per scale. Careful attention was paid to making each item suitable for measuring both actual and preferred classroom environment.

The scoring direction is reversed for approximately half of the items. Each item is responded to on a 5-point scale with the alternatives of almost never, seldom, sometimes, often, and very often. These five response alternatives were chosen because they are identical to those that have proved to be meaningful and useful in numerous studies involving the use of the Individualised Classroom Environment Questionnaire (ICEQ; Fraser, 1990).

The SLEI has passed through numerous revisions based on reactions from colleagues with expertise in questionnaire construction and science teaching at the secondary and higher education levels.

The SLEI has been internationally cross-validated using as a sample 3,727 senior high and university students in 198 science laboratory classes in six countries (Australia, Canada, England, Israel, Nigeria and the United States of America). The results demonstrated that educators and researchers could use the SLEI with confidence (Fraser, McRobbie, & Giddings, 1993).

From this and the work of Fraser (1989), and Fisher and Fraser (1990), the dynamics of student teacher relationships are a measurable interaction in the teaching learning process and relate to environment dimensions (Giddings & Waldrip, 1993). Further to this, Fraser (1981, 1989), Fisher and Fraser (1990), and many others have successfully demonstrated that environmental factors and the perceptions of people in those environments may be quantified with a high degree of accuracy (Giddings & Fraser, 1990). Fraser, Giddings and McRobbie (1991) further validated the SLEI as an instrument of personal assessment. Personal forms of these questionnaires assess a student's individual perceptions of the classroom environment whereas class forms ask for the students' perceptions on how all students might view the classroom environment.

The SLEI exists in two versions, an actual version, where students are asked to rate their current laboratory environment, and a preferred version, where the students are asked to rate the laboratory environment ideally liked or preferred. The items in both versions refer to similar aspects of the laboratory environment. A copy of both the actual and preferred versions are provided in Appendix 2.

The Science Laboratory Environment Inventory initially contained 72 items with nine items belonging to each of the eight scales. After extensive field testing the final and more valid version of the Science Laboratory Environment Inventory was reduced to 35 items with seven items in each of five scales. Each item is responded to on a five-point scale with the alternatives of Almost Never, Seldom, Sometimes, Often and Very Often. The scoring is reversed for approximately half of the items. The five scales are Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment. From Moos' (1974), study for classifying human environments Student Cohesiveness is a relationship dimension, while Open-

Endedness and Integration are personal development dimensions, and Rule Clarity and Material Environment are system maintenance and system change dimensions. Table 2.1 provides the five scales, a description and a sample item for each scale.

Table 2.1
SLEI Scales, Description and Sample Item

Scale	Description	Sample Item
Student Cohesiveness	is the extent to which students know and support each other.	Members of this laboratory class help me.
Open-Endedness	is the extent to which divergent approaches to experimentation are used.	I decide the best way to proceed during laboratory experiments.
Integration	is the extent to which the laboratory activities are integrated with theoretical activities.	My laboratory work and regular science class work are unrelated.
Rule Clarity	is the extent to which student behaviour is guided by formal rules.	There are few fixed rules for me to follow in laboratory sessions.
Material Environment	is the extent to which equipment and materials are adequate and available.	The laboratory equipment which I use is in poor working order.

This study uses the SLEI to assess learning environments in a field based environmental program with students in middle high school. The study compares the differences in learning attitudes and outcomes between students participating in the field-based activity with students who are not involved in the field based activity.

The Science Laboratory Environment Inventory has been validated for normal laboratory use by many researchers but this is the first time with minor modifications in the questionnaire that it is being used to assess a field-based program. While it does not assess constructivism it leads the educator to the process of constructivism as the dimensions that are assessed are integral to constructivist principles.

The literature provides little in the analysis of the learning environment with respect to environmental field programs. Therefore, the work of the author and the use of the SLEI is important in determining learning environments dimensions as it appears there is no other suitable instrument currently available. Learning environment dimensions are connected to learning and the next section reviews some of the research on learning.

2. 3 Research on Learning

As learning in the classroom or the laboratory is an integral component of the psychosocial dimensions detailed above, it is of relevance that the literature on learning be reviewed briefly in relation to outdoor environmental learning. Thus it is considered necessary to briefly outline the related research that has occurred in the past twenty years.

For Piaget (1972), cognitive development was an extension of biological growth, while for Siegel and Cocking (1977), action must be taken before knowledge can be acquired. Brainerd (1978) maintained that action would not occur until maturation of thinking occurs. This implies a process of disequilibration that Lavatelli (1973) pointed out is a major factor in cognition, and explains why some individuals advance more rapidly than do others. Thus assimilation and accommodation provide the schema and the constructs so that the individual can relate to the world and thereby learn.

Gagne (1985) asserted that cognition in the human mind is similar to that of a computer, using the principle of accommodation and the current models of information processing. This is part of a common, if perhaps incorrect, understanding of cognition and learning. Both Vygotsky (1978), and Simon (1983), maintain that some form of cognition occurs within a social interaction dimension irrespective of the instructional design. Lave (1988), and Lave and Wenger (1991), maintain that learning requires structures based on instructional design and a reality base. This is in keeping with the water quality-monitoring program as it provides specific structures that are used in environmental and water quality assessment. Each task structure is student centred and is focussed on assessing a real-time authentic situation.

The water quality-monitoring program contains structured methods on how individual water quality tests are carried out. These tests may be done individually or within groups. The students through collaborative, student-focussed constructivist and hypothetical deductive techniques assess the dynamics of the environment and interpret what they have found out.

Wilson, Teslow, and Taylor (1993) showed that cognition and constructivism are linked, confirming the research by Bednar, Cunningham, Duffy, and Perry (1991), and Shepard (1991), that different aspects for cognition are primarily related to the theories of constructivism. Merrill (1991), summarised constructivism, emphasising that learning should be active, collaborative and in a realistic situation. Thus knowledge and learning result from experience while meaning is negotiated from multiple perspectives. Cunningham (1991), Bransford and Vye (1989), and Wilson and Cole (1991a) argued further that the real world and the interaction within it by the individual need to be holistic in the classroom setting. This is the process used in the water quality-monitoring program where the students are faced with different factors that relate directly to the immediate environment, the tests they have performed and the human impact on the environment they are assessing. The students not only look at an instant in time through their testing of water but also by examining the broader aspects of the water catchment. This allows the students to form negotiated constructs, through active problem solving in an authentic situation.

Lisowski and Disinger (1987) found that there was a paucity of research literature dealing with cognitive learning about the environment and in the environment. This is still the situation and much of the information is anecdotal. Lisowski and Disinger (1987) also have appraised the fact that there is little cognitive instruction in secondary schools that takes place in field settings. This thesis is seminal as it provides both qualitative and quantitative measurements based on outcomes in a field based setting.

In the water quality-monitoring program students are confronted by daily, weekly and monthly changes in the immediate environment. The changes that they perceive relate to the dynamic nature of a river and its immediate environment; bringing about a variety of confrontations about the reality they perceive. They are confronted by real changes and as a result change their conceptions. Thus problem solving arises from these confrontations bringing about permutations and combinations of cognitive constructs for each individual. As a result the students are placed in a situation where they need to make meaningful negotiated constructs to understand the dynamics of what they have appraised individually or within a group. This is in keeping with the research on learning as detailed above.

Vygotsky (1978), a strong proponent of situated learning, recognised that once individuals begin to understand concepts they become operant at the abstract level. This model was affirmed by Papert (1988) and Brown, Collins, and Duguid (1989). Putnam (1991) implies that people follow set routines to develop knowledge, effectively stating that cognition does not occur unless processes are procedural and founded in constructivism. Lave (1988), Resnick (1987), and Wertsch (1985, 1991) maintain that culture and authentic knowledge frame the activities of any domain through constructivism. Faulconer and Williams (1990) proposed the post-modernist model. The teaching techniques involved in post-modernist model were tried by the researcher in 1994 and were found not to be useful in a field-based situation.

According to Spiro and Jeng (1990), the processes by which we learn are complex and are ill-structured domains. This means that there is a process which provides individuals with flexibility so that knowledge is used as an adaptive response, often due to radical alterations in situational change. The theory of cognitive flexibility (Spiro, Coulson, Feltovich, & Anderson, 1988) is scaffolded and framed by the theories of Bruner, Ausubel, and Piaget. This implies that knowledge transfer and related skills are context dependent with the information coming from multiple perspectives. To transfer knowledge it is vital that the constructs of knowledge are a result of schema processes that are constructivist and deductive. Learning must be constructed and not transmitted by the teacher. Collins, Brown, and Newman (1989) maintain that students need authentic knowledge from a real world situation so that constructs may be used for problem solving.

Instruction and learning are highly interconnected active processes that are source specific for the student to gain knowledge and understanding. In order for individuals to use higher order thinking skills and to understand, students usually need to be fully engaged in learning in a constructivist manner (Lave & Wenger, 1991; Merrill, 1991). The constructivist model, redefined by Zahorik (1995), asserts that humans construct knowledge to bring meaning to their experience, although the understandings are always tentative and incomplete, requiring motivation and activation of knowledge from prior structures before knowledge and understanding can be acquired. This requires authentic problem solving and reflection on knowledge processes such as those inherent in the water quality-monitoring program.

Students who are involved in water quality-monitoring need to work with changes in the environment, such as post-storm events or drought situations when the river system is reduced to a trickle. These changes alter the students' perceptions about the environment in which they operate, providing them with a reality that they would not normally encounter in school work. This then alters their patterns of thinking about the environment and how they can solve water quality problems. This provides an opportunity for an individual approach to solving authentic problems that is meaningful to themselves and to each other. For the teacher to elicit meaningful learning from students involved in fieldwork requires a constructivist approach. This is in accordance with Ausubel's (1963, 1978) organisers, Bruner's (1960, 1966, 1973) theories of connections and the induction of good problem solving and reasoning techniques to obtain meaningful learning outcomes (Bruner, 1966; Bruner, Goodnow & Austin 1956; Dijkstra, 1997).

Significantly in the water-monitoring program there are many problems to be solved in a real-time situation, which require students to continually make use of their knowledge and build upon ideas by primarily organising the information appropriately with what is learnt on a theoretical and practical basis. This implies that the learner is selective in what is being learnt and how that information is transformed into ideas to construct an hypothesis to match the real situation. Within the water quality-monitoring program, the learner utilises the information individually or from within a group. This empowers the individual or group to make relevant decisions about what needs to be done and whether further testing is required. It also empowers the student to develop new strategies in solving problems. Silcock (1996), by using the ideas of Bruner (1966) and others, furthered student empowerment by the utilisation of problem solving on an individual level so that students can better learn and understand through constructivism.

Airsan and Walsh (1997) concur with empowerment but suggest that the constructivist deductive process must still be teacher directed. O'Loughlin (1992), argued that there is a need to maintain direct instruction, skill practice, reflection and integrated objective testing for student development. Pohl (1996), through personal observation of water quality-monitoring programs, found around the world that to develop skills students needed a combination of cooperative learning and direct teacher instruction or instructing each other or by carefully reading instruction manuals.

Gruender (1996), Harris and Graham (1996), and Savery and Duffy (1995), maintain that the practice of teaching in a meaningful constructivist manner requires direct instructional skill and problem solving tasks. These must include reflection in a reality-based program as Yarusso (1992) claims. To do this requires prior knowledge on a continuum of inputs (Joyce & Weil, 1980), of real world constructs that may be made and utilised (Kuh, Schuh, & Whitt, 1991), with understanding as Jonassen (1991a; 1991b), Molenda (1991), Perkins (1991), and von Glaserfield (1995) imply.

Teaching in a constructivist manner leads to learning and personal development in both academic and non-academic activities, inside and outside the classroom if students are to purposefully make linkages and sense of the real world (Astin, 1993; Pascarella & Terenzini, 1991). This, as Kuh (1993) maintains, provides students with strengths in decision making, self-confidence in practical skills, knowledge acquisition and application which enhances intellectual structuring and transference (Chickering & Reisser, 1993).

In achieving the above, within the water quality-monitoring program, the two key elements are: that the learner is in control of the learning situation and that the learner is an active participant. Being active allows the acquisition of knowledge and this leads to the ability to transfer knowledge that shows learning has occurred. This is similar to the constructivist activities that were suggested by Brooks and Brooks (1993), Kolb (1984), Papert and Harel (1991), Piaget (1954), Richey (1994), Tobias (1990), and Wagener (1991). All maintain that nurturing a continuum of problem solving in an authentic situation will provoke learning and knowledge. The water quality-monitoring program provides the continuum, the empowerment, acquisition and transfer of knowledge and skills.

2. 3. 1 Learning

Learning outdoors often takes on different dimensions and practices from learning in the classroom. Thus, it is important to connect learning with the SLEI learning environment dimensions because each dimension provides a relational aspect to learning and human environments (Moos, 1974). Furthermore, students are able to make accurate judgements about the consistency of their learning environment (Fraser, 1998) and this affects their motivation to learn (Zahorik, 1995). It is also relevant to assess if students in the field transfer information better through making constructs of real life problems when compared to those students not involved in field work. The learning methods play an important role in psychosocial dimensions and in the way students perceive their activities as well as their own performance.

According to Heimlich (1993), there are four distinct methods of learning (formal, non formal, informal and self directed) that are used to describe learning activities within the framework of field activities, and to a lesser extent the laboratory classroom situation. This work is taxonomic and is applicable to ordinary classroom situations. However, it is the thrust of constructivism that is important in the argument i.e., allowing the learner to have the opportunity to construct meaning out of chaos while in the field. This is almost a reiteration of Lave's (1988) work on authenticity and the need to solve problems that have meaning to the situation in the field and to the activity being carried out. Heimlich (1993) indicates that learning outcomes improve in a non-laboratory situation. Pohl (1996) observed grouping as means of learning in the field while solving a common problem. This is compatible with the concept of teamwork as propounded by Scott and Heller (1991).

Learning described thus far in this section has an intrinsic component: that component is reflection. Reflection is a personal process and may vary in intensity, duration, and degree from one individual to another and will be highly meaningful if the activity being reflected upon has been undertaken as in field-work (Jarvis, 1987), rather than in a superficial situation. Carbo (1987), indicated that whenever learners process new or difficult information they should be introduced to the activity using their primary perceptual strength with learning being reinforced with the secondary perceptual strength and by reflection. Gardner (1991) demonstrated that information could be processed in any mode but that learning best takes place through one or two preferred modes, visual, auditory, or kinaesthetic. Bruner and Hill (1992), Ingham (1991), and in particular Nelson, Dunn, Griggs, Primavera, Fitzpatrick, Bacilious, and Miller, (1993) drew conclusions on learning styles that facilitate the processing, retention, and application of new ideas. According to Gardner (1991), learning styles, whatever they may be, are stronger and more immediate when the learning situation requires only one or two stimuli that suit the student. In the field, the student has that choice in processing information to build a construct.

Science teaching has altered considerably in both method and measurement of outcomes in the past twenty years, although there is still a prevalent procedural method and attitudinal perception in junior high school students that 'the teacher is always right' in both developed and developing countries. This comment is based on discussions with teachers and students, and my own observations. It is particularly the situation in developing countries where teachers operate as demonstrators when resources are scarce, rather than allowing the students to be the investigators. Giddings and Waldrip (1993) have demonstrated through qualitative and quantitative procedures that teachers prefer to perform demonstrations rather than allowing students to be actively involved in experimentation.

Attitudinal influences, according to Giddings and Waldrip (1993), imply that there is a preference amongst teachers for didactic teaching rather than constructivist methods. This it would appear is due to expediency and mark driven curricula. The work by Fraser and Tobin (1989) suggests that exemplary practice is dependent on the teacher and the depth of knowledge that the teacher is able to impart in solving problems and must involve active student participation. The latter part of this is a component of constructivism. The majority of research done in teaching practice is centralised within a classroom laboratory situation and few researchers have considered the application of field work as a classroom tool, except as an 'add on' to the teaching process.

Kyle (1984) showed that the analysis of these procedures required a common measurement for every defined variable and could account for differences in effect size of two populations. This is important when considering the use of instruments for assessing learning or psychosocial dimensions such the SLEI and the instrument's associated statistical analysis. Earlier, Walberg (1980) propounded that the quality and quantity of instruction, together with ability, motivation, maturation and classroom environments best explains learning. Boulanger's (1980) research found a similar situation.

Astin (1987), propounded a theory that the greater the amount of physical and psychological energy a student devotes to an academic experience the greater the dividends paid by that experience in terms of talent development of the student. This, when applied to students who are actively involved in the water quality-monitoring program, will benefit them more in their studies by being able to make better linkages with the concepts learnt and translate these into other subject areas. This has not been recorded before and is an observed phenomenon by teachers of Streamwatch throughout Australia, and in other countries where similar programs are offered, either as a community based project or school activity.

Slavin (1987) highlights Astin's theory regarding the benefits of cooperative learning. Driver (1989), Doherty (1992), and Doran and Hejaily (1992) postulate that the effectiveness of hands on constructivism is essential to the cooperative learning model specifically in the teaching of science outside the classroom and in an integrated manner. The work of Harrison and Treagust (1994) amplifies this integrational need in their approach to constructivism. This has been taken further by Pereira's (1996) comparison of constructivism and Stepping Out, a Western Australian language program (Education Department Western Australia, 1995).

The work of Fortner and Mayer (1991) and Trisler (1993) indicates that classroom activity has the most influence on how students relate to their knowledge about the environment. However their work does not appear to account for the skills and processes needed to ensure relevant and meaningful interpretation of real world situations. Thus it may be argued that learning also requires skills and processes to build constructs that provide meaning when solving and interpreting real life problems. Singletary (1992) points out that what is learnt through environmental experiences clarifies the structure, knowledge and skills that have been gained through meaningful and reality based outcomes. These are directly related to their learning environments and patterns and are components of the water quality-monitoring program.

2. 3. 2 Learning Patterns

Learning patterns should be as Roth (1992) indicates, like apprenticeships that allow students to pursue concepts within their own investigative framework. This kind of learning environment leads students to develop their own constructs, practical and analytical and transference skills if real life situations are used. This provides each student with their own framework to build their own individual constructs of reality.

Constructivism is an active process that occurs from experience, reality and from interpretation of that reality. Constructivism in real life situations provides individuals with learning patterns that lead learners to develop their own constructs of reality, enabling them to apply and transfer the constructs in a practical and analytical manner. Teachers are not just ‘guides on the side’ but expert practitioners of their speciality that lead students to the establishment of specific learning patterns.

However there are assumptions about learning patterns, many of which are incorrect. Berryman (1991) indicates that there are five incorrect assumptions in the teaching learning process, these are:

- Concepts are transferred from one situation to another.
- Learners are passive receivers.
- Learning strengthens bonds between stimuli and correct responses.
- Learners are blank slates.
- Skills and knowledge should be acquired independently of the context of their use.

Each of these fallacious assumptions does not allow a student to develop and work in real life situations, yet within educational organisations many of these assumptions are practised by educators and parents alike and are dependent on learning styles (Jarvis 1987).

2. 3. 3 Learning Style

Learning styles are important to both the teacher and the student as the style adopted is related to how well a student learns. To make meaningful sense of the real world, a learner needs to acquire knowledge in a style that is relevant to the individual, so that further constructs may be built in an integrated manner. How well a student learns within the learning style framework is often up to the motivational aspects of the teacher. It is clear from the work of Fraser and Tobin (1989), that the relationship between the exemplary teacher and students is important to student achievement. This relationship is dependent on classroom management, active student participation and understanding. This is supported by Andersen (1995) and the contention that self-responsibility and the acquisition of meaningful learning come about when students are emotionally and intellectually challenged with a relevant real life goal. These goals are often centred on the reality of the world that the student perceives and how well they can build upon the concepts and the transference of concepts. In short, by the mechanism by which a learner learns.

Griggs (1991) reported positive changes in students' academic achievement and attitudes toward school as a result of changing learning styles. The learning styles that are most effective are those that deal with real world issues and are appropriate to individual needs. Stuessy (1984) provides a definition of science reasoning that shows that reasoning must be consistent, logical thought that enables the individual to propose hypothesise and show relationships which can determine the outcomes of a process as well as predict the logical consequences with proof to justify a particular conclusion. Stuessy's definition stems from the concepts inherent in Piaget's formal operations stage. Keen (1991) noted that students increased their ecological knowledge significantly through appropriate learning style and constructivism. The students in the water quality-monitoring program work with learning styles that are appropriate to their learning needs in a constructivist manner.

2. 3. 4 Learning Outcomes

The last decade has seen a high priority placed on student involvement in pursuit of academic excellence as propounded by Astin (1987), Chickering and Gamson (1987), and the Study Group on the Conditions of Excellence in American Higher Education (1984). Astin (1987) claims that students learn by being involved. This implies that involvement increases reasoning ability and learning. It is argued in this thesis that the same situation occurs but demonstrably more strongly in field-based activities. The level of that increase in reasoning ability in field activities needs to be investigated further but is beyond the scope of this thesis.

Cantrell and Barron (1994) identify a variety of approaches, strategies, and guidelines for environmental activities and learning opportunities in environmental education. On close inspection, the opportunities are based on discovery learning, reflective and constructivist approaches. The outcomes that are sought need to be meaningful and relevant to the real world involvement as propounded by Astin (1987), Bruner and Hill (1992), Disinger (1990), and Lave (1988) and link directly with environmental education through constructivist teaching strategies.

2. 4 Environmental Education

Within environmental education, the learning environments, both formal and non-formal, require a validated measuring instrument to assess the psychosocial dimensions of the learning environment to improve teaching and learning. The literature is based on classroom laboratory practices and not on fieldwork practices. Validated instruments are available for assessing the psychosocial dimensions in classrooms and laboratories but not in fieldwork situations. Clearly there is a need for further investigation in this area, as there is a presumption that the parameters measured in the classroom are the same as those which occurs outside of it. This is not necessarily the situation as personal observations and anecdotes would indicate that out-of-class laboratory work is more relevant and develops concepts at a level which may, until further evidence suggests otherwise, be termed deductive hypothetical, a term coined by Ross (1995). The deductive hypothetical approach is an extension of constructivism and appears to be significant in extending students at their different stages of learning, particularly when working and learning outside of the classroom. It is an approach adopted by practising successful science educators and relates directly to fieldwork (Hare, 1999).

2. 4. 1 Fieldwork as Constructivist Learning

Fieldwork is not currently perceived as a means of constructivist learning, though the very action of taking students into a field situation is perceived as a means of amplifying a specific point or experiential process learning. Yet when students operate in the field they are faced with personal challenges and problem solving exercises that they would not encounter in the laboratory or the classroom. Andersen (1995) hints at this experiential level of problem solving when students are unable to assemble disparate pieces of information in chemistry. It is relevant to consider, as Jarvis (1987) did, the implications of developing constructivism further to bring in different modalities of learning. This is certainly in keeping with Gardner (1989) and Gardner and Hatch (1989) when considering intelligences and modes of learning and the environments in which students learn.

Field based programs are often structured differently from classroom and the laboratory based programs and thus present different problems of assessment. Often the outcomes of an evaluation to assess effectiveness are dependent on the 'train the trainer' method. This method relies on a student teaching another student how to do a particular water test in the field while the teacher after the training period assesses the student. The researcher's own testing of this method has demonstrated that this system, while effective in the instruction of the procedures, does not necessarily provide the student with all the theory, skills, and applications needed to do that specific test. The field-based environmental program as run within the water quality-monitoring school uses assessment tasks that have equal portions of skill, problem solving and knowledge components. The students gain these skills and knowledge from their work in an outdoor setting and a formalised laboratory classroom setting.

The water quality program is cognisant of appropriate social skills such as cooperation and requires sound constructivist methods in a collaborative setting that allows students to have an academic context for their peer group interaction, self-evaluation and integration of skills, constructs and knowledge. This method of integration is a threaded model of the constructs and skills that are necessary for the conceptualisation of a variety of ideas and processes, similar to those which Fogarty (1991) propounds as methods of integrating the curriculum.

Fieldwork on a collaborative basis is very much a real world experience and develops the level of interaction that students are expected to have when confronted within the social and academic morés of the real world. The real world concept is the active involvement of individuals experimenting with phenomena that they are experiencing in their own world. For example, when the students go to the local watercourse they see aquatic plants growing profusely. They are told that this is due to nitrate levels in the water. The students then see if they can determine the source of the nitrate and because they are in the place where this occurs they are more likely to understand the relationships of social impacts of nitrates on the watercourse. If the test for nitrate ions is performed in the laboratory the students don't perceive the relationship between their test and where and how the test is used when water is polluted.

The notion is not new and has had many proponents, for example Waterwatch Australia and the Chesapeake Bay Environment program. What is essential in this context is that students require practical experience which, according to Duggan and Gott (1995), appropriately matches the principle learning outcome desired. Wilkinson and Ward (1997) indicate that there are often mismatches between teachers and students and between what is considered effective in laboratory work. Howe and Disinger (1988) argue that effective programs require real issues and a belief that the individual may make a difference by solving problems. It is this problem solving which leads students to learn more effectively and gain a wider perspective on the world around them. Howe and Disinger's ideas are integral to the effectiveness of the water quality-monitoring program. They further maintain that programs spanning several months to years are more successful than the brief activities found in a laboratory situation. Selke (1994) supports this contention provided that the learning is modelled on constructivist principles and the classroom is well equipped.

Many schools throughout the globe run water quality monitoring programs as extra-curricular activities or alternatively do short term topics once a year without prolonged data collection and cross curriculum activities. Few secondary schools used to include environmental subjects in their curriculum, however, this is changing in NSW with the recent introduction of the Environmental Education Act (1999). Environmental education has usually been taught as a strand or an elective within a specific subject. Presentation of environmental concepts generally is accomplished through use of the same instructional techniques as those that focus on in-the-classroom learning. Most of the learning in the environment is based, according to Disinger (1984), on non-cognitive areas. This thesis is unique as it focuses on the cognitive, the transferability of what has been learnt. This does not appear to be the situation in club or extra curricular programs (Hofstein & Rosenfeld, 1996; Ramey-Gassert, 1997; Wellington, 1990).

Field based programs as extra curricular or club activities are limiting, as demonstrated by Mason (1980). Some of the factors that diminish in-field learning are the lack of planning time, resource people, covering classes, funding and a teacher commitment to field instruction (Michie, 1998). While these attitudes or factors may exist in schools, the water quality-monitoring school program is enhanced as it is incorporated within the school curriculum.

2. 4. 2 Cognitive Achievement in Environmental Education

Schellhammer (1935) demonstrated that field excursions increased knowledge and provided further motivation in students while Raths (1939) demonstrated the ability of students to apply principles learned while on excursions. Fraser (1993) concluded that the greatest value of learning in the field was skill in knowledge acquisition and application. Evans (1958) found that students retained more knowledge and skills from practical excursions while Kuhnen (1959) found that students involved in field trips had limited superiority in knowledge over groups instructed in a laboratory but did not assess the students' skills. Gennaro (1981) demonstrated that pre instruction to a field trip provided students with better academic scores while MacKenzie and White (1981) demonstrated that retention of information was superior in students who participated in field excursions. Similar research by Kern and Carpenter (1984) found that higher order skills were superior in students who were involved in field-orientated activities compared with those students whose activities were laboratory-orientated.

St. John and Shields (1988) reported that informal science education was part of the acculturation of science with the goal of informal science activities being to support formal science education by providing cooperative hands-on learning experiences. School and community based programs, however, generally do not hold the participants accountable nor are they tested on what they have learnt (Nicholson, Weiss, & Campbell, 1994). The students in the water quality-monitoring program are accountable for their learning and are assessed on skills and knowledge. The emphasis on real-life situations and problem solving through constructivist methods is an important component of student achievement in both cognitive and non-cognitive domains (Lisowski & Disinger, 1987; Volk & Hungerford, 1981) and is essential in the water quality-monitoring program.

Duckworth (1978) and Trueba and Delagado-Gaitan (1985) have strongly demonstrated that performance in science is measured either through norm or criterion referenced tests and has little relationship to what science is and what a scientist does. The water quality-monitoring school program provides the opportunity and experience of working in a real-world science situation assessing students on their skills and knowledge through topic and moderator tests.

Ignatiuk (1978) demonstrated that there was a statistically significant positive relationship between science attitudes and concepts when measured against students' fieldwork experiences and activities. MacKenzie and White (1981) support this contention as well as demonstrating conclusively that on cognitive tests students involved in excursions outperformed students who did not go on field trips. Falk and Balling (1982) demonstrated that students learn and perform better on field trips, and are better at recall, fact and skills retention than those who had not participated. Kern and Carpenter's (1984) research is supported by Ianni (1992) who demonstrated the increased importance of fieldwork learning compared with traditional laboratory work.

Knapp's (1996) research regarding knowledge, attitudes and behaviour in respect to environmental programs and excursions demonstrated that the excursions have a positive effect on students' learning and cognitive behaviour. Some field trips affected student attitudes and behavioural intentions. The notion of empowerment and ownership of the environment had little relevance to the student's cognitive ability to transfer information and had no effect on student attitudes and behaviour.

2. 4. 3 Environmental Education and Constructivism

Willett and Yamashita (1983) concluded that the best instructional methodology for achieving positive cognitive outcomes is mastery learning. This requires the student to be active and sequential in learning but it does not necessarily provide the student with the realism of life and context. Constructivism provides that pathway to develop thinking and skills through processes that are necessary to bring meaning and relevance within the reality of the situation. Field-based learning provides a sequential interaction between the learner and the real world through constructs and deductions. This study is unique as it demonstrates the interaction between realism, and the use of constructivist and deductive techniques while providing students with a pathway to achieve better cognitive outcomes and the ability to transfer concepts into other subject areas.

Singletary (1992) points out that in high schools environmental education is departmentalised and topically related with the instruction being often didactic, with the hands on approach being used only to emphasise a topical issue. This finding is substantiated by the study of Ramsey, Hungerford, and Volk (1992) who maintain that constructivist techniques are needed to investigate a real life problem, as is done to a large extent in the water quality-monitoring program, and to foster citizenship. Heimlich (1992) provided a method of framing which allowed students to investigate local and or global issues further by engendering citizenship. However, it does not engender transference of concepts of fieldwork to what the traditional classroom offers, nor does it allow for individual action and responsibility to the global issue. The water quality-monitoring school program, however, uses constructivist methodology and a means for accepting responsibility for local and global issues through problem solving.

2. 4. 4 Problem Solving

All people, according to Lave (1988), deal with real life problems that need to be solved either immediately or within a short-term context. Observations made by teachers and psychologists indicate that people like to have control over what they do; yet quite the opposite appears to occur in the classroom laboratory. A point made by Roth (1992), who further noted that students seldom experience the derivation of inquiry, let alone the surprises of real life situations.

Science as a practical subject is not treated in the same way as technology in schools and universities. The constraints placed on science teaching are more akin to those subjects with less practical time needed to complete a specific topic or course. The constraints are often curriculum driven, and do not provide adequate time for learning or actively reflecting on enhancing learning or teaching, particularly in authentic problem solving activities as postulated by Schön (1987).

Too often the authenticity of a problem is reduced to a conceptual model that has little relationship and application to the student. According to Roth (1992), students often have to second guess what teachers really want from them if they are to solve problems that are specific to their syllabus and more immediately to the topic in hand. The didactic approach as a strategy does not provide sufficient stimulus to uplift the learning environment. Roth (1992) emphasises that authentic fieldwork should contain sensible problem-solving tasks and motivation. Disinger (1990) strongly asserts that these processes, coupled with infusion processes, provide teachers with a cross-curriculum focus for meaningful learning through problem solving if the emphasis is on real issues, irrespective of whether it is classroom or field based. Brooks and Brooks (1993), maintain that teachers often elaborate on the ideas of Piaget and others through careful and constant reflection that bring about good teaching practice. Good teaching practice they maintain is based on the teacher's ability to create relevance through the selection of good problem solving.

Within the water quality-monitoring program good problem solving arises because the student is challenged by the authenticity of the real world and needs to acquire meaningful constructs to solve the problems that arise. This is one facet of the water quality testing program that lends itself to good teaching practice while providing a meaningful interaction with the external world at the individual's own level.

The water quality-monitoring school's program has all of the features that Monroe and Kaplan (1988) suggest are important to problem solving. The elements that are beneficial and important in problem solving in the water quality-monitoring program are:

- Knowledge of the environment and of issues.
- Knowledge of action strategies that help resolve issues.
- Skill in action taking.
- Control and empowerment.
- Attitudes and values.
- Sense of responsibility and commitment.
- Group process and communication skills

These factors are essential in a constructivist approach to learning and relate to the student's perception of the world. Consequently, they relate to learning environments and the inherent dimensions of the SLEI and Moos's categories. These elements are tabulated in the next section.

2. 5 Relationship between Learning Environments and Environmental Education

Table 2.2 shows the relationship between the learning environment dimensions as proposed by Moos, the SLEI scales, and activities used in the water quality-monitoring program. Each category and scale is linked with a specific process and activity that is to be found in the water quality-monitoring program.

Table 2.2

Relationship between Learning Environments, Environmental Education, and the SLEI

Learning Environments **Moos Category**	**SLEI** **Scale Name**	**Environmental Education** **Activity**
Relationship	Student Cohesiveness	Work as a team / individual progression fostered and empowerment given. Whole class links with community to report pooled results.
Personal Development	Open-Endedness	Divergent water testing processes and ecological assessment. Investigation by individual or group.
Personal Development	Integration	Theory and practice are combined as results are combined with feedback from water authority.
System Maintenance and System Change	Rule Clarity	Follow safety rules and procedures for specific tasks in water testing / ecological assessment
System Maintenance and System Change	Material Environment	Most materials as test kits available for student use for water testing and ecological assessment tasks.

2.6 Summary

This literature review describes the issues of learning environments and their measurement, constructivism, cognitive achievement and environmental education in relation to the water quality-monitoring program.

Fostering intellectual development in students ideally requires optimal learning environments. Obtaining optimal learning environments requires mapping of the learning dimensions in the classroom or laboratory. Currently most of the research focuses on the classroom laboratory situation. However, for field based programs, the measurement of learning dimensions is limited. To measure learning environment dimensions requires sensitive assessment instruments that can also be used in field based programs. The instruments that are available need to be extended so that more teachers can optimise learning environments not only in the classroom but also for field based programs.

Good learning environments, as the research indicates, reinforce learning patterns. Coupled with constructivist methodology, field based learning may provide better student learning outcomes. Working in the field is dynamic and provides challenges for students to learn in a meaningful way within the student's own learning context. The closer the match between actual and preferred learning environments the better are the learning outcomes. Fieldwork that is part of the school curriculum may generate more constructivist opportunities for learning than within a laboratory classroom situation. Constructivism is measurable and has been used to determine various aspects of learning environments. Currently there are no instruments available to assess constructivism or learning environment dimensions in a field-based situation. However, there are instruments such as the SLEI that sensitively test learning environments in the laboratory or classroom situation. The SLEI has been modified so that it can be used in the field based water quality-monitoring program to assess learning environment dimensions.

The water quality-monitoring program, like the traditional classroom learning environment, has social and physical dimensions. The measurement of these learning environment dimensions was initially described by Moos (1974). These dimensions were later modified and validated by various researchers to produce various reliable assessment instruments such as the CUCEI, the LEI, the CES, and the SLEI. The SLEI, as the literature indicates, has undergone rigorous development and has been validated for assessing student perceptions about their learning environment. A description of each scale of the SLEI is provided together with a sample item from each of the five scales.

The review links the SLEI with different views about cognitive development in relation to field based environmental learning research. It is shown that cognition occurs with social interaction, instructional design and authentic learning situations, which is in keeping with the learning environment dimensions of the water quality-monitoring program. The research shows that improved learning occurs when it occurs in an active, collaborative, and realistic situation. The water quality-monitoring program employs these features. There is little research on field based education such as the water quality-monitoring program and hence there is a need for further work in this area.

investigate the causes of the salinity increase using a variety of scientific sampling methods and observation. If a source for the salinity increase is found, the students consider actively what they can do to reduce the amount of salt in the watercourse. If the cause of the salinity is a natural event or cannot be managed by the students, the students then devise practical and realistic strategies that may lead to a form of remediation by another organisation such as the Environmental Protection Authority. Often further research on the problem is carried out by the students both in the field and the classroom.

The water quality-monitoring program is based on constructivist principles that are anchored in field work instructional situations so that the students can develop reflective skills, attitudes and values. This provides the students with the opportunity to use their intellectual knowledge in moral, ethical or political contexts. Although students may be politically naïve they are able to quickly pin point a problem that is a social and political issue that affects the whole community. By devising ways to improve or remediate the problem through social interaction they develop constructs that enhance their own intellectual development and community involvement. This provides the students with a sense of contributory citizenship rather than ownership (Howe & Disinger, 1988; Varlotta, 1997).

The water quality-monitoring program does not confirm 'instances' through repetitive experimentation as does the positivist school of thought. The water quality-monitoring program, through its activities of collaborative investigation in the field, attempts to provide viable explanations of what is being investigated, i.e., the students in the water quality-monitoring program actively build their own knowledge constructs. What is learnt by the students is discussed with the learning outcomes being evaluated by the students and their teacher. This is a major principle of constructivism according to Harrison & Treagust (1994).

The main constructivist principles inherent in the water quality-monitoring program are:

- Activating prior knowledge through predicting and procedural activities.
- Acquiring knowledge through understanding the 'big picture' and its related parts.
- Understanding knowledge by cycling through information, challenging the information, and then refining it.
- Using knowledge actively in situations which requires divergent thinking and sharing knowledge structures in real life problem situations.
- Reflecting on knowledge through problem solving which allows the individual to build strategies that provide the individual with a self awareness giving the student a sense of purpose, goal orientation, and knowledge of how to achieve the goal.

Each principle is strengthened through the individuals preferred learning mode with its subsequent learning outcomes (pers.obs.).

Learning outcomes in the field are discussed and it is shown that students learn through preferred modes while the teachers guide as imparters of knowledge. It is also shown that exemplary teaching practice depends on the teacher, the depth of knowledge about the topic that the teacher is able to impart for problem solving and providing good problem solving situations that involve active student participation. The research indicates that the more physical and psychological energy that is used by the student in the learning experiences that they encounter the more learning occurs. The water quality-monitoring program uses these features in its integrated constructivist methodology. The more students are actively involved, according to the research, the more there is an increase in reasoning ability and learning. Discovery learning, reflection and in particular constructivist approaches provide learning opportunities that lead to learning outcomes that are relevant to the real world.

Real world issues are often promulgated in environmental education issues and thus field based laboratory work may be more relevant to students by leading them to further concept development. Fieldwork has a collaborative basis that develops the level of interaction needed in the real world. Thus effective programs that run over long periods of time provide real issues and understandings to further learning such as the water quality-monitoring program.

It is shown in the literature that informal science activities provide valuable hands-on learning experiences but there is scope to extend this by giving students more opportunity to take control of their learning. Long term programs such as the water quality-monitoring program make students accountable for their cognitive achievement and improve students' attitudes and concepts (Howe & Disinger, 1988; Hungerford & Volk, 1990).

There is a large body of research on cognition, learning environments and measuring instruments and much development on previous work. There is a gap in the literature on field-based programs and their learning environments and outcomes. The next chapter discusses the methodology used in this study.

CHAPTER 3

METHODOLOGY

3. 0 Introduction

This chapter outlines the overall methodology and describes the research design of this study. As indicated the theoretical framework was established in Chapter 2 and previous research on classroom environment was described. The use, development and validation of the Science Laboratory Environment Inventory and its contextual relationship with this thesis was discussed. The use of anecdotal evidence is considered in this chapter as a means of supporting findings from quantitative research.

The research design, sample description, quantitative and qualitative data collection, and some of the limitations involved are considered in this chapter. The chapter also describes the method of pre and post-topic testing used for ascertaining some of the cognitive achievement and anecdotal perspectives from 100 vignettes. The methods used for treatment of both qualitative and quantitative data are outlined.

3. 1 Aims and Objectives

As described in Chapter 1, the overall aim of this thesis is to evaluate the effectiveness of students working in the field on a water quality-monitoring program. The specific objectives are:

1. To modify the existing SLEI and validate it for use in outdoor learning situations.
2. To use the Science Laboratory Environment Inventory to determine differences in the actual and preferred perceptions of students of their learning environment when they are working in the field on a water quality-monitoring program.
3. To determine the effectiveness of the water quality-monitoring program on students' reporting on fieldwork, concept learning and academic achievement.
4. To investigate associations between qualitative anecdotal evaluative aspects of the program and the quantitative data gathered by the SLEI.
5. To compare the effectiveness of the field based water quality-monitoring program in other countries that have different environmental education settings.

3. 2 Research Design

The theoretical framework of this thesis was established in Chapter 2. The research was designed to use a modified form of the SLEI for the first time in a field-based situation.

The study was divided into four main components. The first component was the administration of the modified SLEI to the students in the water quality-monitoring school. The SLEI was also administered to students from other high schools that are not involved in water quality monitoring. The second component was the comparison of student achievement data from the non field and field based groups. The third component was the collection of anecdotal evidence from the students to determine if the water quality-monitoring program had any impact on subject and career choices. The fourth component involved an examination of the results from pre and post topic testing as a means of evaluating transference of concepts. Cognitive achievement was also examined by comparing the end of year science examination results of the non-water quality-monitoring schools with the water quality-monitoring school. The examinations are written by each school but each school follows a similar syllabus for content and skills in preparation for the Schools Certificate.

Data regarding water quality-monitoring programs were also gathered from personal observation and discussions held with education ministries, schools and environmental organisations overseas. This was done to allow a comparison with the water quality-monitoring in Australia and more specifically with the water quality-monitoring school's own program.

These components taken together provide a multi-dimensional evaluation of a field-based water quality-monitoring program and also provide evidence that validates the SLEI for use with field based activities.

3. 3 Research Justification

A multi-dimensional research design was selected as the most suitable in terms of the aims and objectives of the study. It is based on a selection of a method or a combination of methods and research techniques that can best answer the research questions. As the study involves the psychosocial dimensions of learning and comparisons between field based and non field based schools, the present study requires a multi-method approach in order to determine the validity of field based learning.

The learning environment dimensions Integration, Student Cohesiveness, Open-Endedness, Rule Clarity and Material Environment have all been demonstrated to be valid dimensions in science laboratories (Fraser, 1998a). As part of the research objectives, specifically the first and second research objectives, it was considered important by the researcher to examine these dimensions within a field based setting.

Given that practical work has unique properties and is central to science education (Henderson & Fisher, 1998), the SLEI (Fraser, Giddings, & McRobbie, 1991) was developed for assessing the multi dimensional aspects of laboratory practice. Fieldwork is inherently practical and contains knowledge aspects similar to those of laboratory work in science education and forms the basis of the second and third research objectives.

The instructional method, styles and fieldwork teaching are considered in the evaluation of the water quality-monitoring program as outlined in Chapter 2. The literature review shows there is a void in science education in relation to the evaluation of field-based programs. The literature that is available is mainly concerned with field trips and excursions and does not specifically relate in most cases to on-going programs such as the water quality-monitoring program. Furthermore the SLEI, in accordance with Fraser and Tobin (1991), indicated that the construction of a 'study specific' questionnaire, using only scales perceived to be salient for a particular study, was considered an acceptable procedure to follow. Thus the procedures needed for a multi-dimensional research study, such as this one, that in part aims to investigate the learning environment dimensions, favours the use of the SLEI in a field based context.

The students from the water quality-monitoring school used a slightly modified version for the actual and preferred SLEI forms. The modifications were the change of the word 'laboratory' to 'Streamwatch' and ‘site’ for ‘laboratory’ and other similar changes as appropriate for the water quality-monitoring group classes to maintain the intent and integrity of the SLEI and the dimensions being assessed. Table 3 below provides example items for each scale of the Actual modified and non-modified forms of the SLEI. The Preferred version is similar but asks the students to rate the laboratory environment ideally liked or preferred. The questionnaires for both the non-modified and modified versions of the Actual and Preferred versions are in Appendix 2.

Table 3.0
Modified and Non-modified Example Items for each SLEI Scale

Scales	Original SLEI	Modified SLEI
Integration	What I do in our regular science class is unrelated to my laboratory work.	What I do in our regular science class is unrelated to my Streamwatch work.
Material Environment	I find that the laboratory is crowded when I am doing experiments.	I find that the Streamwatch site is crowded when I am doing experiments.
Open-Endedness	There is opportunity for me to pursue my own science interests in this laboratory class.	There is opportunity for me to pursue my own science interests in this Streamwatch class.
Rule Clarity	My laboratory class has clear rules to guide my activities.	My Streamwatch class has clear rules to guide my activities.
Student Cohesiveness	I get on well with students in this laboratory class.	I get on well with students in this Streamwatch class.

Written and recorded anecdotes are a suitable means of gaining supporting evidence, as quite often questionnaires do not allow for the full context of a study to be considered (Sorrentino & Bell, 1970). This led to the researcher's decision to collect both quantitative and qualitative data. Anecdotal evidence was obtained from past students who were involved in the water quality-monitoring program. The evidence, which relates to the fourth research objective, considers the students' experiences in their senior schooling, subjects and career choices. This provides a long-term perspective in the thesis from those students who have gone to university and have taken on careers in an environmentally related course after having been in the water quality-monitoring program.

The anecdotes in this study are summarised and utilised with the quantitative data obtained from the Science Laboratory Environment Inventory and address the fourth objective of this thesis. The qualitative data are used to highlight issues and problems surrounding the research. Thus, information from the anecdotes is used to gain an insight into the program of water quality monitoring.

As part of this thesis it was considered necessary to look at overseas teaching learning strategies inherent in water quality-monitoring programs so that the water quality-monitoring program in the researcher's school could be placed in context with what was occurring globally. Evaluative comparisons such as these become important in the context of science education programs and their effectiveness. The significance of this is that it provides an appraisal of the teaching learning process in a field-based context. In this thesis, the information was gathered from schools and education ministries and appraised first hand, as outlined in Chapter 6, and aided the achievement of the fifth research objective. The countries from which the information was obtained are Mauritius, Kenya, Poland, Germany, Russia, United Kingdom and the United States of America.

3. 4 Sample Population

Fifteen high schools in the Sydney metropolitan area were invited to participate in the study. However, due to school and Education Department policies many declined. The schools were chosen at random but had a similar academic record in the School Certificate. The sample population used in this thesis is derived from five State high schools that did not decline the invitation to participate. Three of the schools are single sex high schools. One of these is the girls' high school that uses the water quality-monitoring program. The other two single sex schools are a girls' high school and a boys' high school. The other two schools involved in the study are coeducational high schools. Four of these five schools do not participate in a water quality monitoring program. Both the water quality and non-water quality-monitoring schools have on average 45% non-English speaking background (NESB) students who come from a variety of socio-economic backgrounds.

A total of 580 students from year 10 participated in the study, 209 students were involved from the water quality-monitoring school and 371 students were from the other participating schools. Quantitatively the number of students involved in the study satisfies the statistical rigour requirements for validation of the SLEI and determining if there is any difference in cognitive achievement between those students involved in the water quality testing and those students that are not involved in such a program.

3. 5 Data Collection

The class teachers carried out the distribution of the SLEI forms. The students were asked to include their year level and gender but not their names on the forms. This was done in accordance with the NSW Department of Education's child protection policies and directives. Some schools that participated also insisted on gender not being included.

The teachers from both the water quality-monitoring and non-water quality-monitoring schools that were involved in the study were taught how to administer the SLEI by the researcher. They were asked not to score the questionnaires. The researcher scored the forms and analysed the data.

The actual and preferred forms for the non-water quality-monitoring students were provided within the classroom laboratory. They were not given simultaneously but given at the beginning of a week and at the end of the same week. This was due to class timetable constraints. As schools did not wish students to be identified by gender, they were asked to pencil their initials on the questionnaires. The student responses to the actual and preferred versions were matched by the use of their initials and the schools' initials. After recording these were erased to ensure anonymity. Students in the water quality-monitoring program filled in their questionnaires at the sampling site.

3. 6 Procedure

Students from both the water quality-monitoring school and the non-water quality-monitoring schools were provided with both the Actual and Preferred forms of the SLEI. The Actual and Preferred questionnaires for the water quality and non-water quality-monitoring schools were filled in by the participants in a forty minute lesson after being given instruction by their teachers on how to fill in the questionnaires. The scoring of the questionnaires was carried out by the researcher prior to entering the data into a computer.

3. 6. 1 Data Entry

Recording and analysis of the data were done with a computer. A description of the scoring procedure used was as recommended by Fraser, McRobbie, and Giddings (1993). Students were asked to draw a circle around the number that describes how well each statement describes what the laboratory class is actually like for the individual student. In the case of the fieldwork group, the statement referred to what the monitoring site was actually like for the individual student. In the case of the preferred form, it describes what the student's preferred laboratory, or in the case of the fieldwork group what the preferred site would be like. The response instructions are for the actual form:

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

and for the preferred form:

1. If you would prefer the practice to take place ALMOST NEVER
2. If you would prefer the practice to take place SELDOM
3. If you would prefer the practice to take place SOMETIMES
4. If you would prefer the practice to take place OFTEN
5. If you would prefer the practice to take place VERY OFTEN

Both actual and preferred forms for both the water quality and non-water quality-monitoring schools are included in Appendix 2. The inclusion of the letter R in the Teacher Use Only column identifies items that are scored in the reverse direction, e.g., a 4 becomes 2. All items without the letter R are scored by allocating the appropriate number in the Teachers Use Only column. All items are arranged in blocks and in cyclic order so that all items from the same scale are found in the same position in a block. Omitted or invalidly answered items were scored 3. There are a total of 35 items in both actual and preferred forms.

Item scores for the five items in each scale are added to obtain a scale total. The first, second, third, fourth and fifth items in each block of five, respectively measure Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material

Environment. For example in scoring Rule Clarity, items 4, 9, 14, 19, 24, 29 and 34 are added. The items were entered into a database for analysis using Statview (Abacus Concepts, 1996) a computer statistics software package. The ANOVA eta^2 was done with the statistical package SPSS 6.1. (Norusis, 1993).

3. 7 Anecdotal Aspects

In the anecdotal aspects of the study, 100 students were selected at random and their views sought regarding their involvement in water quality-monitoring, senior school subject choices and career choices. They were also asked if they had chosen environmental aspects in their studies as a consequence of being involved in the water quality-monitoring program. The responses were transcribed directly from a cassette recorder, or where the view sought was done by telephone, their comments were written verbatim. In some instances, the transcriptions were edited for correct English usage or to remove verbose language used by the student. The perspective anecdotal component only applied to the water quality-monitoring school, as logistically it was not feasible to follow up students from non-water quality-monitoring schools. The results and interpretation of the qualitative data are found in Chapter 5.

Chapter 6 also considers qualitative material that has been gathered by direct observation in schools and through discussions with teachers, teacher educators and education ministry officials from various countries. This information was officially obtained during the researcher's visits to the countries concerned. This information is used to provide a comparison with the water quality-monitoring school's program in terms of teaching strategies as well as to provide a global context of field based environmental programs.

3. 8 Pre and Post Topic Testing

Pre and post-topic tests were given. The class science teacher administered the pre and post topic tests to the students in lesson time. The general knowledge test items were derived from the Streamwatch manual and a geography worksheet on catchments. The items involving biological and chemical knowledge and experimental design were modified questions from several different junior science textbooks. The remaining questions were based on general knowledge, and the novelty question was derived from a cognitive psychology textbook. Each item was discussed at length with colleagues and simplified for ease of readability and understanding. A selection of comments is provided to show the change in a student's ability to form and establish constructs. The quality of the answers is also considered in the light of the pre and post-topic testing. Thus it should be possible to determine which factors are essential to the teaching learning process, particularly in the field based situation where no such evaluations have taken place. With cognitive achievement, this component of the study relates to the third research objective.

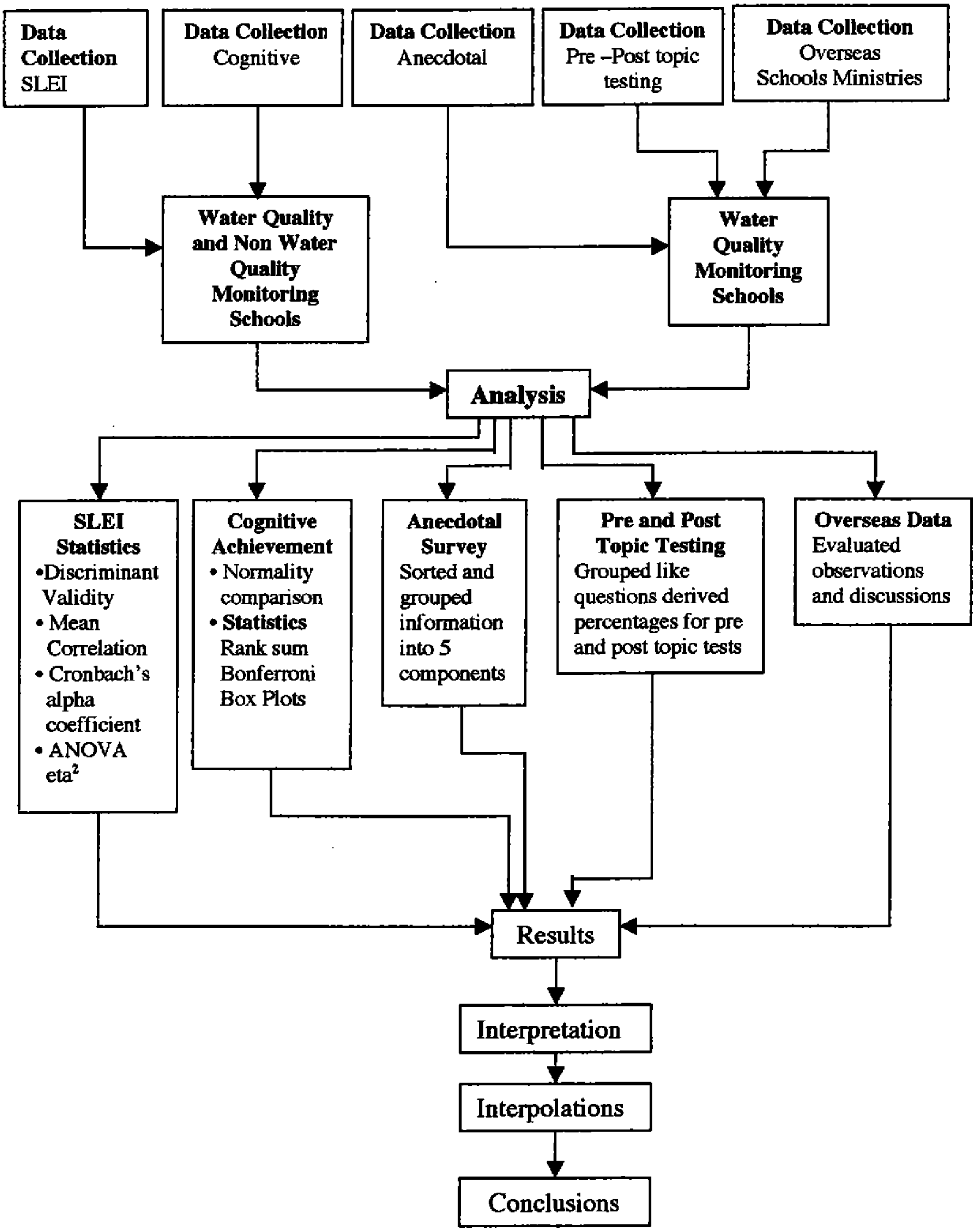
3. 9 Cognitive Achievement

Cognitive achievement has been taken from the student's end of year moderator examination in science which is given to all year 10 students in the study and count towards the NSW Schools Certificate. The moderators are 50% process skills and 50% knowledge or content-based exams. School and student names have been omitted as part of the directives of the NSW Education Department and the policies of individual schools. Each school writes their own examination moderators but most are based on the Australian Science Competition. All schools in this study base their moderator exams on the Australian Science Competition and previous School Certificate Examinations. The student scores from each school's moderator were statistically standardised using SPSS 6.0 (Norusis, 1993). This provided a means of standardising student cognitive achievement scores from different schools. As all the schools involved in the study give their students A, B, C, and D as an assessment grade it was necessary to convert their grade into a number for statistical calculations. As some schools grade on a plus and minus level, the conversions were: A = 17 - 20; B = 14 - 16; C = 10 - 13 and D = 8 - 9; the appropriate conversion was then entered into the database as appropriate. This method also brought the grades in line with the Streamwatch common test that is marked out of 20. The water quality-monitoring school moderator data were also included in the database. The treatment and collection of data was the same for both the water quality and non-water quality-monitoring schools. The cognitive data were entered into a database for all schools that participated.

3. 10 Summary

This chapter has outlined the research methodology as it pertains to the SLEI and the evaluation of a field based water quality-monitoring program that has been employed in conducting this research. It has delineated the methods and procedures used to analyse the results of the research by using both qualitative and quantitative data (see Figure 3.1) The limitations in conducting this research are confined to the schools that participated in the research. The results from the quantitative part of this research are presented in Chapter 4. The results and interpretation of the qualitative and anecdotal information is contained in Chapters 5 and 6.

Figure 3.1.
Summary chart of methodology.



CHAPTER 4

VALIDATION AND USE OF THE SCIENCE LABORATORY ENVIRONMENT INVENTORY

4.0 Introduction

This chapter sets out the results obtained based on the first three research objectives posed in Chapter 1. To reiterate, these objectives are:

1. To modify the existing Science Laboratory Environment Inventory and validate it for use in outdoor learning situations
2. To use the Science Laboratory Environment Inventory to determine differences in the actual and preferred perceptions of students of their learning environment when they are working in the field on a water quality-monitoring program.
3. To determine the effectiveness of the water quality-monitoring program on students' reporting on fieldwork, concept learning and academic achievement.

The chapter includes an account of the results obtained from this study. Section 4.1 discusses the statistical methods employed and the reasons for their use in this study. The data obtained from the use of the actual and preferred versions of the modified SLEI in the water quality-monitoring school are examined for internal consistency of the scales, discriminant validity between the scales, and the ability of the scales to differentiate between classrooms. The mean correlation of a scale with other scales provides a convenient measure of the discriminant validity of the SLEI and has been used in all previous validation procedures of the SLEI. The ANOVA and *eta*^{2} statistic was used to determine the proportion of variance between class membership of each of the scales. The Cronbach alpha coefficient was used to test internal consistency reliability of scales.

The Cronbach alpha coefficient estimates the reliability of items with multiple answers by measuring the ratio of true score variance and observed score variance. The Cronbach alpha coefficient is a measure of the reliability of the dependability of the data and provides a generated analysis of the congruency of the scales. It is generally used for measures where subjects respond to questions on a scale (1 to 3, 1 to 4, 1 to 5, etc.). The SLEI is a 1 to 5 response questionnaire for 35 items. Cronbach's Alpha can range between 0 and 1. Educational researchers in the literature generally consider that if a scale has an alpha above .60, it is usually considered to be internally consistent. The higher the alpha value, the more reliable the test, and indicates the strength of the interrelationship of items. It is important to note that Cronbach's alpha takes variance into account and examines the covariance matrix to draw a conclusion (Afifi & Elashoff, 1966).

The results of the data collected using the actual and preferred versions of the modified Science Laboratory Environment Inventory from the non-water and water quality-monitoring schools are compared with each other to ascertain differences between the water and non-water quality-monitoring schools.

Cognitive achievement differences between the student scores in the non-water and water monitoring schools are analysed and discussed to determine if any particular scale or scales of the SLEI is more strongly associated with cognitive achievement. A summary of the chapter as it relates to the objectives of this thesis is also provided.

4. 1 Data Analysis

This analysis starts out with the null hypothesis that there is no difference in achievement between students in the water quality and non-water quality-monitoring schools, as well as determining if there are any associations between academic achievement and learning environment dimensions as assessed by the SLEI. The data are validated at the 95% confidence level. The sample size of the population of 580 students has already been discussed and provides the study with its statistical robustness. In keeping with the traditional pattern of learning environment research, the modified SLEI as used in an in-field situation was validated in the same manner as in previous research.

Student cognitive achievement in high schools is considered to lie within the parameters of a normal distribution curve. As both the water and non-water quality-monitoring groups are subject to the same curriculum constraints for learning outcomes, it was deemed sufficiently important to determine if both groups complied to a normal distribution curve, and if any there were any differences arising from the water quality-monitoring program. It was also considered important to determine if there were cognitive achievement associations in the water quality-monitoring program that may be linked to specific scales of the SLEI. To examine these cognitive associations, the following additional statistical tests were performed:

- ANOVA.
- Wilcoxon Rank Sum Test.
- Bonferroni box plots.

The tests and their interpretations are considered in sections 4.4 and 4.5 of this chapter. The statistical tests that validate the SLEI and those that determine differences in cognitive achievement link together the second and third objectives of this thesis. The results obtained from the SLEI follow in the next section.

4. 2 Validation of the Science Laboratory Environment Inventory

The research by Fraser, McRobbie, and Giddings (1993) in their cross national validation of the SLEI used factor analyses as well as the following three statistics to validate the SLEI, namely, the Cronbach alpha reliability coefficient, discriminant validity and an ANOVA. In their research, they demonstrated that the Cronbach alphas for the scales of the SLEI ranged from 0.69 to 0.81 for the actual version and from 0.60 to 0.80 for the preferred. They also showed that the resultant eta^2 from the ANOVA indicated that the each scale of the SLEI differentiated significantly (p <0.001) between the perceptions of students in different classes. The low mean correlation of scales, ranging from 0.07 to 0.37 in their study, demonstrated the discriminant validity and scale independence and suggested that the SLEI measures distinct but somewhat overlapping aspects of classroom environments. The results from this study presented in this chapter are comparable with these previous studies using the SLEI.

The various aspects of data collection have been discussed previously in Chapter 3. The items of the Science Laboratory Environment Inventory scales were scored by the researcher and the means for each scale derived for both sets of school populations - the water quality-monitoring and the non-water quality-monitoring schools. A Cronbach alpha coefficient for internal consistency was performed for each scale and compared with overseas data (see Table 4.1) to assess the reliability of the scales in the SLEI. A low alpha coefficient is indicative that the scale has low internal consistency and is thus considered by most researchers as unreliable. According to the literature there is not an agreed cut off point.

The sample size used in the analysis included 371 students from the non-water quality-monitoring schools and 209 for the water quality-monitoring school. The Cronbach alpha coefficient was calculated using the following formula:

$$\alpha = \frac{k}{k-1}\left[\frac{1-\Sigma\sigma^2_{\text{Items}}}{\Sigma\sigma^2_{\text{Total}}}\right]$$

Where k = the number of items and $\Sigma\sigma^2$ Items is the sum of the item variances and $\Sigma\sigma^2$Total is the sum of variances and covariances in the covariance matrix.

Fraser (1994) has provided Cronbach alpha coefficients for six different countries where the SLEI has been used and these figures are presented in Table 4.1. Also shown in Table 4.1 are the Cronbach alpha coefficients obtained in this study with the modified SLEI and it is noteworthy that these are of a comparative magnitude. The figures indicate a satisfactory internal consistency for each scale especially for a small sample. The exception to this in this study is the Open-Endedness actual scale that resulted in a lower value of 0.55, but which is similar to the values found in the study undertaken in Israel and Nigeria (see Table 4.1). The low value could be explained by sample size but care needs to be taken in interpreting results from this scale. The range for the Actual version was 0.55 to 0.83. The range for the Preferred version was 0.60 to 0.82. In this study the individual student was used as the unit of analysis.

Table 4.1
Cronbach Alpha Reliability Coefficients for Actual and Preferred Forms of SLEI

Scale	**Form**	**This Study**	Australia	Canada	England	Israel	Nigeria	USA
Integration	Actual	0.83	0.81	0.80	0.65	0.89	0.68	0.84
	Preferred	0.81	0.80	0.73	0.80	0.84	0.72	0.79
Material Environment	Actual	0.80	0.74	0.79	0.83	0.56	0.71	0.74
	Preferred	0.81	0.73	0.70	0.61	0.74	0.71	0.70
Open-Endedness	Actual	0.55	0.69	0.60	0.78	0.54	0.49	0.75
	Preferred	0.60	0.60	0.54	0.54	0.62	0.43	0.61
Rule Clarity	Actual	0.64	0.72	0.76	0.84	0.71	0.61	0.76
	Preferred	0.74	0.68	0.65	0.68	0.75	0.51	0.71
Student Cohesiveness	Actual	0.76	0.78	0.75	0.77	0.69	0.56	0.81
	Preferred	0.82	0.72	0.63	0.57	0.74	0.51	0.73
Sample size		580	1875	282	108	359	218	885

(After Fraser, 1994)

Table 4.2

Discriminant Validity (Mean correlation of scale with other scales) and Ability to Differentiate between Classrooms for the SLEI

Scale	Mean Correlation of a Scale with Other Scales	eta^2
Integration		
Actual	0.09	0.27*
Preferred	0.08	
Material Environment		
Actual	0.19	0.24*
Preferred	0.17	
Open-Endedness		
Actual	0.12	0.17*
Preferred	0.08	
Rule Clarity		
Actual	0 15	0.09*
Preferred	0.16	
Student Cohesiveness		
Actual	0 17	0.09*
Preferred	0.25	

N= 580 * $p<0.001$

The mean correlation of a scale with each of the other four scales for the Actual form of the instrument scale ranged from 0.09 to 0.19, and in the Preferred scale ranged from 0.08 to 0.25. These values indicate that the SLEI measures distinct although somewhat overlapping aspects of the learning environment. The values for this sample are similar to those found by the previous researchers (Fraser, 1994) using the non-modified form of the SLEI.

Another desirable characteristic of any instrument like the SLEI is that it is capable of differentiating between the perceptions of students in different classrooms (Fraser, McRobbie, & Giddings, 1993). That is, students within the same class should perceive it relatively similar while mean within-class perceptions should vary from class to class. This characteristic was investigated for each scale of the SLEI using a one-way ANOVA, with class membership as the main effect. Table 4.2 indicates that each SLEI scale differentiated significantly ($p<0.001$) between classes and that the eta^2 statistic, representing the proportion of variance explained by class membership, ranged from 0.09 to 0.27 for different scales. The results are generally similar to those reported by Fraser (1994).

The descriptive statistics given above in this thesis indicate that the modified version of the SLEI is a valid and reliable instrument for assessing the dimensions of a field-based program. The results are in keeping with the work of previous researchers on non modified versions of the SLEI and indicate that there is support for the 35 item, five-scale modified version of the SLEI. The use of an instrument such as the SLEI has demonstrated that it may be used to assess student perceptions of their learning environments either in the field or in the laboratory at the secondary school level.

This thesis is unique in this respect as it has not been demonstrated previously that the SLEI can be used in an outdoor environment and validates the use of the Science Laboratory Environment Inventory as an instrument of significance in enhancing the learning of students when doing fieldwork.

4. 3 Differences in Actual and Preferred Student Perceptions for SLEI Scales

The means of the different scales of the water quality, non-water quality-monitoring schools and the combined means for actual and preferred scales are given in Table 4.3 and provide a cursory notion of what may be expected as trends. The total score for a particular scale is obtained by adding the scores for the seven items belonging to that scale with the mean being calculated for each scale. The maximum mean for each scale is 35.

Table 4.3
Comparison of Means for SLEI Scales for Combined, Water, and Non-water Quality-monitoring Students

	Combined		**Non-water Quality-monitoring Students**		**Water Quality-monitoring Students**	
Scale	**Act**	**Pref**	**Act**	**Pref**	**Act**	**Pref**
Integration	24.0	25.4	24.63	25.70	22.80	24.91
Material Environment	24.9	30.3	24.49	30.65	25.53	29.62
Open-Endedness	17.7	23.9	17.20	24.10	18.01	23.77
Rule Clarity	24.20	25.40	23.98	25.31	24.49	25.48
Student Cohesiveness	27.7	29.3	27.61	29.04	27.81	29.64
	N = 580		N = 371		N = 209	

Paired t-tests were performed to determine whether the differences in students' perception of their actual and preferred learning environments were statistically significant. These tests indicated a statistically significant difference at the $p<0.05$ level for all scales for the three samples.

The scale means were graphed to provide a pictorial representation as shown in Figures 4.1 to 4.3.

Figure 4.1.
SLEI scale means for combined non-water and water quality-monitoring schools.

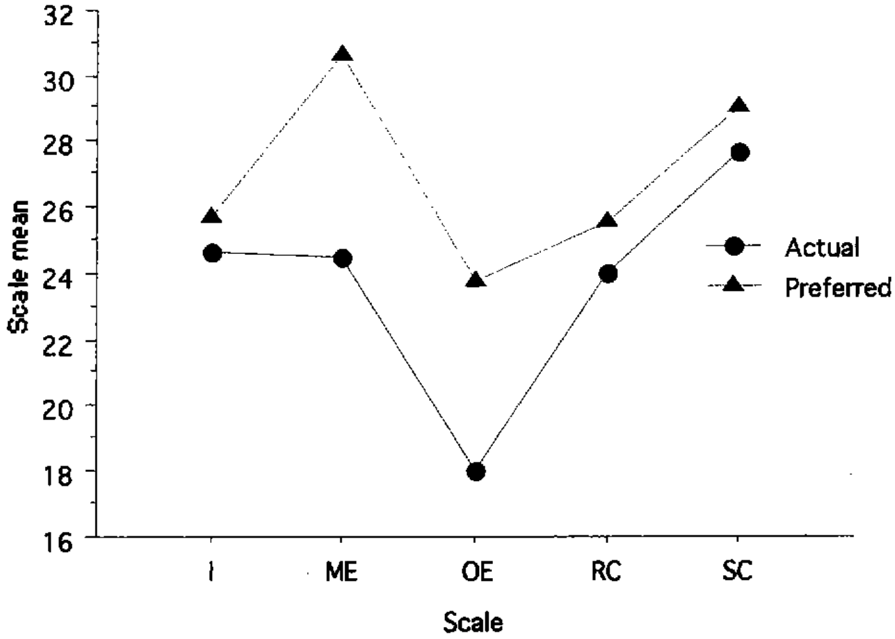


Figure 4.2.
SLEI scale means for water quality-monitoring school.

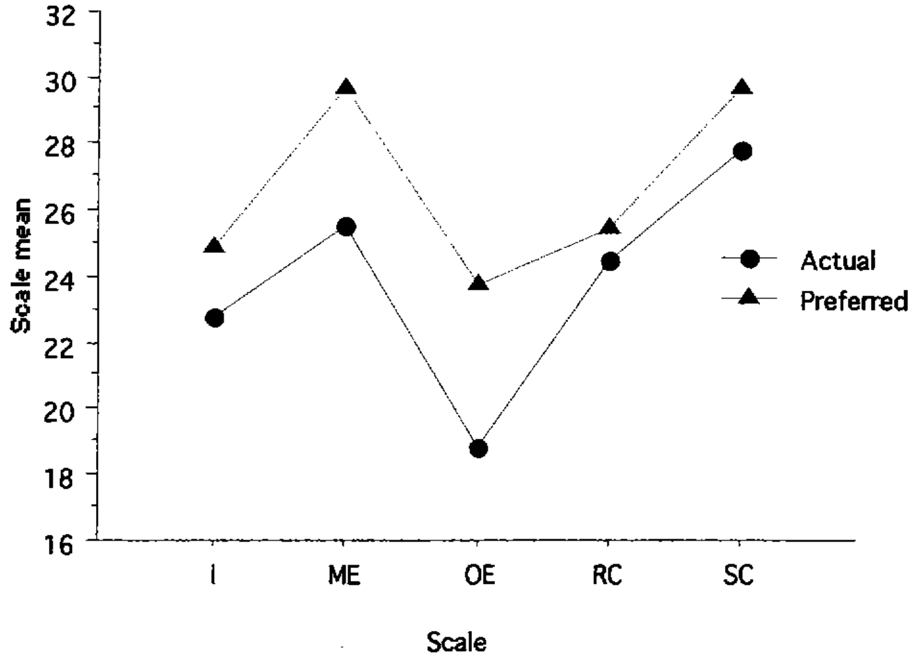
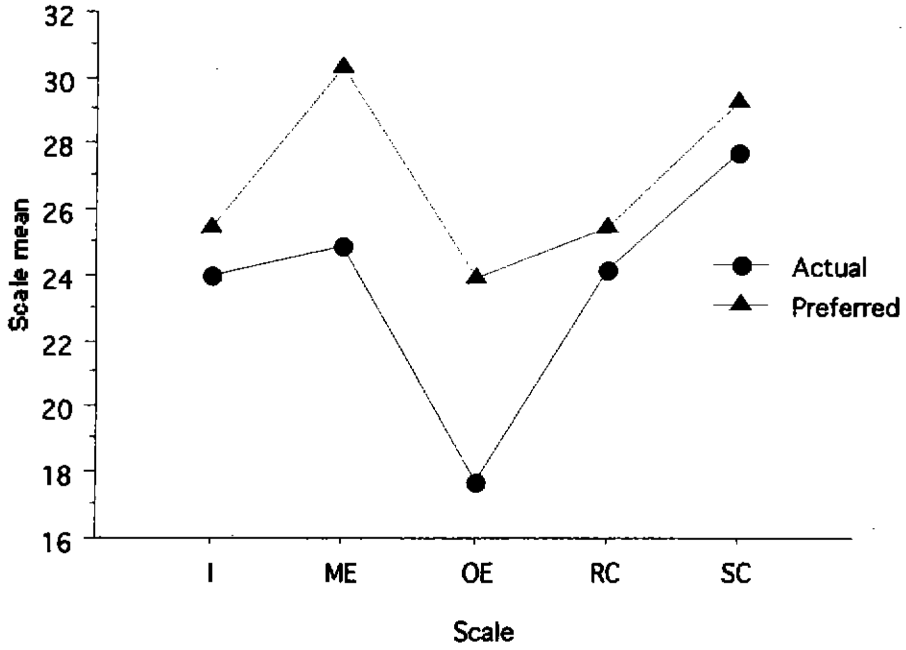


Figure 4.3.
SLEI scales means for non-water quality-monitoring schools.



The Open-Endedness scale in Figures 4.1-4.3 has the larger difference between the actual and the preferred means. However, the difference in combined sample means is closer to the water quality-monitoring program means and has a greater mean value than the non-water quality-monitoring schools. This indicates that students perceive there to be a greater degree of individual work in relation to experimentation and assessing the environmental factors. It also indicates that the student perceptions are that they are working closer to their preferred learning environment. This is in contrast to the non-water quality-monitoring schools where the students' perceptions indicate that they would prefer a better learning environment in terms of Open-Endedness.

The Material Environment scale means in Figures 4.1-4.3, as with the Open-Endedness scale depicts a large difference but again in the water quality-monitoring program the students perceive they are closer to their preferred environment. This perception indicates that the students in the water quality-monitoring program have a better and more preferred material environment than their counterparts in the non-water quality-monitoring schools. This perception is perhaps due to the fact that the students involved in the water quality-monitoring program have the materials they need on hand. It is possible that the non-water quality-monitoring program this implies that materials and/or resources are not always readily available.

The non-water quality-monitoring schools for the Integration scale have very close means for Actual and Preferred scales. This is not the situation for the water quality-monitoring school where the difference between Actual and Preferred is 2.1. This would indicate that the students perceive a greater disparity between doing fieldwork and theory. This was a somewhat unexpected result, as the students are required to work with the theoretical aspects they encounter to solve a real life problem. This aspect requires further investigation.

For both groups, the differences between the actual and preferred means on the scale of Student Cohesiveness are small indicating that students are as involved in working with one another as much as they prefer.

Similarly, for the Rule Clarity scale there is little difference between the means and this would indicate that the degree of teacher control or the rules imposed are greater than is preferred. However, for the water quality-monitoring school the need for rules are more important due to safety concerns while doing fieldwork.

The next section considers cognitive achievement and relates the findings to students' perceptions of their learning environments as measured by the SLEI.

4. 4 Cognitive Achievement

The cognitive achievements of both the water quality-monitoring and non-water quality-monitoring school students were compared to ascertain if there were any differences between them. The cognitive achievement analysis was performed on the students' end of year science examination results, as outlined in Chapters 1 and 3. The examinations in each school contain the same level of skill and science knowledge, in order to conform to the NSW School Certificate, although there may be minor differences between them. The Shapiro-Wilk test was performed on these data together with a one-way ANOVA to determine if the two groups involved in the study conformed to normal distributions. Bartlett's test for equal variances was applied to confirm equal variances between the populations. The Wilcoxon rank sum analysis was performed together with the Bonferroni statistic to ascertain if the achievement data in the water quality-monitoring program obtained better achievement scores than those in the non-water quality-monitoring program. The water quality-monitoring school returned a higher score based on the distribution of marks, as depicted in Figures 4.4a and 4.4b. The cognitive achievement mean score was 16.4 (maximum possible 20) for the water quality-monitoring school and 15.3 for the non-water quality-monitoring school. A t-test indicated that this difference is significant (F = 361.38 with $p<0.001$). This indicates that there is a statistically significant difference in cognitive achievement and that the students in the water quality-monitoring group performed better than those in the non-water quality-monitoring schools.

Figure 4.4a.
Distribution of cognitive achievement scores for water quality-monitoring school.

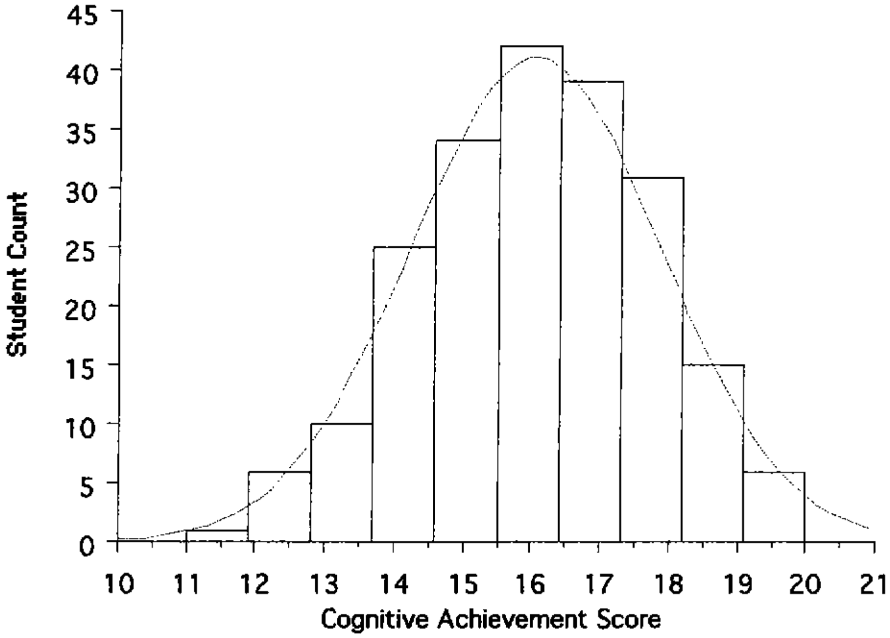
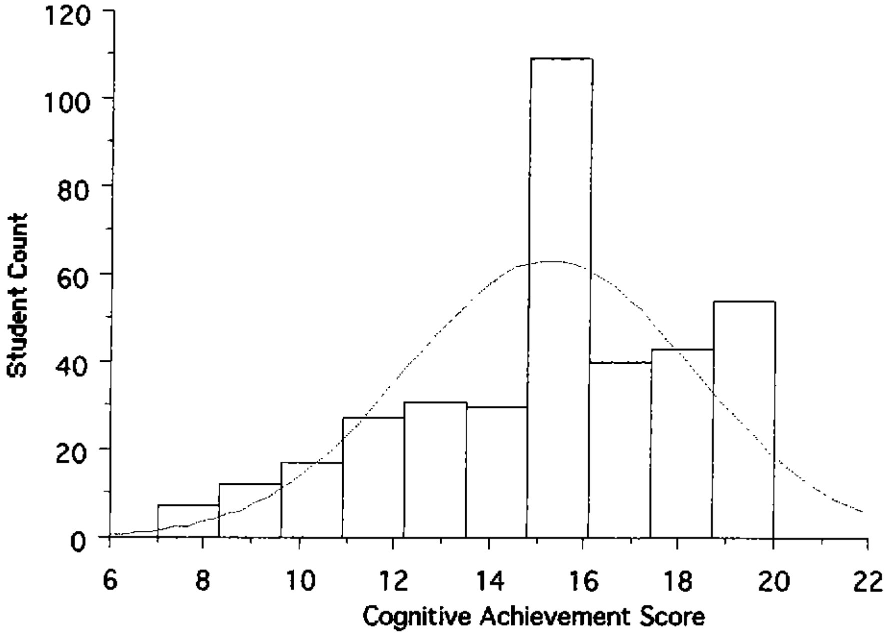


Figure 4.4b.
Distribution of cognitive achievement scores for non-water quality-monitoring schools.



A two sample Wilcoxon Rank - Sum test was performed to determine the equality of medians to demonstrate which item factors were essential in the learning process between the two groups in relation to each scale, as well as to determine the robustness of the testing by calculating a z - statistic. This statistic compares the two groups and determines the likelihood of the observation occurring by chance. Thus a *p* value of less than 0.05 indicates that it is unlikely to have occurred by chance.

Table 4.4
Wilcoxon Rank Sum Test on Equality of Medians to Determine the Scales Essential to the Learning Process

Scale / Variable	**Z score**	**Level of Significance**
Cognitive Achievement	+2.42	0.01 57
Open Endedness Actual	-2.55	0.0107
Integration Actual	-3.80	0.0001
Integration Preferred	-3.80	0.0544
Material Environment Actual	+1.77	0.0775
Material Environment Preferred	-2.10	0.0350

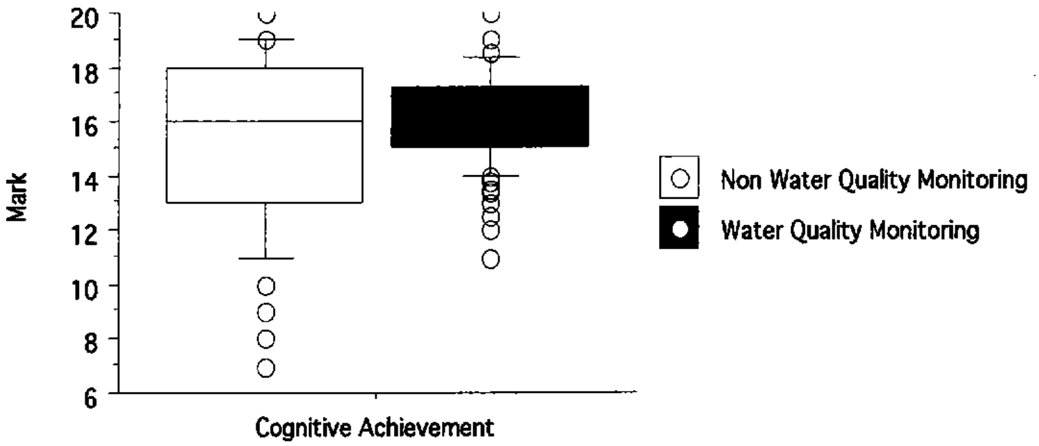
N = 580

\+ water quality-monitoring greater than the non-water quality monitoring.
\- non water-quality-monitoring greater than the water quality-monitoring

The measures that showed significance were Cognitive Achievement, Open-Endedness Actual, Integration Actual and Preferred, Material Environment Actual and Preferred.

To define further the relevance of the SLEI scales and Cognitive Achievement, box plots were utilised to establish the medians of each variable and scale. The medians for the scales of the SLEI indicate the relevance to the teaching learning process irrespective of whether they are in a water or non-water quality-monitoring program and are depicted in Figures 4.5a to 4.5g.

Figure 4.5a.
Cognitive achievement medians for non-water and water quality-monitoring schools.



The medians for Cognitive Achievement (Figure 4.5a) are identical however, the water quality-monitoring group of students shows greater homogeneity about the median than the students in the non-water quality-monitoring group. One possible interpretation for this is that there is a better learning outcome in the water quality-monitoring school, because the percentile range around the median is more compact and with fewer outliers. This is in contrast to the non-water quality-monitoring school that have a lower percentile range around the median with an overall greater range. The percentile bands around the medians for the water quality-monitoring samples for Cognitive Achievement depicted in Figure 4.5a and for the actual scale for Open-Endedness (Figure 4.5b) are evenly spaced. This indicates a greater homogeneity in cognitive achievement in relation to the actual Open-Endedness scale than is evident in the non-water quality-monitoring school sample. This contrasts with the non water-quality-monitoring school sample whose median is slightly higher but with more outliers than with the students in the water quality-monitoring school.

Figure 4.5b.
Open-Endedness actual medians for non-water and water quality-monitoring schools.

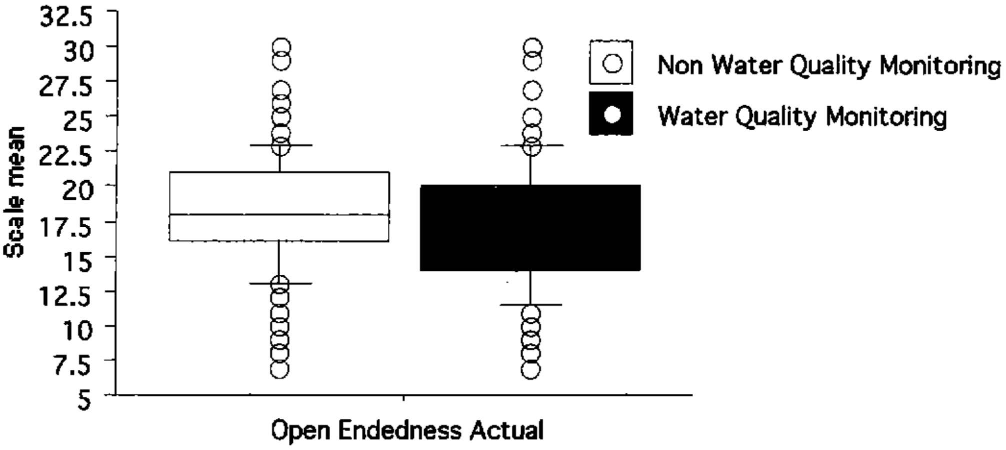
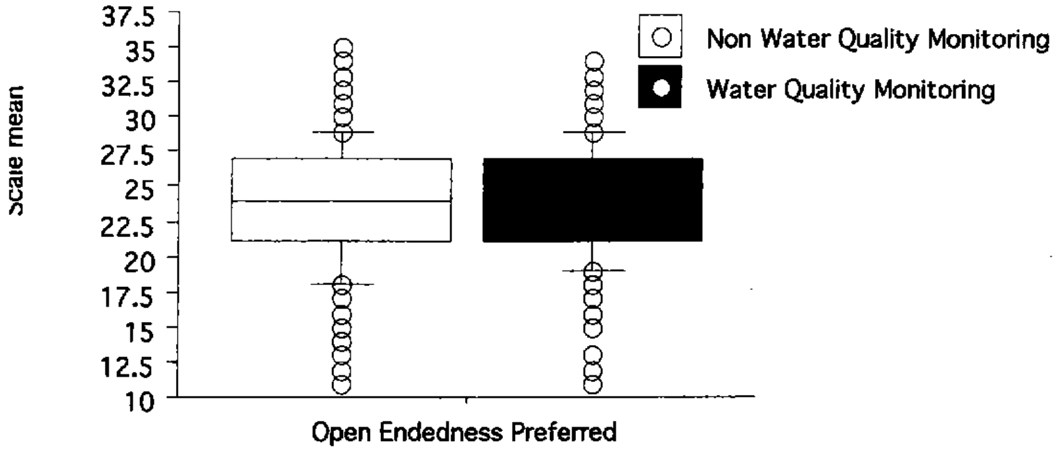


Figure 4.5c.
Open-Endedness preferred medians for non-water and water quality-monitoring schools.



The medians for preferred Open-Endedness scale (Figure 4.5c) indicates no significant differences between the two groups. For Open-Endedness there is a difference in the actual medians. The water quality-monitoring school has a lower median than the non-water quality-monitoring schools. This is possibly due in part to the specific tasks that students perform in the field, and would therefore perceive a lack of Open-endedness. However the students from both groups have indicated that there is little Open-Endedness in their laboratory practices, as shown in Table 4.3. This indicates that there is a perception for a greater degree of Open-endedness. The spread of the scores as indicated by the box plots for Open-Endedness preferred and actual have the same distribution but the median for the preferred scores is higher and is an anticipated outcome as preferred scores are greater than actual scores.

In Figure 4.5d, Integration actual, the degree of homogeneity of response in the non-water quality-monitoring schools is apparent but there is a greater level of homogeneity from the 50th to 75th percentile band with the water quality-monitoring sample.

Figure 4.5d.
Integration actual medians for non-water and water quality-monitoring schools.

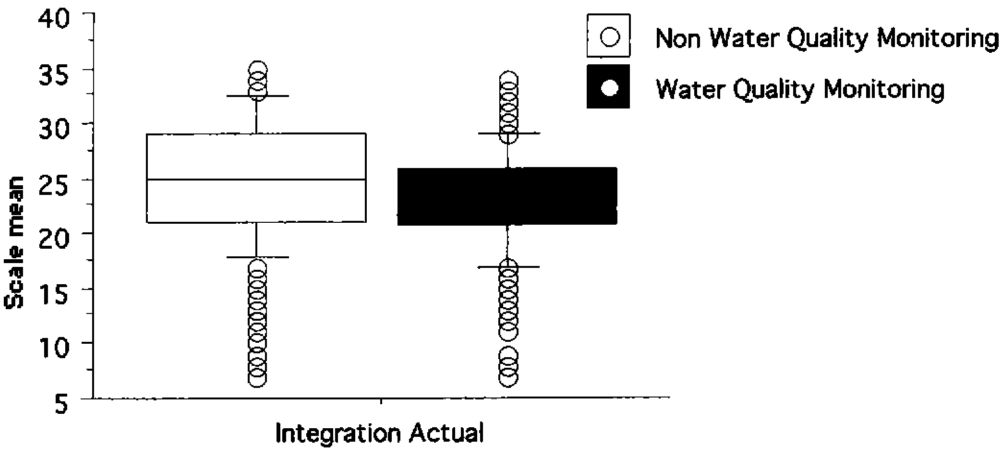
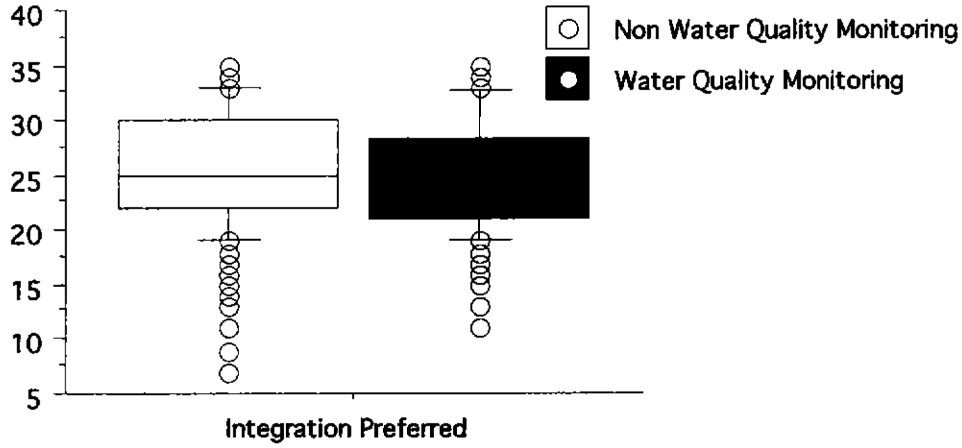


Figure 4.5e.
Integration preferred medians for non-water and water quality-monitoring schools.



In Figure 4.5e, the water quality-monitoring school sample, the medians for preferred Integration scale have a greater degree of homogeneity in the 50th to 75th percentile with fewer outliers than the non-water quality-monitoring school. The medians in relation to Integration show a significant difference in the water quality-monitoring school actual and preferred in that, they would prefer that their learning environment be more integrated with classroom practice.

Examination of Figures 4.2 and 4.3 (see p. 87) indicates that, not only do the students in the non-water quality-monitoring schools perceive higher levels of Integration, but the discrepancy between Actual and Preferred is greater in the water quality-monitoring schools. This is probably due to the perception that the students in the water quality-monitoring program associate the activity as being separate from their normal routine studies, although what they actually do while monitoring is strongly connected to their theoretical and practical work.

The data presented on the Material Environment indicate that students in the water quality-monitoring school are of a higher degree of homogeneity in the inter-quartile range, as depicted in Figure 4.5f, than the non-water quality-monitoring school. This could indicate that students in the water quality-monitoring program are achieving better within their material environment as they have ready access to resources they need. The median for the Preferred scale for the Material Environment for the non-water quality schools (Figure 4.5g) indicates that the ranges are less with a greater level of homogeneity around the median than in the water quality-monitoring school. The water quality-monitoring school has a greater internal range between the 25th and 50th percentile group. This is due in part to the closeness of the actual and preferred scales. It may also be due to other factors that have not been determined but are related to working in an outdoor situation.

Figure 4.5f.
Material environment actual medians for non-water quality and water-monitoring schools.

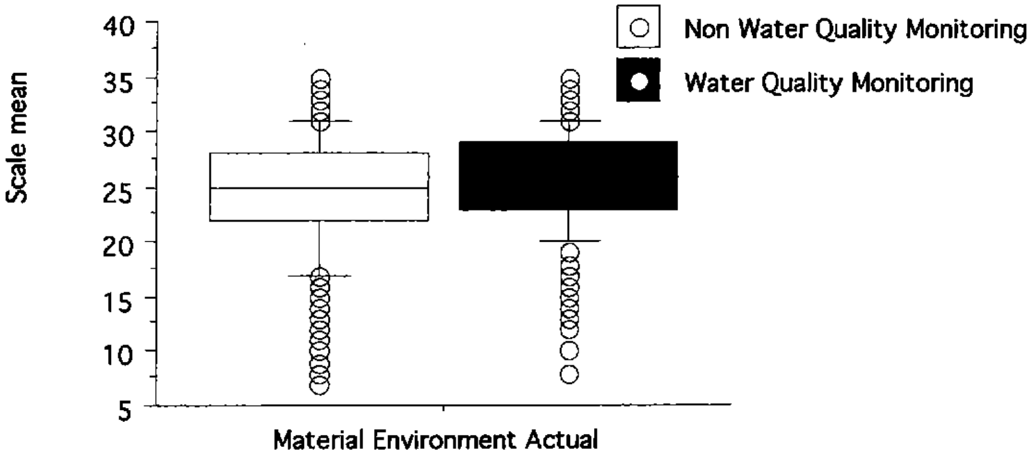
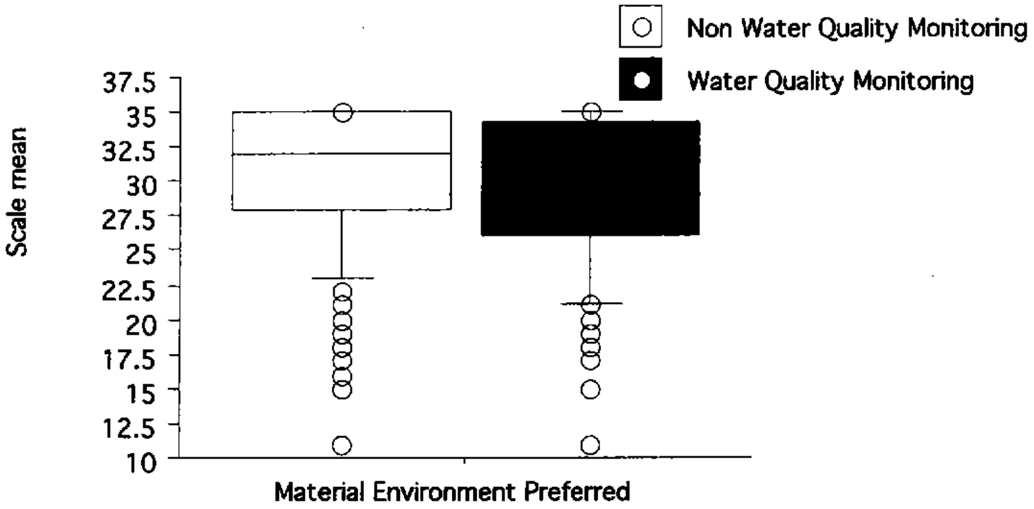


Figure 4.5g.
Material environment preferred medians for non-water and water quality-monitoring schools.



Neither the water nor the non-water quality-monitoring schools demonstrate any statistical difference in Rule Clarity and Student Cohesiveness and it may be assumed that the students perceive the need to follow specified guidelines whether in the field or within the laboratory situation.

4. 5 Interpretation of Statistical Tests

The Bonferroni statistic, a multiple comparison procedure test, adjusts the observed significance level based on the number of comparisons being made to determine which means are significantly different from each other. As some of the mean values appeared to be very close to each other it was considered important to determine if there was any significant difference between the means for cognitive achievement.

It may be inferred that the water quality-monitoring program has a slightly greater effect on student learning outcomes than the non-water quality-monitoring program. In terms of cognitive achievement and the associations made with the SLEI scales, it is in the water quality-monitoring group that the program they undertake in school time assists their achievement performance. It is argued that the transferability of concepts and cognitive achievement is slightly more effective in the water quality-monitoring school when compared with the non-water quality-monitoring schools according to the Bonferroni statistics.

Figure 4.5a (p. 93) shows that the cognitive achievement in the upper and lower percentile band has a greater degree of compactness and less range when compared with the non-water quality-monitoring school. This suggests that the water quality-monitoring school has a stronger association with cognitive achievement. This is also determined by the students' activities and the constructivist strategies used that enable transferability of concepts. This requires active engagement of the student's own learning modality and thinking, irrespective of the thinking level, in the Piagetian sense.

It has been demonstrated that in the water quality-monitoring group there is greater homogeneity in cognitive achievement when compared with the non-water quality-monitoring group. Assessment of the Integration component percentiles indicate that the water quality-monitoring school has a slightly more positive effect on learning outcomes. This is based on the Wilcoxon rank sum statistic and the Bonferroni statistic which is generated by SPSS (Norusis, 1993) and the percentiles in the median box plots ie., there is a correlation between Integration and cognitive achievement outcomes.

4. 6 Summary

This thesis is unique as it demonstrates clearly that the SLEI is a reliable instrument for assessing fieldwork dimensions such as the water quality-monitoring program as well as those of the normal classroom laboratory setting. The methodology used in this study has validated the modified SLEI for use in a field based setting. Furthermore it has been demonstrated that the modified SLEI has comparable values in terms of validity and reliability to the non-modified form of the SLEI as found in previous research on learning environments. As a result the first research objective has been answered satisfactorily within the parameters of previous research. The study has shown that the modified form of the SLEI is as robust as the non-modified form of the SLEI.

Important points arising from the results are summarised below in point form.

- Students' perceptions of Integration is related to learning outcomes.
- Students in the water quality monitoring program would prefer that their learning environment be more integrated with classroom practice.
- Both water quality and non-water quality monitoring groups perceive that Open-Endedness is a desirable feature in the teaching learning process as shown by the analysis of the SLEI data.
- The Material Environment plays an important role in the teaching learning process.
- There is less Student Cohesiveness primarily because the students are able to work individually and at their own level or in groups as the students chose.
- Students are able to utilise information, as measured by cognitive achievement better if they are in water quality-monitoring program within school time and are therefore able to achieve better results than students not involved.

Students involved in the water quality-monitoring program when compared to students in non-water quality-monitoring schools appear to have a greater level of cognitive achievement as has been demonstrated through statistical analysis. The gain in cognitive achievement appears to be associated with the actual scales of Integration and Material Environment used in the SLEI.

Having examined the learning environment dimensions of the water quality and non-water quality-monitoring schools and their relationship to learning it is now relevant to examine the aspects of quantitative and qualitative testing in the next chapter.

CHAPTER 5

QUANTITATIVE AND QUALITATIVE TESTING

5. 0 Introduction

This chapter discusses the results related to the third and fourth research objectives relating to the effectiveness of the water quality-monitoring program on students' reporting on fieldwork, concept learning, and achievement. The chapter also considers the transference of concepts and investigates associations between qualitative anecdotal evaluative aspects of the program and the quantitative data gathered by the Science Laboratory Environment Inventory. While the assessment is in part qualitative it must be seen in the context of the answers and the information depicted in Figures 4.5a to 4.5g in Chapter 4. Care needs to be taken when considering theory and understanding as they are two separate issues, and must not be confused with 'knowing' as often appears to be the situation in examination-driven classrooms (Roth, 1992; von Glaserfeld, 1995).

5. 1 Knowledge and Understanding

Theoretical knowledge needs to be transformed into an operational framework so that understanding occurs, as outlined in Chapter 2. The inference here is that the students have developed a construct of a real working model, which has been achieved through fieldwork. Prior to commencing a topic in the water quality-monitoring program the teacher sets a diagnostic test. The primary task of a diagnostic test is to determine a relevant teaching starting point with a particular group of individuals. It is noteworthy that other teachers involved in similar situations have shown that their pre-test and post-test analysis of students' results in these tests usually demonstrate that students understand less than what is expected of them (pers. obs.).

Many teachers have commented that students can pass examinations by learning the material needed without really understanding the concepts inherent in the topic being examined. Thus for the students, there is a lack of understanding in applying the concepts to problems and authentic situations. Within the water quality-monitoring program, the students are given tasks and skills that are both theoretical, practical and that are new and relevant so constructs may be developed. The students are then given real world problems to work through and find solutions to, before being examined on those tasks and skills.

A large number of the students in the water quality-monitoring program have demonstrated that they have progressed more rapidly through different stages of understanding than students not in the program. This has been evident in the pre, post and other testing that they have done. This would indicate that there are a series of levels in operation in developing constructs and applying the knowledge and skills learnt. This may be best explained by the teaching learning process in a real world situation, the structuring of the program and through their own cognitive development. Prior to the students commencing the water quality-monitoring program, the students are given diagnostic tests to assess their understanding of water catchments, water pollution and ecology. The pre and post topic testing information is in section 5.2. By examining the pre and post topic tests and relating them it becomes evident that there are individual differences in the level of cognitive maturation. One of the pre and post topic questions relates directly to the student's level of maturation by providing a novelty question that provides an insight into determining the student's own level of maturation (Sprinthall & Sprinthall, 1987). These are to draw a noxious weed in the pre topic test and in the post topic test to draw a lizard. The two drawing questions are different as novelty needs to be maintained as well determining a student's general knowledge and observational skills. The noxious weed is used as a starting point as the students generally have knowledge about weeds. The lizard is used in the post topic test as lizards are often observed along the waterway. These two seemingly simple tasks indicate the confidence in the student's ability to try something new. This test is recognised by most cognitive psychologists as an indicator of personal growth and maturation in dealing with real situations (Sprinthall & Sprinthall, 1987). The relevance in doing these tests at the beginning and at the end of the program is to determine the individual level of maturation, observational ability and how well they can make constructs from their general and learnt knowledge. Even though students have different drawing abilities, the tests provide a representation of their cognitive development that is based on observational skills.

5. 2 Pre and Post Topic Tests

As part of the data collection process a pre topic test and post topic test were given only to the water quality-monitoring students involved in the study. It was not possible to have colleagues provide and administer a pre and post topic test to their students. The questions in the pre topic test, though seemingly simple in concept, have underlying general knowledge components. Question 1 addressed students' general knowledge about water catchments. Questions 2 and 3 in both pre and post topic tests were based on knowledge about stormwater and sewage systems, specifically whether the students recognised that two systems were existent. Question 4 was based on the concept of eutrophication and required students to think through the logical sequence of the eutrophication process. Question 5 is based on designing an experiment. Can the students use their knowledge of experimental method to design an experiment, control the variables and be clear in their writing. Question 6 assesses their knowledge of invertebrates. Question 7 assesses their overview of their ability to think past the obvious answer using knowledge gained from wider reading, see also question 1. Question 8 is posed as a discriminator for careful thought taking into account many factors, as opposed to simplistic solutions. Question 9 in both pre and post topic tests seeks to ascertain the students' willingness to attempt to answer a novel question by using their acquired information and observational knowledge. The test is based on a simple cognitive test of "draw a lizard". The pre topic test questions are diagnostic of operant cognitive levels. Examples of typical responses both correct, and incorrect, are given in a table in the next section.

5. 3 Pre and Post Topic Results

Table 5.0

Pre and Post Topic Questions, Expected Responses, Answer Examples and Samples

Question and expected response	Pre topic answer examples sample responses	Post topic answer examples sample answers
Question 1 Where does drinking water come from? **Expected response.** A catchment / dam then treated.	The water comes from dams and underground resources. A catchment dam and is then treated. The tap don't know before that.	From a catchment then the water goes through a filtration plant. Water comes from taps and bottles.
Question 2 Where does the water that goes down the sink and toilet go? **Expected response** - sewage treatment plant.	A sewage treatment plant. Far out to sea.	From the tap to the sewer to the treatment plant then into the ocean. Goes out to the sea.
Question 3 Where does the water that falls on the roof go? **Expected response** - stormwater. Ground infiltration	It goes down the gutters into the stormwater and then to the ocean. To the air it evaporates.	Down drain pipes then into the stormwater pipes then out to sea via the creeks. Into drains and then to the catchment.
Question 4 What would happen if I put all the fish food in the aquarium with 2 goldfish? **Expected response** - eutrophication / pollution / algal bloom	The fish will die and the algae will build up. It would float on top of water.	Escalated algal growth would use up the oxygen and block the light killing other life forms. There would be high change in the death rate.
Question 5 How would you measure the amount of silt / mud in the river water to compare it with some else's measurement of silt / mud? **Expected response.** Measure turbidity / filter sediments etc	Filter out the sediments then measure and weigh it. I would use the same amount of water as another person and we would compare the pH (the amount of water) to compare the mud.	Do a oxygen demand test and compare the results with someone else's oxygen demand test at the same location.
Question 6 What is meant by an invertebrate? **Expected response** - An organism without a backbone.	An organism without a backbone. Algae and moss.	The diversity and number of macro invertebrates gives a good indication of water quality. Some invertebrates are good to have in catchments.
Question 7 What is responsible for water problems at the moment? **Expected response** - Giardia / Cryptosporidium	Giardia and cryptosporidium. A fault in the piping system.	Giardia and other protozoans. Eroding banks, fertilisers, detergents, dog poo, car wastes.
Question 8 How would you fix the water problems? **Expected response** - Chemically treat and filter.	By making sure that the water is 100% clean by filtering and cleaning it better. Cover the catchments and have continued check ups of the water.	Flush out as much of the infected water as possible and disinfect the pumping source. Run fundraisers and cut down on new roads and cars.

Question 9 in both pre and post topic tests involved drawing. The pre topic question was to draw a noxious weed while the post topic required that they draw a lizard. The responses were divided into Highly Competent, Competent, Humour and None. An example of a competent response is given below in Figure 5.1. Evaluating from the results between draw a weed and a lizard there has been an increase in the level of maturation as detailed in Table 5.1.

Figure 5.1.
A competent response.

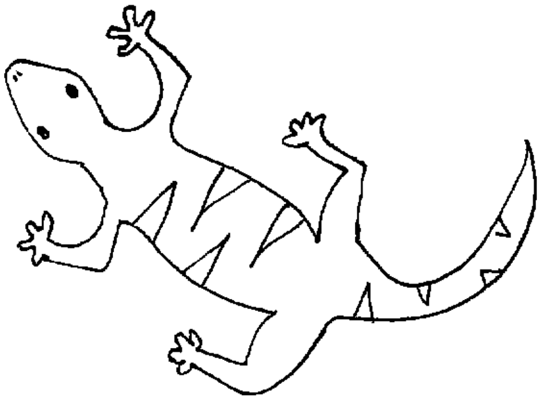


Table 5.1
Pre and Post Topic Test Ability to Attempt a Novel Question as a Measure of Cognitive Maturation

	Highly Competent	**Competent**	**Humour**	**None**
Noxious weed	59%	12.5%	8%	20.5%
Lizard	50%	31.0%	12%	7.0%

The responses of the water quality-monitoring group for the other questions were grouped for correctness of response. A percentage value of correct responses is presented in Table 5. 2. It was not possible for both sample groups to do pre and post topic testing. Only the water quality-monitoring group were asked to do a pre and post topic test and caution needs to be taken in interpreting the results and drawing conclusions from them.

Table 5.2

Percent Correct Pre and Post Topic Questions

Question	Pre Topic		Post Topic	
	% Correct	% Incorrect	% Correct	% Incorrect
Question 1	32	68	88	12
Question 2	42	58	37	63
Question 3	65	35	85	15
Question 4	63	37	81	19
Question 5	27	73	33	67
Question 6	58	42	59	41
Question 7	22	78	31	69
Question 8	17	83	48	52

In consideration of the above data, question 2 indicates that students had not learned that there are two systems in operation, while in question 6 the student knowledge of invertebrates had not deteriorated. All other questions indicate an increase in the ability to utilise concepts and knowledge. Question 8 however strongly demonstrates a highly positive outcome, almost a three fold increase in applying the concepts and knowledge learnt. Question 8 was based on a topical problem that existed in the waterways at the time and was considered as being relevant to them. The question has teaching relevance as the students are asked, given that they have the information as a result of the water testing procedures that they undertaken, what needs to be remedied and how would they solve a real life problem. As mentioned in the previous section, by posing novel questions such as 'draw a noxious weed' and 'draw a lizard' provides the teacher with insight into the willingness of students to attempt something new, as well as gain insight into operant cognitive levels before and after being involved in the program. Students while they are in the water quality-testing program are required to make ecological assessments of the riverine environment.

When the students test the water and make environmental assessments they are asked also to observe and draw fauna and flora as part of auditing the environment. The ability to draw well is not considered a confounding variable as it does not seek to define drawing ability, rather it tests the ability to utilise observational skill, confidence and operant cognitive levels. Thus, Question 9 in the post topic testing indicates that there was an increase in the number of students who became more competent and confident in dealing with novel situations. Table 5.1 indicates that in dealing with novel situations the students in the water quality-monitoring program increased their competence. As stated earlier, drawing ability is not considered as important. What is important is that it indicates the ability of students to utilise the skills learnt, and as a consequence improve in making their own knowledge constructions.

5.4 Interpretation of Pre and Post Topic Testing

In consideration of the pre and post topic assessment, it is important to consider whether the quality of the answers provided demonstrate a greater depth of understanding to what had been learned.

From the pre and post topic testing, the information indicates that the students have learned the concepts needed to understand water catchment systems, pollution problems and how they can be remedied. Thus, it indicates that students have made the relevant constructions of understanding water quality monitoring in an environmental context.

The students involved in the water quality-monitoring program have through a variety of responses in the pre and post topic tests demonstrated that they have gained and developed from the program both in confidence and achievement. Furthermore by assessing their field-work the students have demonstrated that through their interpretation of gathered water quality-monitoring data they have developed their own knowledge of the environment and have sought out new ways of interpreting the impact of human activities in the environment. This has empowered and enabled them to build constructs with greater confidence because of a greater level of independence needed to work either by themselves or in small groups while in the field.

While the students in the control group did not have pre and post topic tests, some of the students provided comments on what they considered the environment to be about. Their knowledge, based on the few comments provided indicated that they were not really interested in environmental matters and thought that it was a problem that would be solved by scientists or the government. As the quantity of comments was insufficient it was considered that the responses given could not be incorporated into this study other than the fact that they thought it was some else's problem. In terms of trying to assess if they had developed and applied their constructs to other areas, the teachers involved in the study felt that it would take too much time out of their teaching day. As a consequence, based on their achievement tests the following assumption was made, that the students had made some gains and may have been able to apply some concepts to other areas.

Importantly, many of the students in the water quality-monitoring program have demonstrated that there is a greater depth of understanding, judging by the quality of their responses. This would indicate that they have developed constructs beyond what was anticipated, supporting Toh and Woolnough's (1994) work. It also infers that the students have better levels of understanding of concepts that have been learnt and may be applied to other learning areas. As it was not possible to measure every component for understanding, it may be asserted that the depth of understanding has arisen from two factors. Firstly, the structuring of the program, and secondly by learning in a real world situation. These assertions are not without foundation and in fact are in keeping with the work of Disinger (1984), Lisowski & Disinger (1987), Roth (1992), and Schellhammer (1935).

The students verbally indicated that participating in the water quality-monitoring program gave them more confidence and greater insight into science and how the environment may be assessed scientifically. This supports the data given in Chapters 4 and 5. This is primarily because they were dealing with real life situations irrespective of which teacher took them for the topic. The program gave them a certain amount of autonomy over what they do, which is to a certain extent in contrast to what normally occurs within a laboratory or classroom situation, as many colleagues report that they still prefer to maintain teacher autonomy as inferred by Provenzo & McCloskey (1996).

Only two teachers did not provide pre and post testing responses of their classes because of time constraints. Time is a major factor as many teachers need to ensure that they provide and meet all the necessary content and skill requirements for a particular topic. It was more important for these teachers to teach the topic than do pre and post topic testing, thus ensuring they had met all the teaching requirements for this particular topic.

5. 5 Anecdotal Responses

As part of the overall consideration of the data a small anecdotal study was carried out. One hundred students were involved in this component of the study and were randomly selected to retain statistical rigour. This was achieved by allocating numbers to the students who had been involved and asking a student to select 100 numbers at random from 600 numbers. The numbers were then matched with the names of the students who were then contacted by the researcher. The students were drawn from years 11 and 12 and from those at university who had been involved in the program. Not all the vignettes are included, however it needs to be emphasised that while only a few vignettes are given from the 100 responses, they were typical and a pattern emerged from their responses. The representative vignettes are provided with the questions and responses, and are as follows:

Did the program make any significant contribution to your understanding of science?

- Streamwatch provided me with a window into realistic science not a fabricated view of the world.

- I learnt more science doing Streamwatch than in any other year because it was really problem solving even when the changes were not really visible. I am doing science at university.
- I learned a lot. It made me feel like a research lab technician. It has made me definitely more aware of the dire problems of water pollution and the need to conserve water and keep it clean.
- I liked the program because it was much more practical than anything we've ever done. It wasn't like an experiment either - it was like our results counted and they were real. It also helped me with other subjects that I'm not too good at.
- It made me more aware of the role science plays in every day life.
- Streamwatch was for me very realistic not like normal science classes.
- Everything we did counted because it was real.
- It made all the other science subjects much more exciting but if I hadn't done Streamwatch I would have become bored very quickly with science.
- It made me realise how important science really is, in understanding our world.
- It was very interesting and if that is science then I think its cool.

Did you choose a science subject for your Higher School Certificate because of Streamwatch?

- I have taken on geography and biology, as I want to be an environmental planner.
- Streamwatch was the reason why I took up Chemistry.
- The program made me a lot more aware of the environment and the problems people cause. It inspired me to study biology.
- I chose biology and chemistry because they are of major importance in understanding our environment. Without Streamwatch I would not have chosen science.
- The biology side of Streamwatch influenced me to study biology.
- Not really as I am enthused by science.
- Streamwatch encouraged me to do more science units than I would have taken.
- Yes, Streamwatch influenced my choice of subjects because it was a good science course.

- Yes my abilities with experiments improved because of Streamwatch giving me confidence to do chemistry in year 11.
- No it didn't but Streamwatch made science exciting.

Have you become more aware of environmental issues because of being in Streamwatch?

- It increased my environmental awareness. Science was made realistic compared to just working with textbooks. It has made my family and me more responsible towards the environment.
- It has given me an understanding about our waterways and how the little things we take for granted affect our environment. It has helped me understand science a lot more but will not change my career choice.
- Streamwatch taught me real problems and problem solving.
- I'll think twice now before I throw something in the gutter. Being down at the water was peaceful as well as helping the environment rather than being in a classroom with textbooks.
- It has made me more environmentally aware about how much pollution we make.
- Much more aware because it was about trying to solve problems.
- Definitely! I am now more alert to the consequences of pollutants in our water.
- Streamwatch showed me how pollutants damage people, animals and the environment.
- No because our family is already concerned about the environment.
- The program certainly opened my eyes to environmental problems.

Have you embarked on a career path involving environmental science?

- I am doing a science degree with a major in environmental studies.
- Streamwatch opened my eyes and heightened my understanding of local, State and federal politics. I am involved in a law course with environment as a major.

- As a result of doing Streamwatch I focussed on biology as a subject. I intend completing my university work in biology so that I can work on environmental matters when I graduate.
- I am currently studying environmental planning and law but would not have done so if I hadn't been involved in Streamwatch.
- Yes I am doing a degree in environmental science.
- I'm doing a course in eco-politics.
- My studies in Streamwatch gave me a good start in doing a course in natural resource management.
- No I'm doing medicine but would like to see more environmental work being done in universities.
- No I'm doing nursing but the environment is very important to everyone.
- I want to specialise in environmental chemistry.

Did Streamwatch give you confidence to do science?

- I'm not confident in doing science but this program made me learn and understand by putting different ideas together.
- It has promoted group work and has helped me as an individual to feel confident in science.
- I am not usually very confident with science but this was really learning and understanding something important.
- After doing Streamwatch in the field I always felt confident in other things. My marks in other subjects have improved because of Streamwatch.
- Because it was fun and interesting it gave me more confidence because we were dealing with real things that affect us all.
- It was the practical part that gave me confidence to do science on my own but still work as a team
- No it didn't because I already love science!
- Science and schooling suddenly made sense and when I see the sense of things I feel confident and positive.

- Working with my girl friends was a help but Streamwatch made it happen because the rules were right and we could do things for ourselves and feel good about it.
- Streamwatch has really helped my grades because it looks at all kinds of problems and getting the problems right gives me confidence.

5. 6 Anecdotal Interpretation

To assess whether or not there is any association between the anecdotal and the quantitative data the following provides an answer to the fourth research question as stated in Chapter 1.

Of all the responses returned by students, 90% agreed that the program instilled them with the confidence to do science. Of these, 13% stated that the water quality-monitoring program provided them with the confidence to do science that they did not previously possess. In consideration of the impact of the water quality-monitoring course on the students and their studies, 63% stated that it made science more meaningful and had positively affected their performance in other subjects. Of the 100 students, 70% either inferred or said that they were very positive that the experiences in working in a "life" laboratory enhanced their understanding of science concepts because they were dealing with real situations and not contrived ones. A total of 27% of the students decided on senior courses and careers in science because of the positive outcomes that they had experienced while 24% stated that it made them more aware of issues.

All the students in the anecdotal study commented that the program was centred on quality outcomes and learning which they had in their opinion achieved.

Significantly, all the students stated or implied that real life situations were preferable to classroom learning. It was not possible to collect vignettes from the students who were not involved in the water quality-monitoring program.

The issue that arises out of these vignette statements is that the program provides a reality component not usually found in a normal science class. There is within the water quality-monitoring program a high level of motivation, an avenue of problem solving that is part of the real world scenario. This, it is maintained, influences the students to do science either at the senior secondary or tertiary levels and is supported by Woolnough (1991, 1994) who demonstrated that motivation, the practical, human and intellectually stimulating aspects of various subjects stimulate students to pursue science and associated careers. Furthermore, Woolnough (1994, p. 672) states that there is not a 'single factor which is universally influential; different students are persuaded by quite different factors.'

While this is true for these vignette statements it is certainly not conclusive that the components of the water quality-monitoring program are the major factors in its success, other than it provides motivation and real life problem solving situations that enables students to develop and control what they do. All people, according to Lave (1988), deal with real life problems that need to be solved either immediately or within a short-term context to obtain a sense of achievement. The vignette statements would certainly support this view. Observations made by teachers and psychologists indicate that people like to have control over what they do, a critical point amplified by Roth (1992).

The anecdotal responses of the students who had previously participated in the water-monitoring program is related to the perceptions of current students. According to their teachers, the current students have gained confidence in doing science and have similar aspirations, to pursue science in senior school as well as taking up a career that involves environmental work. Comparing the previous to current students there is a similarity in their cognitive achievement. However, it was not possible due to departmental regulations to obtain the necessary data to make a statistical comparison.

The anecdotes may be associated with the scales in the SLEI and the dimensions espoused by Moos (1974). The associations are based on the fact that the closer the actual scales are to preferred scales in the SLEI the more effective the learning environment (Henderson & Fisher, 1998). Perusal of the anecdotes in section 5.5 indicates that the learning environment in the water quality-monitoring program has provided the students with confidence to do science, as well as providing the students with a better understanding of science and environmental issues. The anecdotal statements made by the students demonstrate relationship, personal development and system dimensions. For example the personal development dimension is through students making statements such as, 'It helped me with other subjects that I'm not too good at.' This is also an aspect of the learning environment dimension assessed by the Integration scale in the SLEI. Furthermore, the anecdotal evidence provides a level of information that indicates that the understanding of concepts and skills are enhanced if students are faced with a realistic situation, confirming the work of Roth (1992, 1998).

5.7 Summary

All forms of analysis, including the qualitative perspective used in this thesis, provide supporting evidence with regard to the SLEI learning environment dimensions for the water quality-monitoring program. The anecdotal data provide additional support for the Actual SLEI learning environment dimensions, specifically Integration, Student Cohesiveness and Material Environment. The anecdotal information in this chapter highlights the quantitative associations of the SLEI as described in Chapter 4. Furthermore, the qualitative information shows that the students' perceptions are related to their aspirations more than it appears in the quantitative data. The qualitative information also provides an insight into the students' perceptions about their learning environment and their learning while doing fieldwork. The closeness of their actual to their preferred perceptions indicates that the water quality-monitoring program fieldwork provides them with an effective learning environment. As discussed in Chapters 2 and 4, the closer the Actual to Preferred scales are the better the learning environment. Hence, it may be argued that even in the absence of a control group for qualitative information in this chapter there are positive student learning outcomes. This has been demonstrated in this Chapter to be the situation with students who have been involved in the water quality-monitoring program.

Pre and post topic results provide a level of information that provides associative support for the measurement of psychosocial dimensions in fieldwork, confirming the work of Moos (1974) and the many other researchers who use the learning environment dimensions of the SLEI and similar instruments. The depth of understanding of students and their ability to make constructs in a real world scenario are reflected in their responses to the pre and post topic testing. Overall the pre and post topic data have demonstrated that there is cognitive achievement gain by students being in the water quality-monitoring program. As there is a positive gain in achievement it may be argued that the students' have developed their constructs while being in a field based situation.

The vignettes demonstrate that there is an association with the learning environment dimensions indicating that real world fieldwork learning provides student motivation and influences them to take up careers in environmental science or a career in science with environmental components. Programs such as the water quality-monitoring program provide an avenue for the building of confidence to do science and this is best achieved through real life problem solving. Problem solving in a real world situation enhances students' understanding of science and enables them to integrate the constructs they have learnt into other areas of learning. When anecdotal and pre and post topic responses are considered together with the vignettes as psychosocial outcomes of the students' learning, the relationships within that learning that emerge are supportive of the SLEI learning environment dimensions.

It has been demonstrated in this chapter that learning science, through fieldwork, such as that integral to the water quality-monitoring program, is an effective way of learning and integrating constructs. This study so far has focussed on one water quality-monitoring program. The next chapter provides an account of water quality-monitoring programs used in other countries. The account is based on the personal observations of the writer and provides a basis for comparison with the program described in this study.

CHAPTER 6

PERSONAL OBSERVATIONS AND COMPARISON OF WATER QUALITY-MONITORING PROGRAMS

6. 0 Introduction

This chapter provides some personal comments about the water quality-monitoring program and relates to the fifth research objective of comparing the field based water quality program with other programs in developed and developing countries. The first part deals with the evaluation of the water quality-monitoring program. The second part deals with water quality-monitoring programs or similar environmental programs overseas in order to place what occurs in the water monitoring school in this study.

6. 1 Personal Observations of the Water-Quality-monitoring Program.

The Streamwatch program has given schools that wish to participate the opportunity to enrich a school's environmental education by providing students with opportunities to work in real life situations. Not every school has an extensive across-the-curriculum approach as each school establishes its own water quality-monitoring program. The water quality-monitoring school has its program based in science, with an across-the-curriculum approach and maintains an integrated approach to environmental education. All the staff support the integrated approach.

The water quality-monitoring school described in this thesis provides a program that is within school hours with little disruption to any other aspect of the school's activities. The program is rotated through the classes in year 10 with some students in years 7 and 8 participating in macro invertebrate collection and identification as part of their science program. This is in contrast to some other schools that run their water quality-monitoring program as a club, extra curricular activity after school or within the designated time allocated for sport.

The water quality-monitoring school incorporates in-field instruction on the various aspects of environmental monitoring and interpretation. The students are assessed in this program just as in any other subject or topic within the school. Provision is made for the students to utilise the Internet and communicate with other schools across the world. Indeed many of the features within the program have assisted other schools to develop other aspects in environmental education because of the real life involvement of the students in the water quality-monitoring school. Many of the students actively search out environmental careers and have become more environmentally aware, as has been shown in Chapter 5.

The careers that were chosen by the 100 students who participated in providing anecdotal responses indicated that 35% of the students have taken on a tertiary course with an environmental component, such as law, engineering or planning. Another 20% stated that they were involved in full time undergraduate environmental science courses. The remaining 45% of the students have entered tertiary courses such as medicine, nursing, pharmacy and commerce. While it is difficult to measure awareness as a quantity it is perhaps better to measure success as an outcome of the students' activities. Since the inception of the school's program in 1994, the students have won prestigious awards at the local, State, national, and international levels (Waterwatch, 1998). In terms of awareness, the students who had been participants as well as those who are in the program are pro-active in the school or in their community. This has come through their direct involvement with the water quality-monitoring program. Their involvement has led to the writing of musical compositions about the environment, through visual art and the creation of sculpture and paintings. In their local community many of the students have initiated and implemented tree-planting programs and in one situation assisted in the development of 'Catchment Day' that involves all schools and councils in the water catchment area. This day is convened by the water quality-monitoring school students and a public report is written. Many of the current students spend time on the Internet communicating, sharing and solving environmental problems with other students at the national and international levels.

The water quality-monitoring program has direct involvement in real life issues and allows the students to build upon their experiences in the field. This enables the students to build their own science constructs through field based problem solving and interpretation of data. Much of what has been learned in the environmental setting by the students has allowed them to transfer their ideas into other subject areas, specifically in science. Furthermore it has been shown in Chapters 4 and 5 that their academic achievement is slightly better than the non-water quality-monitoring schools.

The use of constructivism and the hypothetical deductive approach that is inherent in the water quality-monitoring school's approach, as outlined in Chapter 2, has contributed through the various activities that the students undertake in the field. This has provided them with success in their subjects and their ability to confidently do science, as demonstrated in Chapters 4 and 5. Even though some of the teaching is eclectic, the tenets of both constructivism and the hypothetical deductive model provide the students with empowerment and confidence to achieve what they have not been able to achieve in the normal class situation. It has been frequently noticed by teachers working with students in the field that the hypothetical deductive and constructivist methods arise 'naturally' in teaching strategy and in the way the students investigate their surroundings. The realism of the constructivist approach that in-field activities provoke is a major aspect of the success of the program. This has also been observed in other schools and has led to achievement levels that have been recognised by industry, education and local community organisations by the granting of awards.

6. 2 The Overseas Experience

This component of the thesis contributes to understanding what is occurring in school-based environmental programs globally. It also serves to highlight what is being achieved in the school's water quality-monitoring program so that a comparison between water quality-monitoring programs can be established. The countries briefly considered are Mauritius, Kenya, Germany, the United Kingdom, Russia, Poland and the United States of America. The information was collected through personal discussions with teachers, teacher educators and education ministry officials. Information was also collected directly by visiting schools.

Within the countries mentioned the public school systems have little or no nationally coordinated water quality-monitoring program, nor do they have Federal or State government support. This is in contrast with Australia where all States and Territories provide support for water quality-monitoring programs. Waterwatch Australia provides assistance to the States. There is a growing perception in the countries mentioned that there is a need to implement water quality programs as part of their environmental education curriculum. The programs that currently exist are based on excursion type activities and may relate to the school syllabus or are provided as extra curricular activities. However, there are some states, such as Hesse in Germany, that offer through their local state education department an integrated thematic curriculum approach from Kindergarten through to Year 13.

However, some of the countries, particularly developing nations, would like to implement an environmental education and water quality-monitoring programs through their science curriculum. The teachers in those countries consider such programs as being necessary for developing science education. However, due to lack of resources and in many cases lack of expertise, the teachers are not able to implement what they consider as being important. Ministry officials, it seems, prefer to give a favourable impression that environmental education is part of the curriculum but the resources are utilised elsewhere. This constraint is a feature where there is a lack of finance and or political bureaucratic difficulties. This is especially the situation for emerging democratic nations such as Russia and Poland. In the African region, the nations are reliant on outside assistance for their educational and environmental programs. The water quality-monitoring school has as a means of support provided some schools in developing nations with educational resource material. In some other countries the water quality-monitoring school's program has established an Internet link, so that students can problem solve and share experiences on a student-to-student, as well as on a coordinator-to-coordinator basis.

In Mauritius, the curriculum is academically orientated and prescriptive in its objectives. Environmental education is based in biology and to some extent in the geography syllabus. According to the educators students undertake field trips, perhaps twice a year, and then usually to the local sugar plantations to assess the environment. This may take only two lessons and it appears there are no further in field environmental assessments. Any further work is done in the laboratory. The teachers, while desiring to have a water quality-monitoring program, see the educational benefits of long term environmental monitoring and feel they are constrained by the prescriptive approach and a lack of funding.

Although the curriculum is prescriptive in Kenya there is a flexibility which allows for field based programs to take place both on a formal and informal basis. Generally, environmental education is taught as an extra curricular activity but has little or no real impact outside of the larger Kenyan cities. Emphasis outside the cities is to achieve literacy. Any additional programs for environmental education or field based activities are dependent on the interest of the teacher and the wealth of the school or organisation supporting the school. In developing a better environmental program for developing countries, Pohl (1996) suggested that the following were perceived as essential for the development of in-field educational activities:

- To establish an active government policy for environmental programs.
- To involve school students as quickly as possible in such a program.
- To incorporate environmental education in the school curriculum.
- To use constructivist methods in the science syllabus.

While it is possible with limited finances to establish such programs some Kenyan educationalists perceive that water quality-monitoring and outdoor environmental programs do not serve the rigour of scientific method. While the teachers and academics are not opposed to fieldwork programs, they perceive that students in schools learn better by being in the classroom rather than outside the classroom. The University of Nairobi, at the time when this information was being collected, was intent on ensuring that strict academic didactic teaching strategies be adhered to in schools to improve literacy and numeracy as well as meet government policies.

German schools are organised in a partially autonomous setting and this has direct consequences on how water programs are organised. Many schools only do a short practical period in aquatic invertebrates and then it is mostly done in a laboratory setting. Those schools that run environmental programs do so either within their ecology strand or as an afternoon activity.

Some German schools, in order to enhance student awareness of environmental matters, use the Global Rivers Environmental Network approach that is similar to the approach used in the water quality-monitoring school. However, the German schools in terms of fieldwork are only active twice a year, in spring and autumn, and then only as part of a science strand. In 1997, Pohl found that the Teacher Inservice Institute of Hesse had developed a program of a 'water experience path' from Kindergarten to year 13 based on a constructivist approach as indicated by Pohl (1996). At the Marburg - Biedenkopf School Biological Centre, a water project has been established and is aimed primarily at the upper primary grades and is similar to that of the water quality-monitoring program. The project focuses on the historical and geographical aspects and incorporates some chemical testing and data exchange. The project is information-based with little hands on experience being used. There seems to be no constructivist methodology. Much of what is done is twice-yearly sampling of invertebrates, with the remainder of the time being spent theorising on what may or may not occur to organisms if water quality changes as well as doing projects on macro-invertebrate identification.

It became evident that fieldwork programs in German schools have little support from the education and water authorities which are being privatised and geared to meeting other political and educational agendas. These perceptions vary from one German State to another and have a direct influence on education. What, however, is common through the three tiered German public school system is that subject expertise is shared within a cluster of schools, and as a result the practice of syllabus implementation fails to meet the reality according to teachers of what is needed in environmental education.

All schools in the United Kingdom follow a national curriculum and this, according to many teachers and educationalists, allows for little leeway in incorporating field based environmental education programs. This mainly due to time constraints within schools rather than direct policy. Environmental work is restricted to the strands within the national curriculum, and to attain the best performance outcomes, teachers need to restrict themselves and their classes to occasional field trips. The curriculum itself is divided into separate levels such that some students who study biology, by way of example, do not have to know about DNA, yet these students may be in the same class as other students who are doing higher level work and need to know about DNA. For teachers to meet the goals of the national curriculum, teaching is often didactic rather than being constructivist and involved in real life problem solving situations.

In Russia education is primarily based on a lock step system mainly due to the lack of educational resources and funding. However there is great interest in environmental issues because students inherently know that the problems in the environment are immense and that they are inheriting the legacy of the previous regime and are desirous of changing their environment for the better. However, little is done, but what is done is through extra curricular and informal activities. All classes that were observed, both in schools and universities used the didactic approach rather than any other method. This is in contrast to what Pohl and Khaustov, in Khaustov (1998), perceive as a necessity, that is, using constructivist methods and fieldwork as the main basis for understanding science in theory and practice.

The Polish Ministry of Education has pointed out that many schools through their own initiative were already proceeding with 'informal' environmental education projects. The projects that have been running consistently have little or no support from the Ministry; any funding for these projects comes from private sector sources who also set an agenda as to what and how something is to be taught. However the Ministry of Education has developed a strategic plan based on a prescriptive curriculum that specifically involves senior high schools.

The Ministry of Education perceives the need for environmental education and has committed itself to ensuring that water pollution education receives top priority. The Polish Ministries of Education and Environment were rather surprised at the degree of government sponsorship for schools in Australia to run water quality-monitoring environmental programs.

It is impressive that the Polish Education Ministry has put environmental education as a priority while grappling with the political problems of democracy. Nonetheless, there are some 130 high schools in the Warsaw area alone that are positively engaged in some activity that is related to environmental water matters. The approach used in environmental education is club based and is linked to the curriculum, though the main teaching strategy is didactic. However, the water quality-monitoring programs are not as successful as the teachers would like as they are constrained by school and government policies. Furthermore, as already discussed in this study, club activities are often considered as additional experiences and may not provide a long term integrated approach to dealing with real life situations.

Within the USA, environmental education methods vary from State to State and from authority to authority. There is little by way of a nationally coordinated approach to water quality-monitoring programs though there is a strong emphasis by the Federal Education Department to strengthen environmental objectives, so that they have a more unified and coordinated educational approach in both schools and universities. Environmental education is pursued on an extra curricular basis, usually as projects or through a club, however this is changing to incorporating environmental education programs that are part of the overall school curriculum. The change in emphasis is perceived by the researcher as being beneficial and in keeping with what occurs in Australia. Teaching methodology often is a mixture of didactic and constructivist approaches. These approaches to teaching are similar to what occurs in the researcher's school, and from this point of view makes the researcher's school similar to that of schools elsewhere. From the researcher's experience and direct contact, many teachers seek a program that combines the hands on approach with constructivism both at the formal and informal level. The water quality-monitoring program serves that purpose as well as to foster science education in a real life situation over a long term period where the students are able to develop their own expertise and integrate what they have learned in other aspects of their schooling.

While there are many and varied water quality-monitoring programs in both developing and developed countries, the water quality-monitoring school program has several points that favour student outcomes. These are:

- material but not financial support by both State and Federal government agencies.
- that the school supports the program as a part of the school day.
- that the science teachers involved in the program are motivated to ensure successful teaching outcomes.
- that the program has an across the curriculum approach and allows for individual and group development while doing fieldwork and class work.
- that the fieldwork program is orientated around constructivism.
- motivation by students to do something that they consider real and important for their environment.

Water quality-monitoring programs are perceived by people in many countries as an important environmental education tool and program for all levels of education as claimed by Waterwatch Australia, the Hesse Teacher In-service Teacher Training Institute and the University of Mauritius, amongst others. There is, because of environmental degradation, a real need to link environmental education to an across curriculum approach such as now enshrined in the NSW Environmental Education Act of 1999. According to many teachers environmental education programs such as the water quality-monitoring program are best taught through constructivism and real life experiences (Disinger, 1984, 1990; Moreira, 1980; Roth, 1992). However, not all countries are able to support such programs due to lack of resources and in some instances lack of expertise.

It is apparent from what has been observed in both developed and developing nations that a water quality-monitoring program is a relevant tool in the provision of science education. Fieldwork programs, such as the water quality-monitoring program, could be integrated into the curriculum with ease and academic rigour retained as has been achieved in the State of Hesse, Germany. In 1999, the NSW Department of Education and Training incorporated a greater level of integration of fieldwork into the new environmental education, science and chemistry syllabi, making programs such as the water quality-monitoring program accessible to senior higher school students.

6. 3 Summary

Because of its real life involvement, constructivist approach to fieldwork, integrated curriculum approach, student academic achievement, and the selection of courses at senior high school and university of environmental subjects, the water quality-monitoring program as described in this study may be considered as being successful. The teaching strategies of constructivism and hypothetical deduction in a real life situation are germane to environmental education, and specifically to the water quality-monitoring program. Programs that are extra curricular and prescriptive, even though they may be carried out in the field, as reported by teachers in other countries, do not appear to have the same level of accomplishment (Pohl, 1997; Pohl & Khaustov, 1998) as those programs that utilise fieldwork that are constructivist or hypothetical deductive in their approach. This is borne out in the studies of Falk and Balling (1982), Knapp (1996), and Kuh, Schuh, and Whitt (1991).

There is a great deal of variance in water quality-monitoring programs in other countries. The programs may be offered as extra curricular activities, clubs, or as a research project, but are not run as a long term activity for a specific class. Many countries implement water quality-monitoring programs as part of their school curriculum but may be constrained by financial or material resources or by government policies. Many are considered to be successful by their respective authorities as they meet the needs of their government policies.

Student involvement and success is dependent on the strategies used. However, the real life situation coupled with constructivism appears to be the model on which the teaching learning process can bring about better academic achievement specifically through field based activities and problem solving such as the water quality-monitoring program described in this thesis. The conclusions and limitations of this thesis are described in Chapter 7.

CHAPTER 7

CONCLUSIONS

7. 0 Introduction

This chapter considers the outcomes of the study, acknowledges its limitations, and discusses the conclusions reached in relation to the research objectives given in Chapter 1. Possible future research investigations and recommendations are also provided regarding the use of the SLEI in fieldwork programs.

Real life problem solving, using constructivism and/or the hypothetical deductive processes are key functions in the water quality-monitoring program. The water quality-monitoring program requires situations, models, and problems that are authentic so students may learn to recognise, understand, and solve problems that are not only relevant to them, but also in the community in which they live. The students' activities require immediacy of action and learning, and demands of the student to build appropriate and meaningful solutions that can be used in other subject areas.

In teaching science, students are expected to develop critical thinking skills from prepared handouts based on experimental work that they have done (Brooks & Brooks, 1993). Often the experiments that are performed bear little resemblance to the theoretical and pre-lab work, and more often than not have little relationship to what occurs in the real world situation (Collins, Brown, & Newman, 1989; Roth, 1992). Time constraints are often placed on students when performing experiments and this brings about a student perception that experiments are contrived or 'non-working' situations. The lack of time and the students' perceptions of what needs to be done do not allow the student to understand the relevance or how to relate to and solve the problems that they perceive in the real world. Thus problem solving that ensues from the laboratory work may be considered by the student to be contrived. As described in Chapter 2, the student's ability to solve and transfer knowledge in a laboratory situation is often overlooked by the teacher and as a result the students perceive laboratory experiments as open and shut situations, and for the teacher the student learning outcomes are not properly considered. This is not the situation within the field-based context. Within the water quality-monitoring program, the students are required to solve authentic real life problems as part of their activities.

Thus, it may be concluded that the immediacy and authenticity of real life problem solving by being in the field is a factor in challenging students to utilise their prior knowledge and develop their own constructs to achieve successful learning outcomes.

The water quality-monitoring program at the researcher's school is considered by many departmental educators to be successful because of the numerous awards which the school has received, such as RiverCare 2000, and the Sydney Water Dolphin Awards. Part of the success is due to the fact that authentic situations in which the students operate provide good problem solving situations. This also enables the students to develop their own learning constructs in a more meaningful manner rather than what occurs in a laboratory situation. This concurs with the work of Disinger (1984), Doherty (1992), and Lave and Wenger (1991). The aim of this study was to evaluate the effectiveness of a water quality-monitoring program with particular emphasis on students' fieldwork. In the next section, the outcomes of each of the research objectives are discussed.

7. 1 Outcomes

The outcomes reached in this study are described below and relate to the specific objectives of this study.

7. 1. 1 Validation of the SLEI when used in a Field-based Learning Situation

The first research objective was to validate the modified SLEI in a field based situation. The modifications that are described in Chapters 3 and 4 indicate that the SLEI is a valid and a suitable instrument for determining the psychosocial learning environment of a field based setting. In validating the SLEI when used in a field based water quality–monitoring program, Cronbach's alpha coefficient for internal reliability of the data was found to range between 0.55 and 0.83 for scales in the

Actual version. The Cronbach alpha coefficients for the Preferred version ranged between 0.60 and 0.82. This compares favourably with Fraser's (1994) data when the SLEI was used with a much larger population. The mean correlation of one SLEI scale with the other scales for the Actual version for the water quality-monitoring group ranged between 0.09 to 0.19 and from 0.08 to 0.25 for the Preferred version. These figures indicate that the scales of the SLEI do have discriminant validity and measure distinct although somewhat overlapping aspects of the outdoor learning environment. These results are of a similar in magnitude to those of the study of Fraser, McRobbie, and Giddings (1993). For the water quality-monitoring school, the ANOVA eta^2 statistic for the scales in the Actual version ranged between 0.09 and 0.27 indicating that the SLEI scales are able to differentiate sufficiently between the perceptions of students in different classrooms. Thus it may be concluded that the SLEI is a valid instrument for measuring learning dimensions in the field.

7. 1. 2 Students' Perceptions of Their Learning Environment

The second research objective was to use the modified SLEI Actual and Preferred versions to determine the students' actual and preferred perceptions of their learning environment when working in the field on a water quality-monitoring program. As discussed in Chapter 4, the students in the water quality-monitoring program perceived that their learning environment had some constraints, specifically in terms of Rule Clarity where the mean for the actual version was 24.49 and for the Preferred version the mean was 25.48. This result is possibly due to the need to impose stringent safety rules rather than to detract from their water quality assessment activities. Within the non-water quality-monitoring schools the Rule Clarity means for the Actual and Preferred versions were 23.98 and 25.31 respectively. The students' perceptions for this scale may be interpreted as there being too much teacher control but this requires further investigation to confirm this interpretation.

The mean for Open-Endedness in the Actual version is 18.01, and the Preferred version mean is 23.77 and is indicative that the students in the water quality-monitoring program would prefer more Open-Endedness in doing their water assessment tasks. In the non-water quality-monitoring program there appears to be a similar situation, with the Actual mean being 17.20 and for the Preferred a mean of 24.10. There is little difference between the two groups and care needs to be taken in interpreting this scale due to its low reliability.

In regard to the Material Environment the means for the Actual and Preferred versions for the water quality-monitoring school were 25.53 and 29.62 respectively. This large difference indicates that the students perceive that they are not satisfied with their Material Environment. The students in the non-water quality-monitoring schools have an even greater difference in their perceptions of Material Environment with a mean of 24.49 for the Actual version and 30.65 for the Preferred version. The gap is thus greater between the Actual version and Preferred version when compared to the water quality-monitoring school. This would seem to indicate that the non-water quality monitoring schools may have the relevant equipment, though it may not always be readily available. This may be due to the necessity of having to share resources with other students from different classes.

Both the water quality and non-water quality-monitoring schools have a small difference in their Actual and Preferred means for Student Cohesiveness. The Actual mean for Student Cohesiveness scale for the water quality-monitoring school was 27.81 and the Preferred mean was 29.64. This compares with the non-water quality-monitoring schools, where the means for the Actual and Preferred means are 27.61 and 29.04 respectively. This indicates that the level of Student Cohesiveness in both sample groups, is close to what students would prefer it to be.

For the water quality-monitoring school the Actual and Preferred version means for the Integration scale are 22.80 and 24.91 respectively, and for the non-water quality-monitoring schools, the Actual and Preferred means are 24.63 and 25.70 respectively. As there is a greater difference between Actual and Preferred versions for the water quality-monitoring school it would indicate that the water quality monitoring school students perceive a greater need to relate more closely theory with practice than their counterparts in the water quality-monitoring program. Whereas the students in the non water quality-monitoring school students appear to be more satisfied with their learning program in which they are involved.

In respect to Rule Clarity the water quality-monitoring students actual mean score are closer to the preferred mean score when compared to the non water quality-monitoring students' actual to preferred scores. This indicates that the students in the water quality-monitoring program, in general perceive that the rules regarding their learning in the field as being closer to what they would prefer it to be, in contrast to the students who are not involved in fieldwork.

7. 1. 3 The Effectiveness of the Water Quality-monitoring Program

Arising from the third research objective are the conclusions that emerged from the statistical analysis in comparing the associations between the two groups and hence the effectiveness of the water quality-monitoring program.

The statistical analysis indicates that the students in the water quality-monitoring program are more homogenous in attaining cognitive achievement, as demonstrated through the use of the Bonferroni statistics in Chapter 4. The statistical analysis on cognitive achievement indicates that the students involved in the water quality-monitoring program are slightly better in cognitive achievement than those students in the non-water quality-monitoring program. In relation to this, through the statistical analysis as described in Chapter 4, and in the pre and post topic testing in Chapter 5, the students have demonstrated gains in cognitive achievement, and that they are able to transfer the concepts learnt into other subject areas.

The information gained from these analyses provides quantitative support for the literature as discussed in Chapter 2 and as described in Chapter 3. The pre and post topic testing in Chapter 5 gives weight to the argument that by being involved in such a multi-facetted program, students need to use all their capabilities, and are better able to transfer concepts. This implies that by solving real life problems through fieldwork students are encouraged to use all their capacities to learn.

7. 1. 4 Associations between Qualitative and Quantitative Data and the SLEI

This section relates to the third and fourth research objectives which assessed associations and effectiveness of concept learning and achievement as well as between qualitative and quantitative information. It was demonstrated in Chapter 5 that there are associations between the qualitative and the additional quantitative information that through statistical analysis can support the SLEI. This was done by relating the cognitive achievement of both groups, as well as by assessing the qualitative information and linking it to the different SLEI scales. The vignette information gathered in this study provides qualitative support for the quantitative measurement of psychosocial dimensions in fieldwork that supports the work of the researchers who developed and validated the SLEI as discussed in Chapter 2 and 5. The vignettes provided a strong insight into the students' psychosocial learning dimensions that would not have been provided through another method. The insights gained demonstrated the need for both qualitative and quantitative information to be linked together, and as a consequence provide relevance for the SLEI scales. The findings are also consistent with the literature as presented in Chapter 2.

7. 1. 5 Comparison between the Water Quality-Monitoring Program and other Educational Settings in other Countries

This section relates to the fifth research objective as discussed in Chapters 1 and 6. The review in Chapter 6 showed that the water quality-monitoring program embedded in the school curriculum appear to be more effective than those that are informal or extra-curricular activities as is often practised overseas. The effectiveness of the water quality-monitoring program may be due primarily to the teaching strategies used from which students can build constructs and deduce meaningful interpretations as they operate within a real life situation. Prescriptive learning situations as found in other countries, while meeting the educational agendas of those countries, limit the meaningful learning outcomes as they are not based on authentic situations that are necessary for students to achieve within the constructivist or through the hypothetical deductive framework.

It is also apparent as shown in Chapter 6 that the water quality-monitoring program is effective as it has motivated students to chose senior school science subjects which they may not have considered if they had not been in the program. The programs appear to increase cognitive achievement and encourage environmental citizenship, as well as foster individual talents across the curriculum. This is because of its integrated, constructivist, authentic problem solving approach that it is well suited to the demands of academic rigour and appears to be a better approach to the teaching of science. It was found that much of what has been achieved in the water quality-monitoring program is in some instances not possible in some countries due to their government policies and other restraints such as resources and funding. As there are limitations in research the next section deals with the limitations of the study as related to the research objectives.

7. 2 Limitations

This study has been constrained by schools imposing policy directives on the collection of data. This has been particularly the situation with gender where some of the schools refused to have student gender written on the forms. This constrained the research to treating the data from non-water quality-monitoring schools as a homogeneous population. While definitive distinctions were made between the non-water and water quality-monitoring schools in Chapter 5, the limitation here was that there were no other water quality-monitoring schools that were prepared to participate. This is mainly due to the fact that most schools do not run full time water quality-monitoring programs in school time. This was further limited by the fact that the water quality-monitoring school has an across-the-curriculum approach to the water quality program while many of the other schools who have a water quality-monitoring program as an extracurricular activity do not have such an approach.

Time constraint for teachers was another limiting factor and many schools that were approached to participate in this study were concerned about the time imposition on both staff and students. Those schools that consented to participate did so provided that no further time would be taken from their schedules to do anything other than complete the SLEI questionnaires. Thus, in all instances except at the researcher's school it was not possible to obtain data that would have been useful to this study. End-of-year cognitive achievement data were provided on the understanding that anonymity and confidentiality were provided and there would be no mention of gender.

As discussed earlier in this thesis, because of the use of single-sex schools, it was not possible to investigate gender differences. However, the importance of ensuring that girls receive an equitable education is acknowledged. In Australia, the National Action Plan for the Education of Girls 1993-97 (Australian Education Council and Curriculum Corporation, 1993) highlights this concern. Of all school subjects, probably the greatest inequity between the sexes in enrolments, achievement and attitudes occurs for science (Parker, Rennie, & Fraser, 1996; Young & Fraser, 1994). There have been a number of other studies investigating our understanding of differences between boys and girls by examining the nature of the their learning environments. For example, Rickards and Fisher (1998) found there were sex differences in the student perceptions of learning environments. Specifically, their study found that females perceived their teachers in a more positive way than did males.

Furthermore, there is an awareness that Australian classrooms are becoming increasingly multicultural and that the way in which people communicate and perceive communication is culturally influenced (Giles & Franklyn-Stokes, 1989; Segall, Dasen, Berry, & Poortinga, 1990). Levy, Wubbels, Brekelmans, and Morganfield (1997) investigated a sample of 550 high school students in 38 classes comprised of three primary investigation groups, namely 117 Latinos, 111 Asians and 322 from the United States. The primary focus was the language and cultural factors in students' perceptions of teacher communication style focused on identifying ways in which the students' culture relates to student perceptions of their teachers. The results suggested that the students' cultural background is indeed significantly related to the perceptions that they had of their teachers' interaction behaviour. The study also concluded that teachers did not seem to be aware of cultural differences in their interactions with students in their classes in the same way as their students were, despite altering their behaviour in classes with different cultural compositions.

In an Australian study, Rickards and Fisher (1998) investigated differences in the way in which teachers interact with students from different cultural backgrounds. Their results showed that there were cultural background differences in student perceptions of student-teacher interactions in that students from an Asian background tended to perceive their science teachers more positively than those from the other groups identified in this study.

These studies typify research on gender and cultural differences and emphasise the need to carry out such studies with the modified SLEI in the future.

Throughout the study, it became apparent that constructivism is an important feature that links the student's activities as well as enhancing the cognitive ability and the learned scientific processes of the students in the water quality-monitoring program. The limitation here is not so much the measuring of cognitive achievement but measuring how the students form the constructs when doing fieldwork. The methods that were used in the pre and post topic testing were utilised from cognitive psychology and applied to a situation that had not been undertaken previously in a field based situation. While the use of pre and post topic testing is a means of assessing transferability of concepts and thus the underlying constructs it is perhaps not the best method for quantifying student outcomes. Further development of an instrument that could assess transferability of concepts while measuring constructs is seen as desirable.

Teaching and managing students in a bushland riverine setting can pose difficulties, such as providing motivation and ensuring student safety. However, because the teachers in the researcher's school are all very experienced, teaching in a riverine bushland setting is not perceived as a major teaching problem. Although not a limitation of this study it is worthy of note because it could, become a problem with less experienced teachers who do not necessarily possess all the expertise of their more experienced colleagues.

A limitation in the teaching of science is that students are expected to develop critical thinking from prepared handouts to do the experiments that are considered mandatory by the NSW Board of Studies. Experiments while relating to theoretical work often bear little resemblance to what occurs in the real world situation. Thus, the problem solving that ensues from laboratory work may be considered contrived. Within the water quality-monitoring program, the students are required to solve authentic real life problems. This is not a limitation in itself but becomes a limiting factor if all the information is not available through both theory and practical work.

While the study utilised a number of statistical methods for analysing the data, the study perhaps would have been better if the qualitative and quantitative methods could have been combined with more rigour (Fraser & Tobin, 1991). In linking actual preferred scores derived from the SLEI questionnaire with qualitative data it may have been better to incorporate a person-environment fit study such as the *Individualised Classroom Environment Questionnaire* (ICEQ) to determine if the students achieve better in the field. However, this was not possible due to time and the constraints placed on the researcher by schools.

In this study, it was not possible to determine what the non-English speaking populations were in the other schools, nor was it possible to assess the cultural differences in schools both here and overseas. The population for whom English is a second language in the water quality-monitoring school is approximately 40%. This however appears to have had little impact on the cognitive achievement as determined by the School Certificate results or on the students' responses to the SLEI, and it is suggested that further research be undertaken to ascertain if cultural differences also play a learning role in field work. The next section continues to consider future investigations.

7.3 Further Investigations

In relation to gender and culture, further investigations could be made concerning learning differences within the water quality-monitoring programs run by different schools and countries. No definitive data were obtainable other than that collected by the author in 1996. Thus, a future investigation could be on learning differences and concept transferability that are specifically related to gender and cultural differences.

In consideration of formal and non-formal water quality-monitoring programs, either as curricular or extra curricular activities, investigations could be carried out using the SLEI. This could be done inconjunction with an instrument such as the *Constructivist Learning Environment Survey* (CLES) or any other suitable instrument that relates to constructivism to determine if indeed there are marked differences between formal and non-formal environmental programs.

As this study did not measure student critical thinking within a field based setting or link it to the different types of teaching, this could be a topic of educational worth for a future investigation. Nonetheless, as described in Chapter 5, the students involved in the water quality-monitoring program were able to perceive and promote relevance of concept and integration of activities. This is not always possible in a laboratory classroom situation or a field based setting. The limitations of measuring the relevance of concepts and integrating activities were the lack of literature and a means of comparing and contrasting the water and non water-quality-monitoring schools. Additionally, all students, according to Gardner and Hatch (1989) learn in a preferred manner that may be by way of example purely visual, auditory or kinaesthetic. While students prefer to utilise one learning method (Gardner & Hatch, 1989), an integrated use of learning modalities appears to be better for cognitive achievement. This has not been tested in this study and is thus a limiting factor in the data collection. It would lend itself to further investigation to determine if constructs are more readily developed in the field. Having considered future investigations the next section deals with the recommendations arising from this study.

7. 4 Recommendations

It is recommended that a modified form of the SLEI be developed to verify both formal and informal environmental fieldwork such as excursions and club activities as well as full time programs such as the water quality-monitoring program. The modifications would need to incorporate scale items that are specific for the particular task e.g., for a zoological excursion. Question changes could be like these:

- The equipment and materials that I need for the zoological activities are readily available.
- My excursion class would be run under clearer rules than my other classes.
- What I do on an excursion helps me to understand the theory covered in my regular class.
- The way I learn about things is teacher directed.
- I would learn better about things if I had more control over what I learn on excursions.

The above questions could be modified for science field trips and could possibly be included in the 35 question survey Actual and Preferred versions of the SLEI as has been done in this study. Developing such a survey could enable teachers to devise better teaching strategies and achieve better learning outcomes. The modifications could then be related to another suitable instrument which could provide additional information for teachers.

Laboratory sessions often appear to students to be unconnected to the real world situation and thus the students do not utilise the concepts in a meaningful manner in the way they were intended (Moreira, 1980; Renner, Abraham, & Birnie, 1985). Thus it is recommended that more real world problem solving situations be incorporated in the teaching of science and other curriculum areas. The water quality-monitoring program is an avenue that permits such situations. Thus, programs that have this environmental aspect should be incorporated into the school curriculum as the interdisciplinary aspects and skills learnt assist in concept transference and personal development, thus improving student learning outcomes.

7.5 Summary

It was found that real life learning situations demand that students confront the problems arising from the situations they find in the environment by using all of their learning modalities to construct meaningful and appropriate solutions. This has led to slightly better cognitive achievement when compared with other groups. The usefulness of constructivist and hypothetical deduction strategies enables students to transfer concepts better and thus improve their cognitive achievement scores.

The modified Science Laboratory Environment Inventory has been shown to be a useful instrument for measuring in-field psychosocial learning dimensions. The statistical analysis of the SLEI, the pre and post topic testing as well as the anecdotal evidence gathered indicates that the water quality-monitoring program through its inherent constructivist strategies is suited to programs that run within a subject area such as science rather than as an extra curricular activity. Further work on gender and critical thinking in relation to constructivism and the hypothetical deductive strategies inherent in fieldwork are worthy of future investigations.

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APPENDICES

APPENDIX 1

TEACHER BACKGROUND NOTES

It is essential that teachers are acquainted with the relevant tests. The following is supplied to provide background information.

The Physical Tests

These tests are Temperature, pH, Turbidity, Total Dissolved Solids (TDS)

Temperature

Temperature directly influences the amount of oxygen that is dissolved in water, the photosynthesis of aquatic plants including eutrophication, the metabolism of micro and macro organisms and the sensitivity of organisms to disease, parasites and toxic wastes.

Thermal pollution from human activity is probably the most deleterious activity that humankind has placed on aquatic systems. It pervades all our water systems, and is caused through many of our activities from power generation, water run off from roads, water coolants, soil erosion, deforestation, poor agricultural practice, military neglect of equipment and the construction of roads and buildings.

It is necessary if samples are taken in the proximity of a point source to measure the temperature up stream and down stream of the point source. The difference of the two temperatures provide the amount of thermal pollution in the system. If by way of example samples are taken near a discharge point of a power station then a sample upstream should be taken as well as one downstream of the discharge point.

pH

In Australia the pH water range is between 6.5 and 8.5, depending on the source of the water and the strata upon which it flows. All organisms are sensitive to pH changes because they have evolved to tolerate a certain level of pH. A change of 0.5

pH units may cause the death of an organism and threaten the food chain. The areas which often experience the worst pH changes are those that are in the smoke plume belt of industries, or are subjected to acid snow and rain.

Very acidic waters will cause heavy metals and aluminium to be released into the water. The release of these metals has a bio-accumulating effect up the food chain and will cause deformities in aquatic organisms.

Turbidity

Turbidity is the measurement (mg/L) of the cloudiness of water. The causes of turbidity are suspended solids such as clay, silt, plankton, urban run off, excess nutrients, industrial wastes and sewage. Increased turbidity is due to more suspended solids in solution and thus decreasing the transmission of light. High levels of turbidity increase the heat of the water and specifically the decrease the ability of the aquatic system to support life. Increased turbidity reduces growth rates of plants because of less light transmission, decreases the resistance to disease in both animals and plants and smothers larvae. Often turbidity will reduce the microhabitats for a variety of nymphs and reduce their food sources.

Turbidity is measured in Nephelometer (NTU) or Jackson Turbidity Units (JTU), the terms are interchangeable. They differ only in the type of device used. The Nephelometer is an optical electrical device that measures the scattering of light. The Jackson Turbidity device is a plastic tube with a calibrated set of graduations on the side of the tube and a cross at the bottom of the tube. Once the cross at the bottom of the tube is no longer visible the reading of turbidity is taken.

Total Dissolved Solids

This test takes in both dissolved solids and suspended solids (turbidity) and is a measure of the saltiness of the water. Dissolved solids in ionic form include calcium, hydrogen carbonate, sulfur, phosphorus, nitrogen and others. Many of these are vital for the maintenance of life. However there are many ions that are not and are found in increasing quantities and cause osmotic changes in aquatic organisms. High concentrations of total dissolved solids may lead to unpleasant taste, laxative effects on mammals, or bind with toxic compounds and heavy metals thus increasing the risking of poisoning and causing the decline of macro invertebrates as well as increasing the water temperature. Dissolved solids increase the temperature as they provide a greater degree of light scatter and absorption of sunlight. Each of these factors is a major contributing factor to the unsustainability of agricultural systems and ecosystems. The effect of salt on both aquatic and terrestrial organisms is highly deleterious. With good management the degree of dissolved solids can be dramatically reduced.

The Chemical Tests

These tests are Dissolved Oxygen, percentage saturated Dissolved Oxygen, Biochemical Oxygen Demand (BOD), Total Phosphate and Nitrate. Additional tests for heavy metals can also be done if required but require more training and a good understanding of chemical processes.

Dissolved oxygen

Dissolved oxygen is essential to all aquatic life. Most of the oxygen comes from the atmosphere through the process of supercavitation, the remainder of the oxygen is dissolved into the water through the photosynthetic processes of aquatic plants and slimes. Dissolved oxygen fluctuates but the degree of fluctuation is at its greatest when there is extensive plant growth, coupled with temperature. Dissolved oxygen levels rise from morning through to the afternoon in relation to the photosynthesis cycle. It is considered that 4 mg/L is the minium needed to sustain fish.

As the quantity of dissolved oxygen is related to climate it is necessary to bear in mind that the flow of the river and its littoral depth must be considered in relation to various conditions such as snow melt and wet weather which will produce a greater level of dissolved oxygen.

Factors that reduce the amount of dissolved oxygen are organic wastes - food, leaves, sewage, urban and agricultural run off, fertilisers, discharge from food processing plants, dairies, industrial sources and a variety of plasticisers that slowly decay such as selenium that is used in road surfacing and more importantly direct thermal pollution from power houses. The increase of these substances increases the aerobic bacteria that require oxygen for the decomposition of these materials.

The chemistry of the dissolved oxygen test using TheTintometer Ltd reagents is:

Manganese (II) sulphate reacts with potassium hydroxide to produce a precipitate of manganese (IV) hydroxide. The dissolved oxygen reacts quantitatively to produce manganese (III) hydroxide as a flocculant:

$$2Mn^{2+} + O_2 + 40H^- \rightarrow 2MnO(OH)_2$$

This reacts with potassium iodide quantitatively, after acidification to produce iodine, which gives a yellow to brown solution. (Sodium azide is included in the reagent to prevent interference by nitrite ions):

$$MnO(OH)_2 + 2I^- + 4H^+ \rightarrow Mn^{2+} + I_2 + 2H_20$$

The iodine produced is then titrated with sodium thiosulphate solution, using starch as the indicator.

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

Simply put the number of drops required is the amount of dissolved oxygen in the river at that sampling time and is measured in mg/L.

Percent Saturation Dissolved Oxygen

The percentage saturation of dissolved oxygen is vital to our understanding of the aquatic environment. The known titrated level of dissolved oxygen is used with the water temperature to determine the percentage saturation. Streams that have a percentage saturation of 90 are considered healthy, unless the water is supersaturated due to eutrophication or other factors.

It should be noted that at sea level there is no need to correct for atmospheric pressure. Correction values are available from the water authority. However as a rough guide at 300 metres the value needs to be attenuated by approximately 0.98 and at 3000 metres by 0.68. Below sea level situations need to be corrected approximately by a factor of 1.05.

The best method of sampling is to obtain a mid stream sample. In lake environments there are a number of other factors to consider with stratification and are related to the kinetics of the thermocline.

Biochemical Oxygen Demand

This test measures the degree of oxygen consumption by microbial mediated oxidation of contaminants in water. Essentially it is a repeat of the dissolved oxygen test 5 days later and indeed the result of the BOD test is subtracted from the original dissolved oxygen. The result determines the consumption of oxygen by micro-organisms.

As is expected there are other factors which influence the quantity of dissolved oxygen and these have to do with oxidisable pollutants. These pollutants may come from vehicle and industrial emissions and discharges or from urban sewers and run off. As a consequence there is a decomposition zone. This is where the added pollutant consumes the bulk of the oxygen. The septic zone as expected increases the bacterial population until the pollutant is exhausted. In what is termed the recovery zone the bacterial population decreases and the dissolved oxygen levels increase until the water regains its original condition.

BOD is a positive way of testing for the presence of micro organisms though it may be cumbersome to wait five days. If however a rapid test is required then a chemical oxygen demand (COD) can be performed using the dichromate ion and 50 % sulfuric acid. It is represented by the following equation:

$$3\{CH_2O\} + 16H^+ + 2Cr_2O_7^{2-} \rightarrow 4Cr^{3+} + 3CO_2 + 11H_2O$$

Total Phosphorus

Total phosphorus comprises both organically bound and inorganic forms of phosphorus. It includes the PO_4^- -P; $H_2PO_2^-$; HPO_4^{2-}; and PO_4^{3-} ions. Free phosphorus is taken up by algae and larger aquatic plants. However because algae requires little phosphorus additional amounts in the water will cause algal blooms. Algal blooms are caused by humans as cultural eutrophication. Natural eutrophication also occurs but is totally insignificant in water events.

Phosphorus is essential to most organisms however most eutrophication is caused through sewage wastes, illegal sewer connections, detergents, animal wastes, food scraps, the removal of vegetation for construction and agricultural uses and agricultural and urban fertilisers. The draining of wetlands and swamps does significant damage in the amount of phosphorus that is put into the aquatic system, as the wetlands, swamps and marshes act as filters and traps of silt and phosphorus. Phosphorus increases biochemical oxygen demand.

Large aquatic plants are stimulated by the excess phosphorus and continue to draw upon the phosphorus that is bound in the sediments and eventually release the phosphorus into the waterway where the algae take advantage of it. This is the beginning of an algal bloom which is characterised by a pea soup green colour. Advanced stages of eutrophication produce anaerobic conditions with a large depletion of dissolved oxygen. Consequently organisms die.

Testing for phosphorus requires the freeing up of the organic form through digestion. This requires the use of potassium persulphate and boiling for 30 minutes. This produces the inorganic phosphate ion. The phosphate ion is then chemically bonded with ammonium molybdate to produce ammonium phosomolybdate:

$$P0_4^{3-} + 12(NH_4)_2MoO_4 + 24H^+ \rightarrow (NH_4)_3P0_4\,(12MoO_3) + 21NH_4^+ + 12H_20$$

The molybdenum is reduced to produce a blue solution that is proportional to the amount of phosphate present in mg/L and is read off from a colorimeter. There are a variety of methods to remove phosphorus from aquatic systems and many of these are practical activities that can be performed by any one. Briefly they are:

- support measures and taxes to have waste water treatment plants to remove the phosphorus;
- preserving natural vegetation along river banks and streams;
- maintain wetlands and marshes and if necessary build them;
- encourage manufacturers to remove or reduce the amount of phosphorus in their products;
- encourage industries to pretreat their wastes before discharging their effluent.

Nitrate

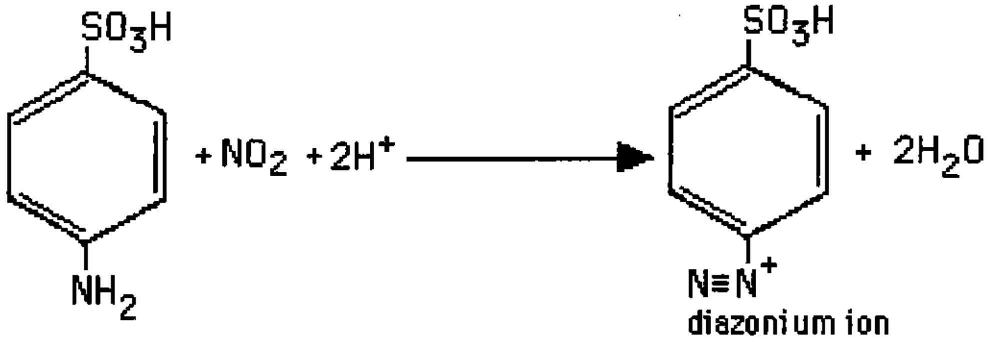
Sewage, run off from farms and fertiliser use are the main sources of nitrate in a waterway. Ground water is increasingly becoming more contaminated with nitrates due to excessive use of fertilisers and sewage spraying on fallow paddocks. In normal situations nitrate comes from rainwater and as a result of decomposition of organisms. Bacteria break down large protein molecules into ammonia that is in turn oxidised by dissolved oxygen into both nitrite and nitrate. High nitrate levels can cause methemoglobinemia if it is used in infant's milk. The disease prevents infant blood from carrying oxygen.

Nitrogen in the form of nitrate and ammonia are good plant nutrients but like phosphorus can cause eutrophication. However unlike phosphorus nitrogen rarely limits plant growth and as a consequence plants are not as sensitive to ammonia and nitrate levels. However when the concentrations of ammonia are increased to a sufficiently high level forest death can occur through a root fungus which metabolises the ammonia to free molecular nitrogen.

The nitrate test involves a reagent in a complex cycle of reactions which produces a diazo dye. The intensity of the dye is directly proportional to the amount of nitrate in the sample and is then colormetrically determined as mg/L. As nitrate is thermodynamically a very active species but kinetically slow to react, the test involves the reduction of nitrate to nitrite. This is achieved by using zinc as the reductant. A nitrate test tablet is added to aid the reaction and assist with flocculation and settlement :

$$N0_3^- + 2H^+ + 2\acute{e} \rightarrow NO_2^- + H_2O$$

The resultant nitrite is then determined by diazotising with sulphanilic acid - and coupling it with N(1-Napthyl ethylenediamine dihydrochloride to form a highly coloured azo dye. The reaction sequence is as follows:



□

(after The Tintometer Pty Ltd)

The diazotisation reaction above is carried out in acid solution and represented by a series of simplified stepwise equilibria and reactions as follows:

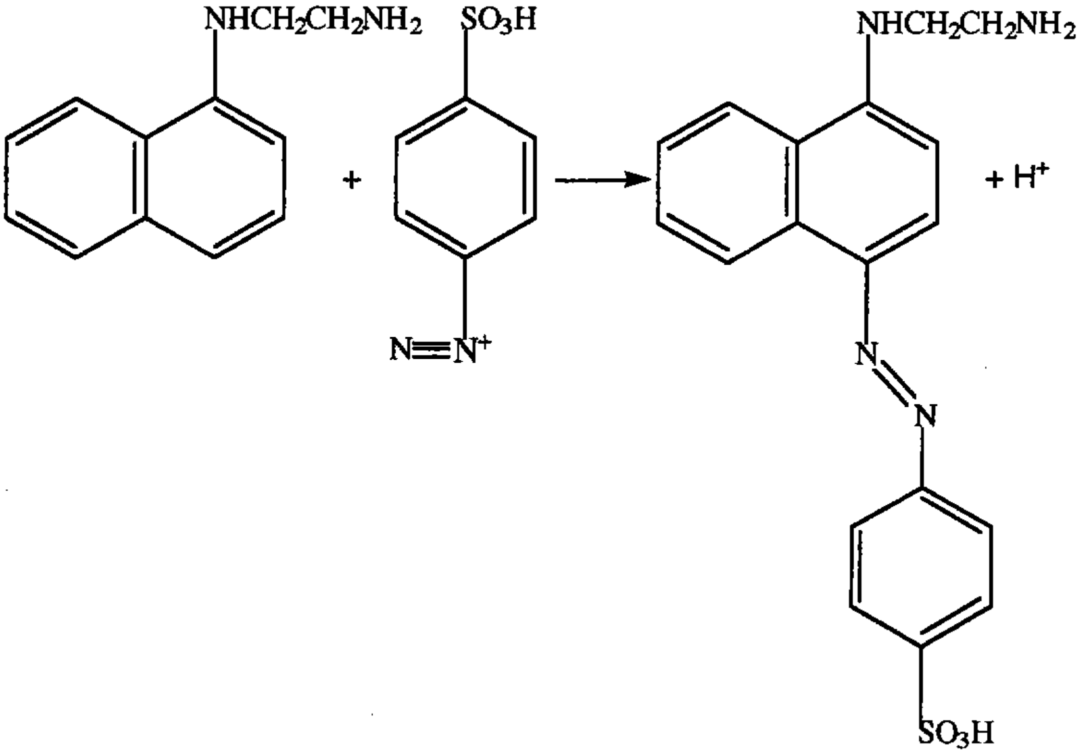
$$HNO_2 + H^+ \text{ R } H_2NO_2^+ \text{ R } H_2O + NO^+ \rightarrow$$

$$R\text{-}NH_2 + NO^+ \rightarrow R\text{-}N^+H_2 - N{=}O \overset{-H^+}{\rightarrow}$$

$$R\text{-}NH\text{-}N{=}O \overset{H^+}{\rightarrow} R\text{-}NH\text{-}N{=}O^+H \overset{-H^+}{\rightarrow}$$

$$R\text{-}N{=}N\text{-}OH \overset{H^+}{\rightarrow} R\text{-}N{=}N\text{-}O^+H_2 \overset{-H_2O}{\rightarrow} R\text{-}N^+N$$

A coupling reaction is then performed between the diazonium ion and an aromatic diamine, N - (1 - napthyl) ethylenediamine (used as the dihydrochloride salt; this enhances reactivity and brings the organic material into aqueous solution).



(after The Tintometer Ltd)

The azo dye (so named because of the diazo, - N=N - , coupling group) has a pink colour, the intensity of which is used to determine the amount of nitrite in the sample in mg/L.

Heavy Metals

Heavy metals and trace metals are two terms that can be used interchangeably. The term usually refers to cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver and zinc. Aluminium and arsenic maybe added to the list as they are being found in ever increasing quantities in water systems but still in small amounts. Many of the heavy metals are used in industry for a variety of purposes. However, many of their salts are being found in the aquatic systems at ever increasing levels. Under anaerobic conditions many of these salts are converted to methylated forms of the salt and can be ingested by organisms; concentrating the metal further and further up the food chain. In trace amounts many of the elements are necessary for mammalian bodies to function correctly. By way of example nickel is needed for the manufacture of blood cells, iron for oxygen uptake, zinc for activating enzymes.

As water hardness decreases the toxicity of the metal increases and this can be further amplified if the pH of the waterway is lowered and the temperature increased. In cold water environments and where the pH is above 6 many of the metals will precipitate out as carbonates or as sulfides if anaerobic conditions occur.

Storm events or the first flush increases the concentration of lead, zinc and copper in urban environments. Most of these come from car parks and motorways. Lead comes from petrol, the zinc from motor oils and greases together with copper and iron coming from brake linings and other metal scrapings.

Many metallic products complete their cycle by being dumped in landfills. The leachate from these can often concentrate and produce a peculiarly strong soluble cocktail which is highly detrimental to the aquatic system.

Cadmium and uranium may be found in eroded soil material after the first flush while arsenic is often found in pesticide and herbicide residues.

Most of the metals have an exceptionally strong affinity for sulfur and attack bonds in enzymes as well as protein, carboxylic acids, and the amino group (NH_2) a derivative of ammonia. The heavy metals also precipitate out many phosphate bio compounds or catalyse their decomposition. Either way the heavy metals are perceived, the line between what constitutes as harmful and beneficial is many instances a matter of micrograms.

Alkaline treatment of the heavy metals is one of many methods of removing heavy metals from an aquatic system. There are others sulfide precipitation, the reduction of Cr(VI) to Cr(II) by Fe(II) or sulfur dioxide, alkaline chlorination (pH 10-11) and the use of sunlight to increase the dissolved oxygen content which can then oxidise arsenic to a less dangerous form before precipitating the arsenic out.

Testing for heavy metals often requires digestion of the substance and this needs to be done in a fumehood before spectroscopy can take place. Some of the reagents pose a health risk and therefore it is essential that tertiary students be taught the relevant procedures.

The Biological Tests

The two main tests here are faecal coliform and macro invertebrate identification.

Faecal Coliform

Faecal coliform bacteria are found in the faeces of all warm blooded animals. The bacteria enter the aquatic system through, bird and animal droppings, storm water run off, agricultural run off, sewer pipes that have ruptured or have been illegally installed. Heavy rains and snow melts often flush bird and pet droppings into a river system.

If faecal coliform counts are consistently high over 200 colonies per 100 mL there is a good chance that there will be other pathogens in the water. Faecal coliform in itself is not a pathogen but pathogenic material is found together in the intestinal tract of vertebrates.

The faecal coliform test is useful in determining if there is a sewer leak in the area in which the sample is being taken. It is essential that when testing that the equipment is sterile and incubated at 44.5 °C for 24 hours. The faecal coliforms after incubation are seen as bluish spots. Any other colour than blue is not a faecal coliform and should not be counted.

If it is at all possible it best to do several replicates using 10 mL and a 1 mL aliquots of water. Ideally the replicates should be incubated within an hour of sampling. If this is not possible place the samples in ice and test within 6 hours.

Macro invertebrates

Macro invertebrates are extremely sensitive to pollution and the invertebrates that are sampled are an excellent indicator of the health of the river or stream. As they are sensitive to pollution and in most cases are unable to move away if conditions change, they become displaced with an organism that is not as sensitive to pollution such as black fly.

The evaluation of water quality is linked to the kind of pollution sensitive to pollution tolerant organisms eg freshwater shrimp are pollution sensitive and mosquito larvae are pollution tolerant. Pollution sensitive organisms would be mayflies, caddisflies while those that are tolerant to pollution would be midges, bloodworms, leeches etc. This test is sometimes termed the Pollution Tolerance Index. It is useful for assessing water quality but its down side is that it does not measure abundance. The index works on the basis that the organisms may be identified using biological drawings or using a key. Each group of animals is provided with an index value, the least tolerant species have the highest value. The water value is determined by multiplying the number of kinds of organisms together and adding the resulting three group numbers together.

With all of these factors borne in mind an assessable evaluation can be made and strategies can be devised to improve the aquatic system. Ecologically speaking it is those aquatic systems that have greater diversity that tend to be stable than those with less diversity.

The following is a compilation of CSIRO notes and Sydney Water Streamwatch and are acknowledged accordingly. The habitat field guide follows.

HABITAT SURVEY FIELD GUIDE

Excellent	Good	Fair	Poor	Very poor

Bank Vegetation

(10)	(8)	(6)	(4)	(2)
Mainly undisturbed native vegetation. No sign of site alteration	Mainly native vegetation. Little disturbance or no sign of recent site disturbance	Medium cover, mixed native / introduced. Or one side cleared, the other undisturbed.	Introduced ground cover, little native understorey or overstorey, predominantly introduced vegetation	Introduced ground cover with lots of bare ground. Occasional tree. Also includes sites with concrete lined channels

Verge Vegetation

(10)	(8)	(6)	(4)	(2)
Mainly undisturbed native vegetation on both sides of stream. Verge more than 30 m wide	Well vegetated wide verge corridor Mainly undisturbed native vegetation on both sides of stream; some introduced or reduced cover of native vegetation	Wide corridor of mixed native and exotics, or one side cleared, and other wide corridor of native vegetation	Very narrow corridor of native or introduced vegetation.	Bare cover or introduced grass cover such as pasture land.

In - stream cover

(10)	(8)	(6)	(4)	(2)
Abundant cover, frequent snags logs or boulders with extensive areas of in - stream aquatic vegetation and overhanging bank	A good cover of snags, logs or boulders, with considerable areas of in-stream and overhanging vegetation	Some snags or boulders present and or occasional areas of in-stream or overhanging vegetation.	Only slight cover. The stream is largely cleared, with occasional snags and very little in-stream vegetation. Generally no overhanging vegetation.	No cover. No snags, boulders submerged or overhanging vegetation. No undercut banks. Site may, have rock or concrete lining

Bank erosion - stability

(5)	(4)	(3)	(2)	(1)
Stable. No erosion / sedimentation evident. No under cutting of banks, usually gentle banks covered with root mat grasses, reeds or shrubs.	Only spot erosion occurring. Little undercutting of bank, good vegetation cover, usually gentle cover, usually gentle slopes, no significant damage to bank structure.	Localised erosion evident. A relatively good vegetation cover. No continuous damage to bank structure or vegetation.	Significant active erosion evident especially during high flows. Unstable extensive areas of bare banks, little vegetation cover.	Extensive or almost Continuous erosion. Over 50% banks have some form of erosion; very with little vegetation cover.

Riffles, pools bends (flowing water only)

(5)	(4)	(3)	(2)	(1)
Wide variety of habitats. Riffles and pools present of varying depths. Bends present.	Good variety of habitats - eg riffles and pools or bends and pools. Variation in depth of riffle and pool.	Some variety of habitat- eg occasional riffle or bend. Some variation in depth.	Only slight variety of habitat. All riffle or pool with only slight variation in depth.	Uniform habitat. Straight stream, all shallow riffle or of uniform depth - eg pool channelled stream or irrigation channel

The Streamwatch WATER BUG DETECTIVE GUIDE

Produced by the Water Board (Sydney - Illawarra - Blue Mountains) and CSIRO's Double Helix

Using water bugs to measure water quality

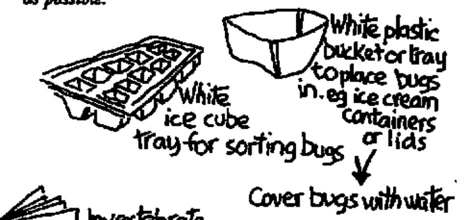
A stream is usually a home for many different types of animals. These include insects, crustaceans, molluscs and worms. They are commonly referred to as water bugs. Scientists have found that the number and variety of water bugs found in a stream can give an indication of the relative levels of water pollution. In other words, by sampling the water bugs in your local stream, you can get an idea about the quality of the water!

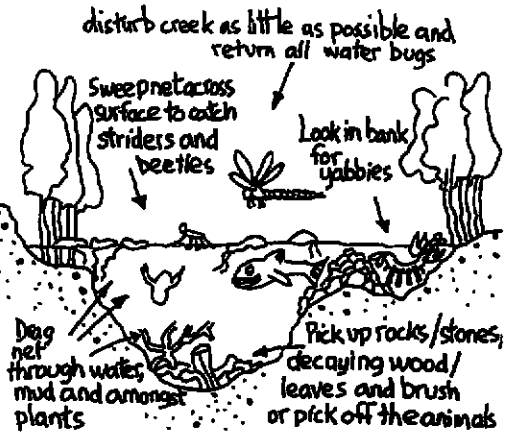
This Water Bug Detective Field Guide is designed to provide you with information on how to collect water bugs, make some basic identifications, and, based on what you've found, work out a Stream Pollution Index for the stream sampled. The higher the Index, the lower the level of pollution, and the healthier the stream.

Collecting Water Bugs

Water bugs live in many different parts of the stream. Some live on the water's surface, some in the water itself, others on or in the bottom of the river or creek, in the surrounding vegetation, or amongst the rocks. The idea is to sample as many of these different 'microhabitats' as possible.

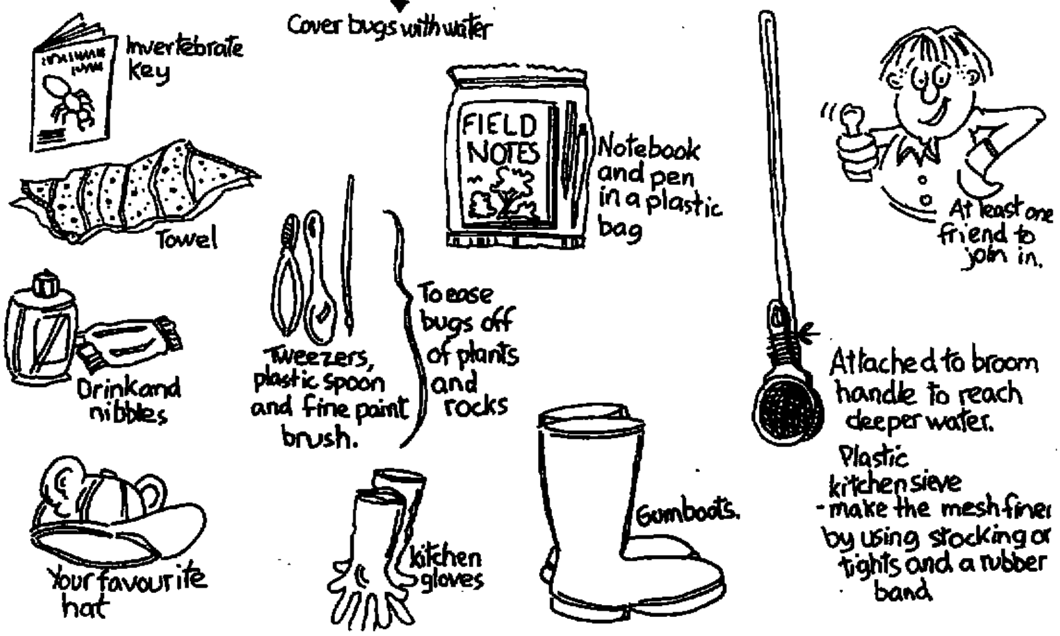
Before setting off on a sampling expedition, assemble as much of the following equipment as possible:





Once you've gathered your equipment, head down to the local stream and try to sample as many of the different stream environments as possible.

Using your net, strain the water at different depths, including the water surface. Run your net over the surface of the bottom, through the plants growing on the water's edge. Wash larger rocks and stones into the net to remove attached animals. Stir the bottom to a depth of two centimetres for two minutes and run your net through the disturbed sediments. Closely examine rocks and plant for bugs and use your tweesers and brush to transfer them to a collecting container. Examine the banks for yabbies and other life. Even look for their homes – yabby holes or caddisfly cases.



An alternative method is to set up an artificial home made of a wire basket (or a nylon mesh bag) containing rocks and debris, and attach it to the bottom of the stream. After four weeks, which should be sufficient time for bugs to colonise the artificial home, remove the basket and wash all the rocks into a small hand net. Remove the water bugs, and transfer them to a collecting container with water.

Sort the water bugs you've collected into their different types, temporarily storing them in separate compartments of the white ice cube tray. Now, using this Guide (look at the pictures), and any of the invertebrate keys you may have, try to make basic identifications of the bugs you've collected. Record what you've found, and, if you want, make drawings of them.

You don't have to identify the water bugs right down to species. Just determine what kind of water bug they are.

Once you've finished making your records, return the insects you've collected to the stream.

Calculating a Stream Pollution Index

The water bugs listed in this guide are split into four groups depending on how sensitive they are to pollution. The groups are: very sensitive, sensitive, tolerant, and very tolerant. Each water bug also has a number next to it. When you've completed your collection and identification, add the numbers together and you've got a Stream Pollution Index for the part of the stream you've sampled. The higher the total, the cleaner the water.

Pollution Index	**Stream Quality Rating**
20 or Less	Poor
21-35	Fair
36-50	Good
51 or more	Excellent

Here's an example of how to calculate a Pollution Index from one set of collection results. Note: if you have two or more morphologically distinct (they look different) organisms from the same group, count them separately.

Very Sensitive	**Sensitive**	**Tolerant**	**Very Tolerant**	
Yabbies (7)	Dragon Flies(6)	Leech (3)	Mosquito (1)	
May Flies (7)	Mussels (6)	Beetles (5)	Blood Worm (1)	
	Shrimp (6)	Snails (3)		
Totals				
14 +	18 +	11 +	2	=45

Pollution Index 45 **Stream Quality Rating:** GOOD

Using the Index you can compare your sample site with other sites. You can compare the same site at different times of the year, or with different sites on the same stream, or with different streams.

Keep in mind that the Index is only a rough guide, and its accuracy is very dependant on how well you do your sampling. To make comparisons meaningful, it's important that you use the same sampling technique at each site. It's no good being very thorough at one site, and then not taking the same amount of care at another. It's important that you take the same number of samples, and the same amount of care with each sample.

Water Bug Identification and Ratings

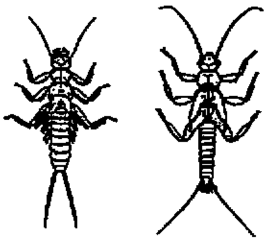
The following pictures and descriptions are of the more common water bugs that are found in most streams. Using this guide and other reference sources, attempt to identify what bugs you've collected.

Pollutions ratings are in square brackets. The higher the number, the more sensitive the animal is to pollution. In other words, water bugs with high numbers usually only occur in healthy streams.

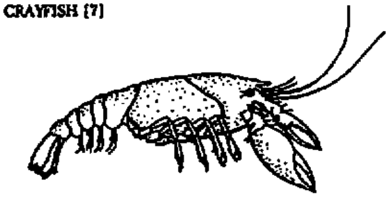
Very Sensitive Water Bugs

STONEFLY NYMPHS [8]

Stonefly nymphs have 2 long tails, tubes of thread like gills on their undersides, wing pads, antennae, and two claws on each foot. Found among stones or plants in clear streams.

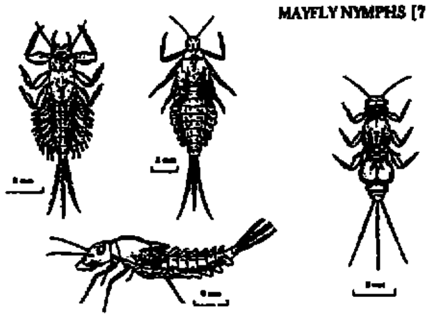


FRESHWATER YABBIE
OR CRAYFISH [7]



Strong grasping claw-like forelegs.
Grow up to 40cm long. Found in burrows or near rocks on stream banks.

MAYFLY NYMPHS [7]



Mayfly nymphs usually have 3 long filaments at the end of their abdomen, with wing pads and lateral gills along abdomen. They have short antennae, and a single claw on each foot. They're found under stones in fast flowing water or among plants in slow flowing water.

Sensitive Water Bugs

FRESHWATER MUSSEL [6]

Soft bodied animal. Enclosed in two hinged shells. Found on a stable sandy or muddy bottom.

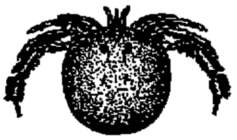
FRESHWATER SANDHOPPER (AMPHIPOD) [5]

Crustacean less than 3cm long. Flattened from side to side. Free swimming at all levels.

FRESHWATER SHRIMP [6]

Small crustacean with slender legs and claws found among aquatic plants and loose stones.

WATER MITE [5]

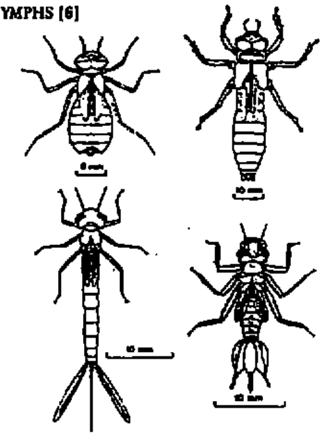


Flat disc-like body. Less than 5mm long Found swimming in water, among plants or on bottom of slowly flowing water.

FRESHWATER SLATER (ISOPOD) [5]

A variety of different shaped free swimming crustaceans. Generally flattened top to bottom — slater like.

DRAGONFLY OR DAMSELFLY NYMPHS [6]



Dragonfly nymphs are short, chunky predators with wingpads and internal gills. Damselfly nymphs are more slender, and have 3 tail like gills on the tail tip. Both have mouth parts and extendable jaws. They are found on plants, among stones, leaf litter or on the bottom.

CADDISFLY LARVAE [6]

Worm-like insect larvae with 3 pairs of legs on the 1st three segments and possibly stumps on last segment. Some are found in cases such as in leaves, twigs, cemented stones or cone-shaped webs.

……

Tolerant Water Bugs

LEECH [3]

Segmented worm with a sucker on one or both ends. Found in water column, on plants in both the water and on land, or on bottom of stream.

FLAT WORM [3]

Small flattened worm like creatures with 2 eye spots. They move in a gliding fashion. Found among loose stones.

SNAILS [3]

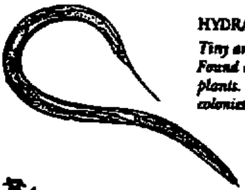
Soft bodied animals with a coiled shell. Found on plants and on rocks.

The Streamwatch WATER BUG DETECTIVE GUIDE

Produced by the Water Board (Sydney - Illawarra - Blue Mountains) and CSIRO's Double Helix

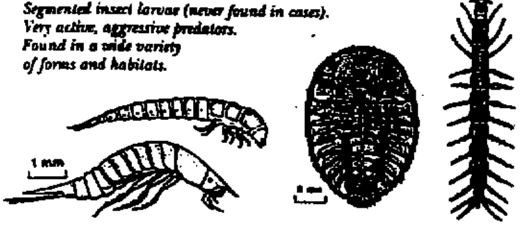
Tolerant Water Bugs continued

NEMATODES [4]
Thread like worm less than 1cm long, tapering to a fine point at one end.
Moves in a whip-like fashion.



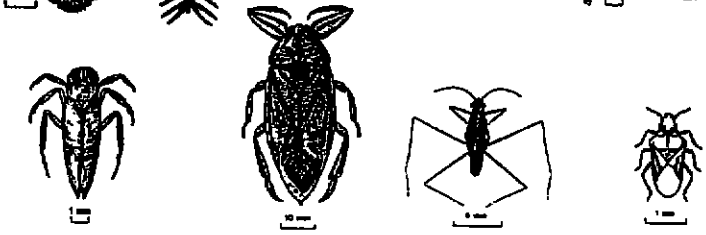
HYDRA [4]
Tiny animals with tentacles. Found attached to rocks or plants. Often found in colonies.

BEETLE LARVAE (COLEOPTERA) [4]
Segmented insect larvae (never found in cases).
Very active, aggressive predators.
Found in a wide variety of forms and habitats.



BEETLES — (COLEOPTERA) [3]
Insects with hard front wings. Folded side by side along the centre of the back. Found swimming in or on the water at all levels or on plants.

TRUE BUGS (HEMIPTERA) [4]
Front wings are folded, soft and overlapping leaving a small triangle on the back. Found among aquatic plants on water surface, or swimming freely at all levels of slowly flowing water.

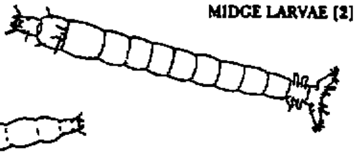


Very Tolerant Water Bugs

AQUATIC EARTHWORM [1]
Segmented worms, opaque or flesh coloured with round ends and no suckers.

FLY LARVAE [2]

MIDGE LARVAE [2]



BLOOD WORM [1]– (RED MIDGE LARVAE)

Chironomids —
slender wormlike creatures with no legs, or stumpy, unjointed legs.
Found in all sorts of aquatic habitats, swimming, on rocks, or on the bottom, in soft muddy tubes.

MOSQUITO LARVAE [2]

References

Lakes and Rivers of Australia by V Serventy & R Raymond
Summit Books 1980
Australian Freshwater Life by W D Williams, 2nd edition
Macmillan 1980
Animal Life in Fresh Water by H Mellanby
Methuen 1965
Freshwater Invertebrates by Ralph Miller
Gould League of Victoria 1985

Acknowledgements

Illustrations were provided by W D Williams (Uni Adelaide), Murray Darling Basin Commission, Rob Welan (Water Board) and Alec Ellis.

The Guide was written by Fiona Van Dort (Water Board), Geoffrey Smith (Water Board), Bruce Chessman (Water Board), Rafael Chemke (Water Board), and David Salt (CSIRO).

APPENDIX 2

THE SLEI FORMS

SUPPLEMENT A

SCIENCE LABORATORY ENVIRONMENT INVENTORY

ACTUAL FORM

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked how often each practice actually takes place.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted
Think about how well each statement describes what this laboratory class 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	SEL DOM
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

Be sure to give an answer for 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.

Practice Example. Suppose that you were given the statement "I choose my partners for laboratory experiments." You would need to decide whether you thought that you actually choose your partners *Almost Never, Seldom, Sometimes, Often* or Very *Often.* For example, if you selected *Very Of ten, you* would circle the number 5 on your Answer Sheet.

Don't forget to write your name and other details at the top of the reverse side of this page.

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SCHOOL____________________ YEAR __________ M/F __________

Remember that you are describing your *actual* classroom	Almost Never Seldom Sometimes Often Very Often	
1. I get on well with students in this laboratory class.	1 2 3 4 5	______
2. There is opportunity for me to pursue my own science interests in this laboratory class	1 2 3 4 5	______
3. What I do in our regular science class is unrelated to my laboratory work	1 2 3 4 5	R ______
4. My laboratory class teas clear rules to guide my activities.	1 2 3 4 5	______
5. I find that the laboratory is crowded when I am doing experiments	1 2 3 4 5	R ______
6. I have little chance to get to know other students in this laboratory class.	1 2 3 4 5	R ______
7. In this laboratory class, I am required to design my own experiments to solve a given problem.	1 2 3 4 5	
8. The laboratory work is unrelated to the topics that I am studying in my science class.		______
9. My laboratory class is rather informal and few rules am imposed on me.	1 2 3 4 5	R______
10. The equipment and materials that I need for laboratory activities are readily available.	1 2 3 4 5	R______
	1 2 3 4 5	
11. Members of this laboratory class help me.	1 2 3 4 5	______
12. In my laboratory sessions, other students collect different data than I do for the same problem	1 2 3 4 5	______
13. My regular science class work is integrated with laboratory activities.	1 2 3 4 5	______
14. 1 am required to follow certain rules in the laboratory.	1 2 3 4 5	______
15. I am shamed of the appearance of this laboratory	1 2 3 4 5	R ______
16 I get to know students in this laboratory class well.	1 2 3 4 5	______
17. I am allowed to go beyond the regular laboratory exercise and do some experimenting of my own	1 2 3 4 5	______
18. I use the theory from my regular science class sessions during laboratory activities.	1 2 3 4 5	______
19. There is a recognized way for me to do things safely in this laboratory.	1 2 3 4 5	______
20. The laboratory equipment which I use is in poor working order.	1 2 3 4 5	R ______
21. I am able to depend on other students for help during laboratory classes.	1 2 3 4 5	______
22. In my laboratory sessions, I do different experiments than some of the other students	1 2 3 4 5	______
23. The topics covered in regular science class work are quite different from topics with which I deal in laboratory sessions.	1 2 3 4 5	R______
24. There are few fixed rules for me to follow in laboratory session.	1 2 3 4 5	R______
25. I find that the laboratory is hot and stuffy.	1 2 3 4 5	R______
26. It takes me a long time to get to know everybody by his/her first same in this laboratory class.	1 2 3 4 5	R______
27. In my laboratory sessions, the teacher decides the best way for me to carry out the laboratory experiments.	1 2 3 4 5	R______
28. What I do in laboratory sessions helps me to understand the theory covered m regular science classes.	1 2 3 4 5	______
29. The teacher outlines safety precautions lo me before my labo-atory sessions commence.	1 2 3 4 5	______
30. The laboratory is an attractive place for me to work in.	1 2 3 4 5	______
31. I work cooperatively in laboratory sessions.	1 2 3 4 5	______
32. I decide the best way to proceed during laboratory experiments.	1 2 3 4 5	______
33. My laboratory work and regular science class work are unrelated	1 2 3 4 5	R ______
34. My laboratory class is run under clearer rules than my other classes.	1 2 3 4 5	______
35. My laboratory has enough room for individual or group work.	1 2 3 4 5	______

For Teacher's Use Only: SC______ OE______ I______ RC______ ME______

SUPPLEMENT B

SCIENCE LABORATORY ENVIRONMENT INVENTORY

PREFERRED FORM

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked how often each practice actually takes place.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted
Think about how well each statement describes what this laboratory class 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	SEL DOM
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

Be sure to give an answer for 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.

Practice Example. Suppose that you were given the statement "I choose my partners for laboratory experiments." You would need to decide whether you thought that you actually choose your partners *Almost Never, Seldom, Sometimes, Often* or Very *Often.* For example, if you selected *Very Of ten, you* would circle the number 5 on your Answer Sheet.

Don't forget to write your name and other details at the top of the reverse side of this page.

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SCHOOL______________________________YEAR______________M/F________

Remember that you are describing your ***preferred*** classroom	Almost Never Seldom Sometimes Often Very Often	
1. I would get on well with students in this laboratory class.	1 2 3 4 5	______
2. There would be opportunity for me to pursue my own science interests in this laboratory class.	1 2 3 4 5	______
3. What I do in our regular science class would be unrelated to my laboratory work.	1 2 3 4 5	R ______
4. My laboratory class would have clear rules to guide my activities.	1 2 3 4 5	______
5. I would find that the laboratory is crowded when I am doing experiments	1 2 3 4 5	R ______
6. I would have little chance to get to know other students in this laboratory class.	1 2 3 4 5	R ______
7. In this laboratory class, I would be required to design my own experiments to solve a given problem.	1 2 3 4 5	______
8. The laboratory work would be unrelated to the topics that I am studying in my science class.	1 2 3 4 5	R______
9. My laboratory class would be rather informal and few rules would be imposed on me.	1 2 3 4 5	R______
10. The equipment and materials that I need for laboratory activities would be readily available.	1 2 3 4 5	______
11. Members of this laboratory class would help me.	1 2 3 4 5	______
12. In my laboratory sessions, other students would collect different data than I would for the same problem.	1 2 3 4 5	______
13. My regular science class work would be integrated with laboratory activities	1 2 3 4 5	______
14. I would be required to follow certain rules in the laboratory.	1 2 3 4 5	______
15. I would be ashamed of the appearance of this laboratory	1 2 3 4 5	R ______
16. I would get to know students in this laboratory class well.	1 2 3 4 5	______
17. I would be allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	1 2 3 4 5	______
18. I would use the theory from my regular science class sessions during laboratory activities.	1 2 3 4 5	______
19. There would be a recognized way for me to do things safely in this laboratory.	1 2 3 4 5	______
20. The laboratory equipment which I use would be in poor working order.	1 2 3 4 5	R ______
21. I would be able to depend on other students for help during laboratory classes.	1 2 3 4 5	______
22. In my laboratory sessions, I would do different experiments than some of the other students.	1 2 3 4 5	______
23. The topics covered in regular science class work would be quite different from topics with which I deal in laboratory sessions.	1 2 3 4 5	R______
24. There would be few fixed rules for me to follow in laboratory sessions.	1 2 3 4 5	R______
25. I would find that the laboratory is hot and stuffy.	1 2 3 4 5	R______
26. It would take me a long time to get to know everybody by his/her first name in this laboratory class.	1 2 3 4 5	R______
27. In my laboratory sessions, the teacher would decide the best way for me to carry out the laboratory experiments	1 2 3 4 5	R______
28. What I do in laboratory sessions would help me to understand the theory covered in regular science classes.	1 2 3 4 5	______
29. The teacher would outline safety precautions to me before my laboratory sessions commence.	1 2 3 4 5	______
30. The laboratory would be an attractive place for me to work in.	1 2 3 4 5	
31. I would work cooperatively in laboratory sessions.	1 2 3 4 5	______
32. I would decide the best way to proceed during laboratory experiments.	1 2 3 4 5	______
33. My laboratory work and regular science class work would be unrelated	1 2 3 4 5	R ______
34. My laboratory class would be run under clearer rules than my other classes.	1 2 3 4 5	______
35. My laboratory would have enough room for individual or group work.	1 2 3 4 5	______

For Teacher's Use Only: SC______OE________I__________RC________ME________

SUPPLEMENT A

MODIFIED SCIENCE LABORATORY ENVIRONMENT INVENTORY

ACTUAL FORM

Directions

This questionnaire contains statements about practices which could take place in this Streamwatch class. You will be asked how often each practice actually takes place.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted
Think about how well each statement describes what this laboratory class 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

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

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SCHOOL______________________________ YEAR________________ M/F__________

Remember that you are describing your *actual* Streamwatch area	Almost Never Seldom Sometimes Often Very Often	
1. I get on well with students in this Streamwatch class.	1 2 3 4 5	______
2. There is opportunity for me to pursue my own science interests in this Streamwatch class	1 2 3 4 5	______
3. What I do in our regular science class is unrelated to my Streamwatch work	1 2 3 4 5	R ______
4. My Streamwatch class has clear rules to guide my activities.	1 2 3 4 5	______
5. I find that the Streamwatch is crowded when I am doing experiments	1 2 3 4 5	R ______
6. I have little chance to get to know other students in the Streamwatch class.	1 2 3 4 5	R ______
7. In the Streamwatch class, I am required to design my own experiments to solve a given problem.	1 2 3 4 5	______
8. The Streamwatch work is unrelated to the topics that I am studying in my science class.	1 2 3 4 5	R______
9. My Streamwatch class is rather informal and few rules are imposed on me.	1 2 3 4 5	R______
10. The equipment and materials that I need for Streamwatch activities are readily available.	1 2 3 4 5	
11.Members of this Streamwatch class help me.	1 2 3 4 5	______
12. In my Streamwatch sessions, other students collect different data than I do for the same problem	1 2 3 4 5	______
13. My regular science class work is integrated with Streamwatch activities.	1 2 3 4 5	______
14. I am required to follow certain rules in Streamwatch.	1 2 3 4 5	______
15. I am shamed of the appearance of this Streamwatch site	1 2 3 4 5	R ______
16 I get to know students in this Streamwatch class well.	1 2 3 4 5	______
17. I am allowed to go beyond the regular Streamwatch exercise and do some experimenting of my own	1 2 3 4 5	______
18. I use the theory from my regular science class sessions during Streamwatch activities.	1 2 3 4 5	______
19. There is a recognized way for me to do things safely in this Streamwatch.	1 2 3 4 5	______
20. The Streamwatch equipment which I use is in poor working order.	1 2 3 4 5	R ______
21. I am able to depend on other students for help during Streamwatch classes.	1 2 3 4 5	______
22. In my Streamwatch sessions, I do different experiments than some of the other students	1 2 3 4 5	______
23. The topics covered in regular science class work are quite different from topics with which I deal in Streamwatch sessions.	1 2 3 4 5	R______
24. There are few fixed rules for me to follow in Streamwatch session.	1 2 3 4 5	R______
25. I find that the Streamwatch area is hot.	1 2 3 4 5	R______
26. It takes me a long time to get to know everybody by his/her first name in this Streamwatch class.	1 2 3 4 5	R ______
27. In my Streamwatch sessions, the teacher decides the best way for me to carry out the Streamwatch experiments.	1 2 3 4 5	R ______
28. What I do in Streamwatch sessions helps me to understand the theory covered in regular science classes.	1 2 3 4 5	______
29. The teacher outlines safety precautions to me before my Streamwatch sessions commence.	1 2 3 4 5	______
30. The Streamwatch area is an attractive place for me to work in.	1 2 3 4 5	______
31. I work cooperatively in Streamwatch sessions.	1 2 3 4 5	______
32. I decide the best way to proceed during Streamwatch experiments.	1 2 3 4 5	______
33. My Streamwatch work and regular science class work are unrelated.	1 2 3 4 5	R ______
34. My Streamwatch class is run under clearer rules than my other classes.	1 2 3 4 5	______
35. My Streamwatch area has enough room for individual or group work.	1 2 3 4 5	______

For Teacher's Use Only: SC______OE________I__________RC_________ME________

SUPPLEMENT B

MODIFIED SCIENCE LABORATORY ENVIRONMENT INVENTORY

PREFERRED FORM

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked how often each practice actually takes place.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted
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2	if the practice actually takes place	SELDOM
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4	if the practice actually takes place	OFTEN
5	if the practice actually takes place	VERY OFTEN

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Practice Example. Suppose that you were given the statement "I choose my partners for laboratory experiments." You would need to decide whether you thought that you actually choose your partners *Almost Never, Seldom, Sometimes, Often* or Very *Often.* For example, if you selected *Very Of ten, you* would circle the number 5 on your Answer Sheet.

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SCHOOL____________________YEAR____________M/F________

Remember that you are describing your ***preferred*** Streamwatch area	Almost Never	Seldom	Sometimes	Often	Very Often	
1. I would get on well with students in this Streamwatch class.	1	2	3	4	5	
2. There would be opportunity for me to pursue my own science interests in this Streamwatch class.	1	2	3	4	5	
3. What I do in our regular science class would be unrelated to my Streamwatch work.	1	2	3	4	5	R
4. My Streamwatch class would have clear rules to guide my activities.	1	2	3	4	5	
5. I would find that the Streamwatch is crowded when I am doing experiments	1	2	3	4	5	R
6. I would have little chance to get to know other students in this Streamwatch class.	1	2	3	4	5	R
7. In this Streamwatch class, I would be required to design my own experiments to solve a given problem.	1	2	3	4	5	
8. The Streamwatch work would be unrelated to the topics that I am studying in my science class.	1	2	3	4	5	R
9. My Streamwatch class would be rather informal and few rules would be imposed on me.	1	2	3	4	5	R
10. The equipment and materials that I need for Streamwatch activities would be readily available.	1	2	3	4	5	
11. Members of this Streamwatch class would help me.	1	2	3	4	5	
12. In my Streamwatch sessions, other students would collect different data than I would for the same problem.	1	2	3	4	5	
13. My regular science class work would be integrated with Streamwatch activities	1	2	3	4	5	
14. I would be required to follow certain rules in the Streamwatch.	1	2	3	4	5	
15. I would be ashamed of the appearance of this Streamwatch area.	1	2	3	4	5	R
16. I would get to know students in this Streamwatch class well.	1	2	3	4	5	
17. I would be allowed to go beyond the regular Streamwatch exercise and do some experimenting of my own.	1	2	3	4	5	
18. I would use the theory from my regular science class sessions during Streamwatch activities.	1	2	3	4	5	
19. There would be a recognized way for me to do things safely in this Streamwatch.	1	2	3	4	5	
20. The Streamwatch equipment which I use would be in poor working order.	1	2	3	4	5	R
21. I would be able to depend on other students for help during Streamwatch classes.	1	2	3	4	5	
22. In my Streamwatch sessions, I would do different experiments than some of the other students.	1	2	3	4	5	
23. The topics covered in regular science class work would be quite different from topics with which I deal in Streamwatch sessions.	1	2	3	4	5	R
24. There would be few fixed rules for me to follow in Streamwatch sessions.	1	2	3	4	5	R
25. I would find that the Streamwatch is hot.	1	2	3	4	5	R
26. It would take me a long time to get to know everybody by his/her first name in this Streamwatch class.	1	2	3	4	5	R
27. In my Streamwatch sessions, the teacher would decide the best way for me to carry out the Streamwatch experiments	1	2	3	4	5	R
28. What I do in Streamwatch sessions would help me to understand the theory covered in regular science classes.	1	2	3	4	5	
29. The teacher would outline safety precautions to me before my Streamwatch sessions commence.	1	2	3	4	5	
30. The Streamwatch would be an attractive place for me to work in.	1	2	3	4	5	
31. I would work cooperatively in Streamwatch sessions.	1	2	3	4	5	
32. I would decide the best way to proceed during Streamwatch experiments.	1	2	3	4	5	
33. My Streamwatch work and regular science class work would be unrelated	1	2	3	4	5	R
34. My Streamwatch class would be run under clearer rules than my other classes.	1	2	3	4	5	
35. My Streamwatch would have enough room for individual or group work.	1	2	3	4	5	

For Teacher's Use Only: SC______OE______I______RC______ME______

APPENDIX 3

LETTER TO SCHOOLS

Cheltenham Girls' High School
The Promenade
Cheltenham
NSW 2119
Tel 987654481
9 July 1997

Letter to Colleagues

Dear Colleague,

I am seeking the cooperation of you and your students who are involved in Streamwatch, or if your school is not participating in Streamwatch to fill out two questionnaire forms. If your students are doing Streamwatch the modified Science Laboratory Environment Inventory (Preferred and Actual) is required or if your students are not participating in Streamwatch the non modified Science Laboratory Environment Inventory (Preferred and Actual). The questionnaires take approximately 30 - 35 minutes to be completed by your year 10 students. Clear instructions are on each form and you only need to administer them to your students. The scoring and analysis of the completed questionnaires will be done by myself.

Enclosed is a letter to parents to obtain their consent for their child to fill in the Science Laboratory Environment Inventory questionnaires as required by the Child Protection Directive.

It would be appreciated if you would administer the questionnaires to your students as a 'before and after situation' on completion of the Streamwatch topic. I will provide the relevant photocopying of the questionnaires and letters.

Once completed, could they please be sorted into two separate bundles Supplement A and Supplement B, then placed in an A4 envelope and given to the school courier and sent to me at Cheltenham Girls High School.

I assure you of total anonymity of yourself, students and school in this questionnaire. I may be contacted at Cheltenham Girls' High School on 98764481.

Copies of the questionnaires and letters have been sent to your Principal and the Department of Education.

Yours sincerely,

Raimund R Pohl

LETTER TO PARENTS

Cheltenham Girls' High School
The Promenade
Cheltenham
NSW 2119
Tel 9876 4481
9 July 1997

Dear Parent,

I am currently doing a doctorate in science education (environment) through Curtin University and seek the cooperation of your son / daughter who is doing Streamwatch.

As your son / daughter is involved in Streamwatch that is run by your school or has been selected as a non Streamwatch school for the purposes of a controlled survey, I am seeking your permission for your son / daughter to fill out the Science Laboratory Environmental Inventory Forms A and B questionnaires.

The Inventory seeks your son's / daughter's opinion about Streamwatch. The questionnaires do not seek any personal information. The questionnaires take approximately 30 - 35 minutes to complete. For the students not involved in Streamwatch the same inventory is to be used but the words laboratory / class and other appropriate words will be substituted. Otherwise the questionnaires are the same.

You may be assured of total anonymity of your son / daughter, school and staff in this questionnaire. I have undertaken a written agreement with Department of School Education acknowledging my responsibilities in this and in child protection matters.

If you have any enquiries regarding this research please contact me on (02) 98764481.

Yours sincerely,

Raimund R Pohl

PARENTAL CONSENT

I hereby give consent for my son / daughter to fill in the Science Laboratory Environment Inventory supplementary forms A and B for the purposes of educational research and understand that total anonymity is assured.

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Signature of Parent or Guardian