Science and Mathematics Education Centre

An Evaluation of the Effectiveness of Laptop Computers in Science Classrooms

Eddie Orest Stolarchuk

This thesis is presented as part of the requirements for
the award of the Degree of Doctor of Philosophy
of the
Curtin University of Technology

December, 1997

ABSTRACT

Numerous educational research studies have shown that students' perceptions of teacher-interpersonal behaviour and classroom environment are positively associated with students' attitude to science and students' cognitive achievement in science. Laptop computers have become increasing popular in science classrooms since the late 1980s; however, their effects on students' perceptions of teacher interpersonal relationships or classroom environment have not been studied.

The aim of this study was to assess the effectiveness of laptop computers in science classrooms, in terms of the effects laptops had on students' perceptions of teacher-student interpersonal behaviour and classroom environment. Students' attitude to science and their cognitive achievement in science were also assessed.

Student data were collected from 433 grades 8 and 9 science laptop students in 23 classrooms, in 14 Independent schools, in four Australian states. Both quantitative and qualitative data were collected.

The study confirmed the reliability and validity of the QTI and ICEQ for use in science laptop classrooms, described students' perceptions of teacher-student interpersonal behaviour and classroom environment in science laptop classrooms and identified associations between students' perceptions of teacher-student interpersonal behaviour and classroom environment with each of the student outcomes. The attitudinal outcomes were found to be more strongly associated with both perceptual areas, than were the cognitive achievement outcomes.

The study also found that there was a difference in the way science laptop and non-laptop students perceived teacher-student interpersonal behaviour and classroom environment, but that there was no significant difference in the attitudinal and cognitive achievement outcomes between science laptop and non-laptop students.

ACKNOWLEDGEMENTS

I wish to thank and acknowledge the following people, without whose help and understanding, I would not have been able to complete this study.

First, my supervisor, Associate Professor Darrell Fisher, Science and Mathematics Education Centre, Curtin University of Technology. Darrell helped me to focus my study, and then provided me with timely advice, guidance and consistent encouragement over four years. Darrell always provided insightful comments and opinions which proved to be invaluable as the study developed; he was an outstanding mentor and supervisor for this study.

Second, my wife Carmel and daughters Kathryn, Andrea and Tess. Their encouragement, understanding and patience during the course of this study was crucial to its completion. I will always be indebted to Carmel for looking after our daughters and home, during the final months of this study, while I was away at the university.

Third, all the schools, administrators, teachers and students who either managed, supervised or completed the questionnaires and took part in the interviews.

Fourth, my employer, Trinity Anglican School, for the release time granted for my study, and the administration's unconditional support during the study.

Finally, to all Science and Mathematics Education Centre staff and fellow doctoral students who offered advice, encouragement, friendship and help during each of my visits to the Centre.

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

ICEQ	Individualised Classroom Environment Questionnaire
CLES	Constructivist Learning Envrironment Survey
SCES	Science Classroom Environment Survey
QTI	Questionnaire on Teacher Interaction
TOSRA	Test of Science-Related Attitudes Instruments
TOES	Test of Enquiry Skills
ICL	Interpersonal Adjective List
SLEQ	School Level Environment Questionnaire
MBTI	Myers-Briggs Type Indicator
SSQ	School Science Questionnaire
OCDQ	Organisational Climate Description Questionnaire
WES	Work Environment Survey
CCI	Colleges Characteristics Index
LEI	Learning Environment Index
CES	Classroom Environment Survey
SLEI	Science Laboratory Environment Instrument
CUCEI	College and University Classroom Environment Inventory
MCI	My Classroom Inventory
GCEI	Geography Classroom Environment Inventory
ASEP	Australian Science Education Project
CAL	Computer-Assisted Learning
CAI	Computer-Assisted Instruction
CMI	Computer-Managed Instruction
CML	Computer-Managed Learning

CSE	Computer-Simulated Education
CBE	Computer-Based Education
CBI	Computer-Based Instruction
CBL	Computer-Based Learning
CEI	Computer-Enhanced Instruction
ES	Effect Size
IT	Information Technology
PULSE	Pupils Using Laptops in Science and English

CHAPTER 1

INTRODUCTION

This study focuses on the effects of laptop computers in lower secondary science classrooms in Australian Independent schools. The introduction of laptops in these schools began in the late 1980s. There are no other reported studies into the effects of laptops in science classrooms in Australia, except for a few local school-based evaluations. It appears there is a growing trend to introduce laptops, and with little known research occurring on the effects of laptops on science classrooms, this study is desirable to provide an initial insight into the effects of laptop computers in science education.

1.1 BACKGROUND TO THE STUDY

The advent of relatively cheap, robust personal computers (laptops), over the past decade, has resulted in an increasing number of Australian Independent schools prescribing laptop computers as one of the standard items of equipment students must bring with them to the science classroom. To date, there has been a minimal amount of reported research on the impact of laptop computers in science education, and there are no published reports on the impact of laptop computers on students' perceptions of classroom environment or teacher-student interpersonal behaviour in science laptop classrooms. The few published laptop studies have focussed on the traditional areas of 'computers in science classrooms' evaluation, for example, grade improvement, motivation, communication skills improvement, work presentation, content retention and so on (McMillan & Honey, 1993; Gardner, Morrison, & Jarman, 1993; Mitchell & Loader, 1993; Loader, 1993a; Rowe, 1993; Shears, 1995).

Since the late 1960s science education researchers have led the world in the conceptualisation, development, validation and application of classroom environment measurement instruments both overseas and in Australia (Fraser, 1994; Fraser & Walberg, 1991; Fraser, 1986a). The reported research using these instruments is extensive and varied in nature (eg., Anderson & Walberg, 1968; Walberg & Anderson, 1972; Moos, 1979a; Fisher & Fraser, 1983a; Fraser, 1985; Wierstra, 1984; Raviv, Raviv, & Reisel, 1990; Dorman, Fraser, & McRobbie, 1994; Teh & Fraser, 1993; Rawnsley & Fisher, 1997). One instrument that was developed during this period was the *Individualised Classroom Environment Questionnaire* (ICEQ) (Fraser, 1990). An additional scale from the *Constructivist Learning Environment Survey* (CLES) (Taylor, Fraser, & White, 1994) was added to the ICEQ instrument to create the *Science Classroom Environment Survey* (SCES) which is used in this study. Furthermore, it has been demonstrated that students' perceptions of science classroom learning environment have been favourably associated with student attitude and achievement (Fraser, 1994; McRobbie & Fraser, 1993; Fraser, 1991; Fraser, Walberg, Welch, & Hattie, 1987; Haertel, Walberg, & Haertel, 1981).

The early 1980s witnessed increased research in the area of teacher-student interpersonal behaviour, especially in The Netherlands. The result of this research activity was the conceptualisation, development, validation and application of a teacher-student interpersonal behaviour measurement instrument (Wubbels & Levy, 1991, 1993). Reported research using this instrument, the *Questionnaire on Teacher Interaction* (QTI), is well established and varied in nature (eg., Wubbels, Brekelmans, & Hermans, 1987; Brekelmans, Wubbels, & Créton, 1990; Wubbels, Brekelmans, & Hooymayers, 1991; Levy, Rodriguez, & Wubbels, 1993; Fisher, Henderson, & Fraser, 1995; Fisher, Kent, & Fraser, 1997; Fisher, Fraser, & Rickards, 1997). This questionnaire has recently been revised to produce an economical version which has been validated for use in Australia (Wubbels, 1993). Favourable associations have also been reported between students' perceptions of teacher-student interpersonal behaviour and student attitude and achievement (Rawnsley, 1997; Henderson, 1995;

Wubbels, Brekelmans, Créton, & Hooymayers, 1990; Brekelmans, Wubbels, & Créton, 1990; Wubbels, Brekelmans, & Hermans, 1987).

Over the past three decades computers have also become increasingly popular in classrooms, and have been applied in many different ways to assist students and teachers in the learning/teaching process. Many evaluations as to the effectiveness of computers in education have been completed over the years, with most concentrating on such factors as achievement, retention, learning efficiency, attitude and cost effectiveness (eg., Vinsonhaler, 1972; Thomas, 1979; Okey, 1985; Ortiz & Ellet, 1990, Rowe, 1993; Morrison et al., 1993; Shears, 1995).

Furthermore, Chaiklin and Lewis (1988) state that the role of the teacher and the classroom structure changed significantly when intelligent computer-assisted instruction was introduced into the classroom. For example, they report that teachers had to reorganise what they teach, evaluate the time spent on 'traditional' activities and take on new roles such as servicing hardware and maintaining software. It follows that the role of the teacher and the structure of the classroom, will also be affected, by the students having their own personal laptops in science classrooms.

Much of the research, whether in the area of teacher-student interpersonal behaviour, classroom environment or computers in education, includes measurement of students' attitude and/or cognitive achievement. Previous research (eg., Haladyna & Shaughnessy, 1982; Haladyna, Olsen, & Shaughnessy 1982; Oliver & Simpson, 1988; Germann, 1994) has shown a significantly positive relationship between students' attitude and their cognitive achievement, and between students' attitude and their likelihood of future study in the subject area (Mager, 1968). Valid and reliable instruments to measure students' attitude to science and their cognitive achievement in science, have been developed in Australia over the past 20 years.

Research in the areas of teacher-student interpersonal relationships and classroom environment, in science classrooms, is well established and documented in Australia and overseas. Most of the studies referred to earlier report on this research in science classrooms, and attest to a multitude of factors evaluated, ranging from innovations in instructional techniques, to innovations in classroom tools for teachers and/or students, to curriculum innovations. However, there is a minimal amount of reported research evaluating laptop computers in science classrooms.

The availability of proven educational research instruments to measure students' perceptions of teacher-student interpersonal behaviour and classroom environment in science classrooms, and the availability of reliable instruments to measure science students' attitudinal and cognitive achievement outcomes, make this study possible. The recent introduction of laptop computers into science classrooms, and the lack of research in this area, make this study timely and unique.

1.2 RESEARCH QUESTIONS

The QTI and the SCES questionnaires had not been used in science laptop classrooms before this study. The validation of these questionnaires in science laptop classrooms formed the focus of the first research question.

> Research Question 1: Are the QTI and SCES valid and reliable instruments for use in science classrooms where laptop computers are in use?

As previously indicated, it is timely to examine the effect of laptop computers on students' perceptions of teacher-student interpersonal behaviour and classroom environment in science classrooms. This provides the focus for the following two research questions. Throughout this thesis, laptop students are those students that own or lease laptop computers and must bring them to science classes each day. Non-laptop students are those that do not own or lease laptop computers and thus never use them during science classes.

Research Question 2: What are laptop students' perceptions of teacher-student interpersonal behaviour in science classrooms?

Research Question 3: What are laptop students' perceptions of classroom environment in science classrooms?

As this is the first study to measure laptop students' perceptions of both teacher-student interpersonal behaviour and classroom environment in science classrooms, a comparison between laptop and non-laptop students' perceptions was thought important. This formed the focus of the next two research questions. Laptop science classrooms, are those science classrooms where students use their own personal laptop computer in most classes. Non-laptop science classrooms are those science classrooms where students do not use laptop computers during any of their classes.

Research Question 4: Are there any differences in students' perceptions of teacher-student interpersonal behaviour between laptop and non-laptop science classrooms?

Research Question 5: Are there any differences in students' perceptions of classroom environment between laptop and non-laptop science classrooms?

Prior research has indicated an association between students' perceptions of teacher-student interpersonal behaviour and their outcomes, and students' perceptions of classroom environment and their outcomes. This formed the focus of research questions six and seven.

Research Question 6: What associations exist between laptop students' perceptions of teacher-student interpersonal behaviour in science classrooms, and their attitudinal and cognitive achievement outcomes?

Research Question 7: What associations exist between laptop students' perceptions of classroom environment in science classrooms, and their attitudinal and cognitive achievement outcomes?

Again, as this was the first study to measure laptop students' attitudinal and cognitive achievement outcomes, a comparison between laptop students' attitudinal and cognitive achievement outcomes, with that of their non-laptop counterparts was thought important. This formed the focus of the final two research questions.

Research Question 8: Are there any differences in attitude to science between laptop science students and non-laptop science students?

Research Question 9: Are there any differences in cognitive achievement between laptop science students and non-laptop science students?

1.3 SIGNIFICANCE OF THE STUDY

This study contributes significantly to the fields for teacher-student interpersonal behaviour and classroom environment, in science classrooms, in a number of ways. Firstly, it validates the Questionnaire on Teacher Interaction (QTI) and the Science Classroom Environment Survey (SCES) for use in science laptop classrooms. Secondly, this study provides the first reported findings of the effects of laptop computers on students' perceptions of teacher-student interpersonal behaviour and classroom environment, in science classrooms.

Thirdly, this study is unique in that it explores and reports on the association between science laptop students' perceptions of teacher-student interpersonal behaviour and their attitudinal and cognitive achievement outcomes, and science laptop students' perceptions of classroom environment and their attitudinal and cognitive achievement outcomes. This has not occurred before.

This study is also unique in that qualitative interview data, collected from laptop students and their teachers, and the researcher's own experiences and perceptions of teaching a science laptop class, were used to supplement the quantitative findings. Finally a plan is proposed for schools to consider when contemplating the introduction of laptop computers in science. This latter point is of great practical significance as it provides an 'ideal minimum plan' that schools should follow when introducing laptop computers into the science classrooms. Science students and teachers, in schools that follow this plan, should experience fewer frustrations and a greater number of successes in the first few years of their laptop program.

1.4 OVERVIEW OF METHODOLOGY

The 48-item, eight scale, economical version of the QTI (Wubbels, 1993) was used to determine students' perceptions of teacher-student interpersonal behaviour. Students' perceptions of science classroom environment were determined using a six-scale Science Classroom Environment Survey (SCES) instrument.

Students' attitude to science was measured using an attitude scale adapted from the *Test of Science-Related Attitudes* (TOSRA) instrument (Fraser, 1981a). Students' cognitive achievement in science was measured using three scales of the *Test of Enquiry Skills* (TOES) instrument (Fraser, 1979).

The QTI, SCES, cognitive achievement scales and the attitude scale were administered to 433 laptop and 430 non-laptop students in grades 8 and 9 science classes, in 14 Independent schools across four Australian states. A sub-sample of laptop students and teachers was interviewed in two schools, and the researcher's perceptions and experiences of teaching a science laptop class were recorded. This resulted in three data sources being available to answer the research questions.

The quantitative data were statistically analysed, as required to answer the research questions, and the qualitative data was reviewed and summarised under the major headings of teacher-student interpersonal behaviour, classroom environment and attitude and achievement outcomes, as was the researcher provided data. The qualitative data was used to support and enrich the quantitative findings.

1.5 OVERVIEW OF THE THESIS

This chapter describes how and why the objectives of this study were formulated, provides some pertinent background information to set the context of the study and gives a brief overview of the methodology. Chapter 2 contains a literature review focusing on the theoretical framework on which teacher interpersonal relationships research is based, along with instrument development and research completed using the QTI in this area; the theoretical framework on which classroom environment research is based, along with instrument development and research completed using the ICEQ instrument in particular; and an historic overview of computers in education including a synopsis of some of the major meta-analysis studies completed covering computers in education. With regard to computers in education, an emphasis was placed on any published 'laptop computers in education' studies, especially in science education.

Chapter 3 contains a description of the methodology used in this study. All aspects of the methodology are reviewed, including instrument selection, sample selection, data collection and data analysis. In addition, detailed validation data are provided for the two main quantitative data collection instruments used in this study, the Questionnaire on Teacher Interaction and the Individualised Classroom Environment Questionnaire. This is followed by a brief description of, and summary validation statistics for, those instruments where only part of the instrument was used to collect quantitative data.

Chapter 4 reports on the descriptive statistics, based on the laptop sample, used to confirm the reliability and validity for the QTI and SCES. Reliability statistics are also reported for the attitude and cognitive achievement scales. Chapter 5 explores and reports on the findings of the analyses of the quantitative data. Science laptop students' perceptions of both teacher-student interpersonal behaviour and classroom environment are reported, along with the associations between each of these students' perceptions with each of the two student outcomes of attitude and cognitive achievement. Differences in perceptions of both teacher-student interpersonal behaviour and classroom environment, between science laptop and non-laptop students are reported, as are differences in attitude and cognitive achievement between the two groups.

Chapters 6 and 7 report the qualitative data collected. Chapter 6 reports on the analysis and interpretation of the interview data collected from the laptop student and teacher sub-samples. Chapter 7 reports the researcher self-reflection data based on the researcher's experience of teaching a science laptop class.

The answers to the research questions appear in Chapter 8. Major findings of the study are reported, using all three data bases where possible. Implications for teachers and schools that flow on from these findings, are suggested, along with a proposal schools could find useful to consider if contemplating the introduction of laptops. The chapter and thesis conclude with a review of the limitations of this study and recommendations for future research.

CHAPTER 2

LITERATURE REVIEW AND RELATED RESEARCH

2.1 INTRODUCTION

The main aim of this study was to evaluate the effectiveness of laptop computers in science classrooms at the grades 8 and 9 levels, in Australian Independent schools, in terms of teacher interpersonal relationships and classroom environment. Data were also collected on the student outcomes of cognitive achievement and attitude to subject. The first intent of this chapter is to provide the conceptual framework on which teacher interpersonal relationship research and classroom environment research is based, including an overview of instrument development in each area. The second intent is to review research completed in teacher interpersonal relationships and classroom environment, including reported associations between these and the student outcomes of attitude to science class and cognitive achievement. Thirdly, an historic overview is provided of computers in education from PLATO to laptops, including an overview of studies completed from the 1960s onward and a review of published laptop studies. The chapter concludes with a summary linking the above three areas.

2.2 CONCEPTUAL FRAMEWORK OF TEACHER INTERPERSONAL RELATIONSHIPS

Research in this area originated during the 1970's as a result of a Dutch 'Education for Teachers' research program at the University of Utrecht (Wubbels & Levy, 1993). One of the aims of this research program was to put to practical use, in teacher-training or teacher in-service programs, the results of research findings.

One of the problems studied in the 'Education for Teachers' research program was that of classroom discipline experienced by beginning teachers. This problem came to the fore as a result of analyses of the various research areas in the 'Education for Teachers' program (Wubbels, Créton, & Hooymayers, 1987) and led the researchers to the conclusion "that interpersonal teacher behaviour was a key factor in the discipline problems of beginning teachers" (Wubbels, Créton, & Hooymayers, 1992, p. 2). The first step in addressing this problem was the identification of a language that could be used to describe the communication that occurred within the classroom (Wubbels, Créton, & Hooymayers, 1985). Such a language was identified in the systems communication theory of Watzlawick, Beavin, and Jackson (1967) developed in the field of family therapy. Once minor adaptations of the language were made, to better reflect classroom communication, the search began for an instrument with which to measure teacher interpersonal behaviour. No such instrument was found; however, the Leary (1957) model of interpersonal behaviour, in the area of clinical psychology, was selected as the theoretical base on which to construct an appropriate instrument.

2.2.1 The Systems Theory of Communication Model

The basic supposition of this theory is that the behaviours of any participants in communication influence each other mutually, that is, the communicator's behaviour influences the type of response received and, in turn, the type of response received influences the communicator's behaviour. This is referred to as circularity and change (Créton, Wubbels, & Hooymayers, 1993) and implies total intertwining of all aspects of the system, so that all communication not only consists of behaviour but also determines behaviour. According to this theory, to not respond, is a response in itself.

2.2.2 Leary's Interpersonal Behaviour Model

This model postulates that interpersonal behaviour is directly dependent on the personality of the individual, and that interpersonal behaviour is driven by the individual's desire to reduce fear and maintain self-esteem (Leary, 1957). It follows, then, that each instant of an individual's communicative behaviour is such that it reduces anxiety and maintains self-esteem. If the individual is successful in reducing anxiety and maintaining self-esteem, then the communicative behaviour is repeated thus establishing a communication pattern. It is therefore logical to assume that the established communication pattern must also be personality dependent.

Leary's model also provides a framework for measuring specific interpersonal behaviours. The analyses of numerous patient-therapist dialogues, and group discussions in clinical and other situations, enabled Leary and his co-workers to identify sixteen categories of interpersonal behaviour. These sixteen categories were later reduced to eight (Wubbels, Créton, Levy, & Hooymayers, 1993). Leary (1957) mapped the various categories on a two-dimensional coordinate system, using one dimension to represent the degree of cooperation between the communicators and the other dimension to represent the degree of control, over the communication, by the communicator under scrutiny. Leary mapped the first dimension on a continuum labelled the 'Affection-Hostility' axis and the latter dimension on a continuum labelled the 'Dominance-Submission' axis. The 'Affection-Hostility' axis is known as the proximity dimension and the 'Dominance-Submission' axis is known as the influence dimension.

The Leary model has been validated numerous times in psychological research settings and the dimensions of proximity and influence have been widely accepted as universal indicators of human interpersonal behaviour (Wubbels, Créton, & Hooymayers, 1992).

2.3 DEVELOPMENT OF THE QUESTIONNAIRE ON TEACHER INTERACTION (QTI)

A model to map teacher interpersonal behaviour, based on the Leary model, was developed in the early eighties by Wubbels, Créton, and Hooymayers (1985). The first attempt at the model involved the use of an instrument, called the *Interpersonal Adjective Checklist* (ICL), to collect data on teacher interpersonal behaviour and then have it mapped on a two-dimensional plane using the two Leary dimensions of proximity and influence (Wubbels, Créton, & Hooymayers, 1992). The ICL proved unsuitable because of the inappropriate wording of items when applied to teachers, the wording of items at four levels of behavioural intensity, items being responded to with a simple 'yes' or 'no' and the time factor of responding to 128 items (Wubbels & Levy, 1993); however, the concept of the ICL was embraced. The mapping of data using the two Leary dimensions of proximity and influence posed no difficulty. These two dimensions transferred easily into the education setting. They were also identified by other researchers, be it by different names, for example, status and solidarity by Brown (1985), warmth and directivity by Dunkin and Biddle (1974), as the two dimensions necessary to describe interpersonal behaviour.

The Questionnaire on Teacher Interaction was then developed by adapting the ICL to the teaching situation within the context of the Leary model and the model on systems communication theory. Numerous items in the ICL were dropped, as was the wording of items at the four levels of behavioural intensity. Remaining items were reworded, yielding seventy-seven appropriately worded items. The method of response to the items was changed from 'yes' or 'no' to a five-point Likert-type scale, ranging from 'never' to 'always'.

The coordinate system of the Leary model maps the Influence dimension along the vertical axis and the Proximity dimension along the horizontal axis, as shown in Figure 2.1. Leary's Proximity dimension continuum of 'Affection-Hostility' was renamed 'Cooperation-Opposition' for the QTI

(Wubbels, Créton, Levy, & Hooymayers, 1993), but the Influence dimension continuum of 'Dominance-Submission' was not altered. This allowed for the graphing of eight sectors, each representative of a particular behaviour type. The eight sectors were labelled DC (Leadership), CD (Helping/Friendly), CS (Understanding), SC (Student Responsibility/Freedom), SO (Uncertain), OS (Dissatisfied), OD (Admonishing) and DO (Strict), as portrayed in Figure 2.2. The first letter in each behaviour type 'code' indicates which of the two dimensions in that particular quadrant dominate, for example, in the Cooperation/Submission quadrant, when cooperation dominates over submission, then the interpersonal behaviour is described as CS but if submission dominates over cooperation, then the interpersonal behaviour is described as SC. The 77 items were grouped into eight scales, with the number of items per scale varying between nine and eleven (Wubbels, Créton, & Hooymayers, 1985), so that each scale corresponded to one of the eight sectors or interpersonal behaviours.

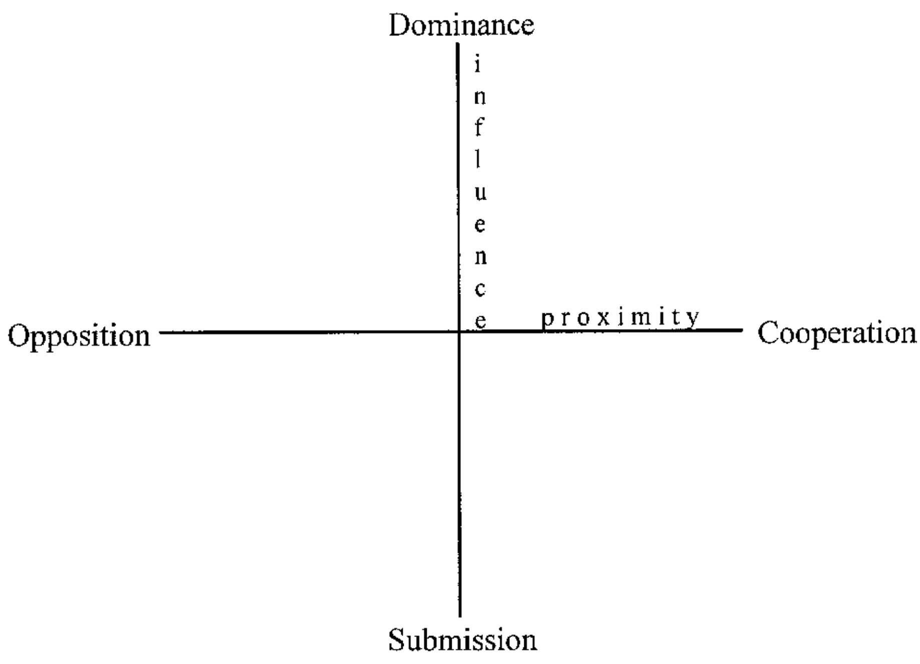

Figure 2.1. The coordinate system for the QTI. (Wubbels & Levy, 1993)

The final version of the QTI was completed after four trial runs (Wubbels, Créton, Levy, & Hooymayers, 1993). When this version was used with 2,407 students and 91 teachers Wubbels, Créton, and Hooymayers (1985) reported acceptable internal consistency reliabilities, using the Cronbach alpha coefficient, for each scale with values ranging from 0.77 to 0.87 using the student as the unit of analysis and from 0.91 to 0.96 when using the class mean as the unit of analysis.

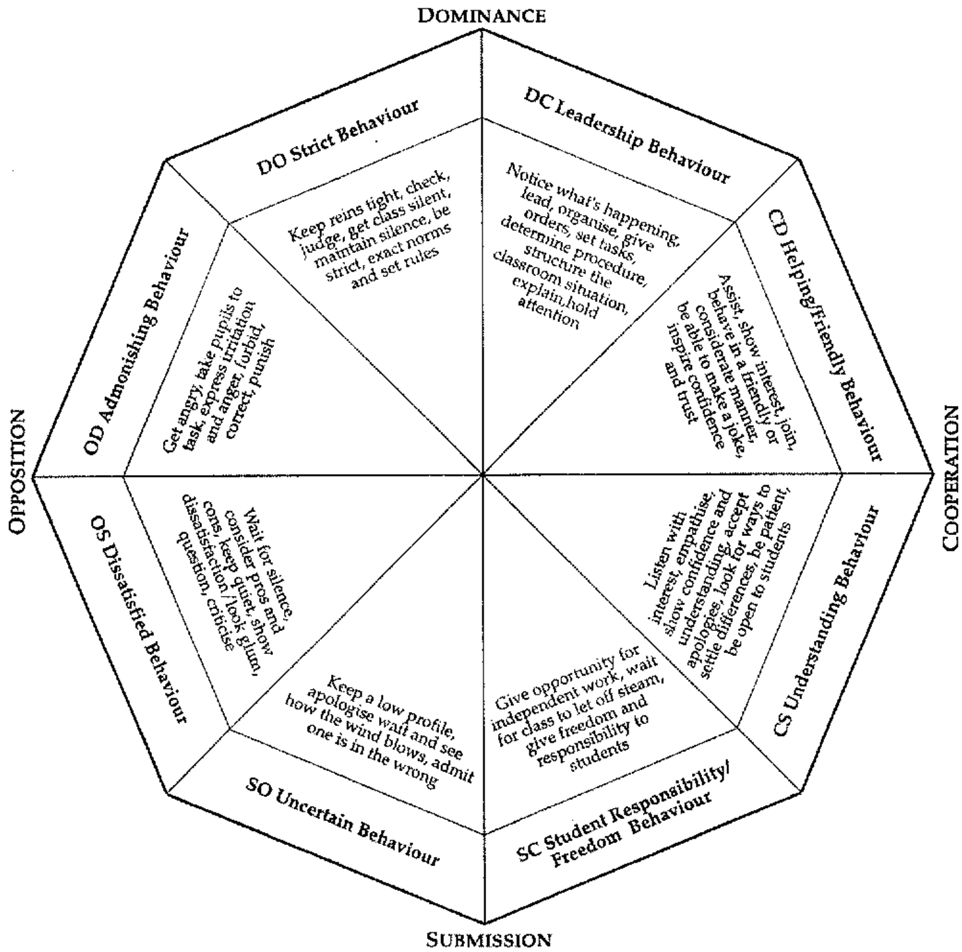

Figure 2.2. The model for interpersonal teacher behaviour.
(Wubbels & Levy, 1991)

For the teacher version the Cronbach alpha coefficients ranged from 0.76 to 0.90. Test-retest reliability, using 80 students, was reported to range between 0.65 and 0.84 for the eight scales, while the intra-class correlation, calculated using the Horst (1949) formula, was reported to range between 0.94 and 0.97. Factor analyses performed on item scores, for the student data, validated the division of the items into scales. These results supported the validity and reliability of the QTI and that it could be used with confidence in research studies.

A 48-item, economical short form of the QTI was developed in Australia (Wubbels, 1993). The 48 items are distributed evenly amongst the eight scales and students respond to each question, as in the Dutch and American versions, on a five-point, Likert-type scale ranging from 0 (Never) to 4 (Always). Responses are recorded on the question sheet. This version of the QTI was used in this study and its specific reliability and validity statistics are provided in Chapter 3.

An elementary school version of the QTI was recently validated (Goh & Fraser, 1996) in Singapore. This version contains 48 items evenly spread amongst the eight scales; however, it differs in two main ways from the 48-item Australian version. One, items at a high reading level were rewritten using simpler language and, two, the five-point Likert-type response scale of Never to Always was reduced to a three-point Likert-type response scale of Seldom, Sometimes and Most of the Time. This version of the QTI was administered to 1,512 students in 39 grade 5 mathematics classrooms in 13 randomly selected schools throughout Singapore. Cronbach alpha reliability coefficients, using the class mean as the unit of analysis, ranged from 0.73 to 0.96 and the ANOVA (the ratio of 'between' to 'total' sums of squares) statistic values, indicating scale abilities to differentiate between classrooms, ranged from 0.13 to 0.38.

2.4 REVIEW OF PAST STUDIES USING THE QTI

2.4.1 Overseas Studies

Following is an overview of research studies completed where the QTI was used as one of the instruments, or the only instrument, to collect quantitative data on student and/or teacher perceptions of teacher-student interpersonal behaviour.

To determine if there were differences between student and teacher perceptions of teacher interpersonal behaviour, Brekelmans and Wubbels (1992) collected data using the QTI from 1,156 teacher-class combinations, in all kinds of subjects, in about one hundred secondary schools in The Netherlands. Students were asked to complete the QTI on their teachers and teachers were asked to respond to the questionnaire twice, once describing their behaviour and once what they perceived as ideal behaviour. Amongst other findings, this study showed that in general students and teachers do not agree about their perception of teacher interpersonal behaviour, the degree of disagreement is greater for teacher interpersonal behaviour types associated with low student outcomes and teachers rated themselves closer to their perceived ideal than did their students, again, especially teachers with interpersonal behaviour types associated with low student outcomes.

A study reported by Brekelmans, Wubbels, and Créton (1990) investigated grade 9 physics students' perceptions of the interpersonal behaviour of their teachers. Data for the study were gathered by students completing the QTI in 65 classrooms, 21 using a new curriculum, 44 using the traditional curriculum. Schools involved were part of the Dutch option of the Second International Science Study. The main outcome reported was a rather strong relationship between teacher interpersonal behaviour and student outcomes. The relationship between teacher interpersonal behaviour and the affective outcome was reported as being stronger than the one between teacher interpersonal behaviour and the cognitive outcome. Leadership interpersonal behaviour was reported as being most closely related to both high affective and high cognitive student outcomes.

Wubbels (1993) used the QTI with a sample of 66 grade 9 physics classes in the Dutch option of the Second International Science Study, where he investigated relations between interpersonal teacher behaviour and student achievement and attitude. Amongst his findings were that students' perceptions of interpersonal teacher behaviour appeared to account for much of the outcome differences between classes of similar ability (70% variability in achievement and 55% in attitude) and that differences in student outcomes varied much more due to different teacher interpersonal behaviours than different curricula or teachers' age or teaching experience. This study also revealed that students taught by teachers who had higher scores on the submissive side of the D-S axis, than the 'average teacher', had better attitudes toward physics, and that students taught by teachers showing more DO, DC and CD sector behaviour had better achievement.

A Dutch study completed by Terwel, Brekelmans, Wubbels, and van den Eeden (1994) reported on gender differences in perceptions of learning environment in physics and mathematics. This study involved two projects, a Physics Project and a Mathematics Project, with the former collecting information, using the QTI, from 33 grade 9 physics classes taught by 33 different teachers in 33 different schools. Data collected using the QTI included both students' and teachers' perceptions of teacher interpersonal behaviour. Information on openness of the learning environment was also collected in this project. The Mathematics Project collected information from 23 classes in six secondary schools using the Perception of the Curriculum in Action Questionnaire. The following findings relate to the Physics Project only. Internal consistencies (Cronbach alphas) ranging from 0.71 to 0.90 were reported for the QTI scales using the class mean as the unit of analysis, there was no significant relationship, in general, found between gender and the two dimensions of teacher interpersonal behaviour; however, there was a reported significant variance between gender and the perceptions of the degree of cooperation and closeness (proximity dimension) between teacher and students across classes.

A study, part of a 10-year research project on effective teaching in the United States, reported by Levy, Wubbels, Brekelmans, and Morganfield (1994) examined whether students' cultural background influenced their perceptions of teacher communication style. Student perceptions of teacher communication style were determined by the administration of the QTI to 550 high school students in 38 classes. Of the 550 students, 322 were US, 117 were Hispanic and 111 were Asian. US students were born in the US and spoke English at home, Hispanic students were born in Latin America and spoke Spanish at home and Asian students were born in Asia and spoke an Asian language at home. Each class had a mixture of students from each of the three cultural groups. Qualitative data were also collected through interviews with 10 native English-speaking students, 8 native Spanish-speaking students and 2 native Asian-language speaking students. QTI response analyses indicated that as the percentage of USA/English students increased in a classroom the teacher was perceived as less dominant, and that Hispanic students perceived teachers as more dominant than did other cultural groups. This study concluded that it was reasonable to believe that cultural membership is a significant variable in students' perceptions of teacher communication styles and teacher behaviour.

2.4.2 Australian Studies

One of the first reported uses of the QTI in Australia was in a study designed to determine if there were any associations between school learning environment and teacher interpersonal behaviour (Fisher, Fraser, & Wubbels, 1993). The QTI was used in conjunction with the *School Level Environment Questionnaire* (SLEQ). Data were collected from seven schools, with 46 teachers participating. Teachers completed the SLEQ and two copies of the QTI, one in which they indicated their perceptions of their behaviour and one in which they indicated their perceptions of ideal teacher behaviour. Teachers selected one of their classes to respond to the QTI. A total of 792 students completed the QTI indicating their perceptions of the teacher interpersonal behaviour in their class. The findings of this study led to the conclusion that the relationship between school-level environment perceptions and teacher interpersonal behaviour perceptions was a weak one indicating that, perhaps, teachers' perceptions of school environment have little to do with their interpersonal behaviour in class. Reliabilities, Cronbach alpha coefficients, for the QTI scales ranged from 0.68 to 0.85 with the student as the unit of analysis and from 0.80 to 0.95 using the class mean as the unit of analysis.

Wubbels (1993) used the more economical Australian version of the QTI with a sample of grade 11 science and mathematics students in Western Australia and Tasmania. A total of 792 students and 46 teachers were involved in this study. Students completed two copies of the questionnaire, once indicating their perceptions of their science or mathematics teacher and once indicating their perceptions of the best teacher. Teachers also completed two questionnaires, once indicating their perception of themselves, and once indicating their perceptions of an ideal teacher. Wubbels' findings were similar to previous studies in that students perceived their best teachers to be strong on leadership and more helping and friendly than average teachers. Furthermore, teachers perceived their behaviour more favourably than did students, generally teachers did not reach their ideal and from a students' point of view, teachers do not match best teacher perceptions.

A study completed in Tasmania, Australia involved the first use of the QTI in senior secondary biology classes. The instrument was used to collect students' perceptions of teacher interpersonal behaviour and the results were correlated with students' attitudinal, cognitive achievement and practical performance outcomes (Fisher, Henderson, & Fraser, 1995). This study reported Cronbach alpha reliability figures for the different QTI scales ranging from 0.63 to 0.83 with the student as the unit of analysis, and from 0.74 to 0.95 with the class mean as the unit of analysis. It was also reported that each QTI scale differentiated significantly ($p<0.001$) between classes and that the ANOVA eta^2 statistic, showing proportion of variance based on class membership, ranged from 0.20 to 0.48 for different classes. The study confirmed the reliability and validity of the QTI when used with senior secondary biology classes and found significant associations between teacher interpersonal behaviour and student outcomes. The association between teacher interpersonal behaviour and student attitude was reported as being strongest. A negative correlation was reported between the Strict scale and performance on practical tests.

Fisher, Kent, and Fraser (1997) completed a study in Tasmania using the QTI and the *Myers-Briggs Type Indicator* (MBTI) to investigate the relationship between student perceptions of teacher-student interpersonal behaviour and teacher personality, teacher perceptions of their interpersonal behaviour and their personality and the proportions of personality types in the sample. The sample consisted of 108 teachers, in eight government secondary colleges, and their classes containing 1,883 grade 11 and 12 students. This study reported Cronbach alpha coefficients for the scales of the QTI ranging from 0.66 to 0.83 using the student as the unit of analysis and 0.83 to 0.93 using the class mean as the unit of analysis. A significant association was found between perceptions of teacher interpersonal behaviour and teacher personality type, with a stronger relationship between teacher self-perception and teacher personality than with students' perceptions of teacher interpersonal behaviour and teacher personality.

Another Australian study using the QTI involved 504 grade 8 students, who wrote the 1993 National Science Competition in six schools in Tasmania (Fisher & Poh, 1997). The study was designed to compare science students' perceptions of teacher-student interpersonal behaviour, as measured by the QTI, student attitudes to science, as measured by Rennie's (1994) *School Science Questionnaire* (SSQ), as cited in Fisher & Poh (1997), and student cognitive outcomes based on end-of-year reports. The study reported Cronbach alpha reliabilities ranging from 0.66 to 0.89 using the student as the unit of analysis, and from 0.83 to 0.95 using the class mean as the unit of analysis. When one-way ANOVAs were calculated, to indicate each scale's ability to discriminate between classes, the eta^2 statistic ranged from 0.14 to 0.27 at the $p<0.01$ significance level. Amongst other findings presented in this study, was the assertion that the quality of teacher interaction, as measured by the QTI, probably had a greater effect on students who did poorly in the Science Competition than on those students who did well.

In a Fisher, Rickards, Goh, and Wong (1997) study the QTI was administered to 720 students in 20 grades 8 and 9 science classes in Singapore and 705 students in 29 grades 8 and 9 classes in Australia, and their teachers. Students completed the 'actual' form of the QTI and teachers completed the 'actual' and 'ideal' form of the QTI. Students also completed a seven-item 'attitude to this class' scale based on the Test of Science-Related Attitudes Instrument, (TOSRA) (Fraser, 1981a). This was a cross-cultural study designed to compare students' perceptions of teacher-student interpersonal behaviour, teachers' perceptions of their actual behaviour and teachers' perceptions of the ideal situation, along with attitude to the subject science. Cronbach alpha reliabilities, for the Singaporean sample, ranged from 0.50 to 0.88 using the student as the unit of analysis and from 0.60 to 0.96 using the class mean as the unit of analysis. For the Australian sample, these values ranged from 0.60 to 0.88 using the student as the unit of analysis and from 0.64 to 0.96 using the class mean as the unit of analysis. The ANOVA eta^2 statistic values indicating each scale's ability to discriminate between classes, at the significance level of $p<0.001$, ranged from 0.13 to 0.52 and from 0.15 to 0.40 for the Singaporean and Australian samples respectively.

The study confirmed the cross-cultural validity of the QTI and highlighted some small, but significant differences, in students' perceptions of teachers in the two countries, on a majority of the eight scales. Australian students perceived their teachers as being more uncertain, dissatisfied and admonishing. Singaporean students perceived their teachers as being stricter. Australian students also perceived they received more responsibility and freedom, than did their Singaporean counterparts, and that their teachers exhibited more helping/friendly, understanding behaviour.

Fisher and Rickards (1997) conducted a study using the QTI to primarily investigate how teacher-student interpersonal behaviour in the science classroom varied with student gender and cultural background. Data were collected from 3,589 students in 173 classrooms in 35 Tasmanian and Western Australian schools. Cronbach alpha reliability figures for the eight QTI scales ranged from 0.63 to 0.88 when the student was used as the unit of analysis and from 0.78 to 0.96 when the class mean was used as the unit of analysis. The ANOVA eta^2 statistic, indicating each scale's ability to discriminate between classes, ranged from 0.22 to 0.35 at the $p<0.001$ significance level. The study found that small, but statistically significant differences did exist in all of the QTI scales, except for the Student Responsibility/Freedom scale, in the way female and male students perceived their teachers. Small but statistically significant differences were also reported between cultural background and student perceptions of teacher-student interpersonal behaviour in two the QTI's eight scales. The two scales were Helping/Friendly and Student Responsibility/Freedom.

In an article published by Fisher, Rickards, and Fraser (1996), they explained how the QTI could be used by science teachers to improve their teacher-student interpersonal behaviour in the classroom. The authors suggested that three forms of the QTI be completed, the student actual, the teacher actual and teacher ideal. Upon collection and analysis of the data, teachers can reflect on classroom practice and modify it to create a more desirable environment from both the student and teacher perspective. Other suggested uses of the analysed data included identification of professional development needs, effects of new curricula or teaching methods and differences in perceptions of teacher interpersonal behaviour by students of different gender and ability levels.

The studies reviewed above have confirmed the QTI as being a reliable and valid instrument for collecting student and teacher quantitative data on teacher interpersonal behaviour. The QTI has been used to collect student perceptions of actual and best teacher, and teacher perceptions of actual and ideal teacher. The instrument has been used in a variety of classroom settings to measure the effect of, and/or associate, student/teacher perceptions of teacher interpersonal behaviour with new curricula, student achievement and attitude, cultural factors, and comparisons between student and teacher perceptions of actual/ideal teacher interpersonal behaviour, to name a few (Brekelmans, Wubbels, & Créton, 1990; Wubbels, 1993; Levy, Wubbels, Brekelmans, & Morganfield, 1994; Fisher & Rickards, 1997; Wubbels, 1993; Fisher, Rickards, Goh, & Wong, 1997). However, the QTI has not been used to measure teacher interpersonal behaviour in science classrooms where students use their own laptop computer during each lesson.

2.5 CONCEPTUAL FRAMEWORK OF CLASSROOM ENVIRONMENT RESEARCH

Research in this area originated, almost simultaneously, approximately three decades ago by Herbert Walberg and Rudolf Moos (Fraser, 1986a, 1989, 1992). Walberg's research stemmed from his need for an improved method of evaluating curriculum innovation, namely the Harvard Physics Project (Anderson & Walberg, 1968; Walberg, 1968; Walberg & Anderson, 1968) while Moos' research stemmed from his quest to develop social climate scales for use in psychiatric hospitals (Moos & Houts, 1968) and correctional institutions (Moos, 1968).

The pioneering work on classroom environment perceptions by Walberg and Moos, plus the research that it initiated, is heavily influenced by the theoretical, conceptual and measurement foundations set by Lewin and Murray, plus the most notable of their followers, Pace and Stern (Fraser, 1994). The work of Walberg, Moos and their followers was also greatly influenced by the prior low-inference, direct observational methods employed in the study of classroom environments (Chavez, 1984).

2.5.1 The Lewinian Formula

Lewin (1938) proposed that the environment and the personal characteristics of the individual, through their interactions, determined human behaviour. Moreover, he proposed a formula which expressed his belief that human behaviour (B) was a function of both the person (P) and the environment (E), that is, $B = f(P,E)$. Lewin proposed this formula to stimulate new human behaviour research strategies (Stern, 1970).

2.5.2 Murray's Needs-Press Model

Murray applied Lewin's theory and conceptualised the dual process of personal needs and environmental press (Moos, 1979b). Murray (1938) defined as 'needs' those specific innate personal requirements of an individual, as well the individual's desire to achieve these, as being determinants of an individual's personality. He defined as 'press' those factors outside the individual (the environment) that either facilitated or impeded the individual's attainment of these personal needs. Murray also recognised that the environment could be perceived by an external observer or by those inhabiting the environment. He used the term *alpha press* to describe the environment as perceived by an external observer and *beta press* to describe the environment as perceived by its milieu inhabitants.

Pace and Stern's (1958) research popularised Murray's needs-press theory and provided one of the first examples of the rigour of high-inference measures of educational environments. Rosenshine (1970) further elucidated the difference between low-inference and high-inference measures, positing that low-inference measures involved an observer, in a classroom, recognising and recording the occurrence of a set of predetermined event/actions/behaviours, while high-inference measures involved a judgement or interpretation as to the extent or degree certain events/actions/behaviours occurred. Obviously, the high-inference measures could best be described by an environment's milieu inhabitants.

Moos (1974) identified three basic types of dimensions that are characteristic of all human environments. One is the Relationship dimension, which assesses the support and involvement of people within the environment along with the nature and intensity of personal relationships within the environment. Another is the Personal Development dimension, which assesses the way personal growth and self-enhancement generally occur, and the third is the System Maintenance and System Change dimension which assesses the nature of the orderliness, responsiveness, expectations and control in the environment.

The scales of the questionnaires developed to assess classroom environment can be classified into one of Moos' three dimensions, and this provides for a convenient framework for the comparison of perceptions of classroom environments assessed using different questionnaires.

2.6 DEVELOPMENT OF EDUCATIONAL ENVIRONMENT PERCEPTION QUESTIONNAIRES

The study of educational environments is commonly divided into two areas, one dealing with the school-level environment and one dealing with the classroom-level environment (Anderson, 1982; Fraser & Rentoul, 1982; Genn, 1984). The two areas developed independently of each other and are generally based on different theoretical and conceptual frameworks. Researchers in each area often have little knowledge of each others' work, despite the many logical linkages between the two areas (Fraser, 1994). Anderson (1982) states that school-level environment research is significantly grounded in the theory, instrumentation and methodology of earlier business organisational climate research. The influence of this business research is evident upon the examination of two commonly used school climate research instruments, specifically, Halpin and Croft's (1963) *Organisational Climate Description Questionnaire* (OCDQ) and Moos' (1981) *Work Environment Scale* (WES). Stern's (1970) *College Characteristic Index* (CCI), although specially designed for the educational setting, also reflects the influence of business research. Recently attempts have been made to bring the two areas together because of the logical linkages between them (Fraser, 1991).

The existence of questionnaires to evaluate institutional-level environments, Pace and Stern's suggestion that questionnaires have potential in predicting personal achievement by assessing the relationship between a student's personal needs and environmental press, and the need for improved evaluation tools by Walberg and Moos, all contributed to the development of classroom environment perception questionnaires.

The Learning Environment Inventory (LEI)

The initial development and validation of the *Learning Environment Inventory* (LEI) occurred in the late 1960s in conjunction with the evaluation and research of a new physics course for high schools, the Harvard Project Physics (Anderson & Walberg, 1974; Walberg, 1976; Fraser, Anderson, & Walberg, 1982). The LEI is an expansion and improvement of the 18-scale *Classroom Climate Questionnaire* developed by Walberg (1968). The selection of the 15 dimensions that were included in the LEI (Fraser & Walberg, 1981) was based on the following concepts. Concepts had to be previously identified as good predictors of learning, concepts had to be relevant to social psychological theory and research, concepts had to have been intuitively judged relevant to the social psychology of the classroom and concepts had to be similar to those found useful in theory and education research.

With seven items per scale, the final version of the LEI contains 105 statements describing typical school classroom environments. Respondents indicated their degree of disagreement or agreement with each statement on a four-point scale ranging form strongly disagree to strongly agree. Scoring direction was reversed for some of the statements.

Fraser, Anderson, and Walberg (1982) stated that the LEI has two distinct uses, assessing student perceptions and gauging class-group perceptions of the classroom learning environment. They further indicated that the individual as the unit of analysis should be used when studying variables such as pupil gender or self-concept, and that the class mean was the appropriate unit of analysis when studying variables such as curriculum or teacher characteristics.

In a 1969 North American study, the LEI was administered to 1,048 students in 64 grades 10 and 11 classes in various subjects. When Cronbach alpha coefficients were calculated to determine scale reliabilities, values ranged from a low of 0.54 to a high of 0.85 using the individual as the unit of analysis. Test-retest reliability, using the individual as the unit of analysis with a 1970 North American sample of 139 students, ranged from 0.43 to 0.73. Each scale's mean correlation with the other scales, using a 1967 North American study of 149 physics classes, was reported to range from 0.08 to 0.40. These results supported the validity and reliability of the LEI, indicating it could be used in confidence in future research studies.

The Classroom Environment Scale (CES)

The *Classroom Environment Scale* (CES) was developed by Edison Trickett and Rudolf Moos (Moos, 1979b) as a consequence of Moos' program of research across a variety of human environments, including hospital wards, military companies and university residences (Moos & Trickett, 1974; Moos, 1974; Trickett & Moos, 1973). The CES was constructed focusing on the psychosocial environment of schools and the conceptualisation that this environment was a dynamic system including teacher behaviour, teacher-student interaction and student-student interaction. The selection of the nine dimensions that were included in the CES (Fraser, 1986b) was guided by the following process. A literature review was conducted of conceptual and empirical literature in educational and organisational psychology, descriptions of classroom environments from popular literature and prior educational research was reviewed, structured interviews were conducted with teachers and students in several contrasting high schools and classrooms were observed in several different schools. In addition, the selection, development and organisation of the dimensions to be evaluated were based on a conceptual framework.

This conceptual framework delineated three sets of variables, Relationship, Personal Growth, and System Maintenance and System Change, and was grounded in the literature on educational and organisational psychology. It reflected the previous work of Moos and Trickett (Moos, 1979b). Moos differentiated Relationship variables as those measuring factors such as friendship, loyalty and support; Personal Development variables as those measuring factors such as self-esteem development and self-enhancement opportunities; and System

Maintenance and System Change variables as those measuring factors such as classroom order, structure and innovation.

The 242 items representing 13 dimensions in the original version of the CES were reduced to 90 items representing nine conceptual dimensions (Fraser, 1994). These final items all discriminated significantly between the perceptions of students in different classes and they all correlated highly to their conceptual dimensions or scale scores. The 90 items have a true-false format and the scoring direction is reversed for approximately half of the items (Moos, 1979b).

A common characteristic of many classroom environment instruments is to have several forms of the one instrument, for example, an 'actual' form, an 'ideal' form or a 'preferred' form. The 'actual' form of the instrument requires students to provide perceptions of the classroom environment they are now in, while the 'ideal' form requires students to provide perceptions of an ideal classroom environment. The 'preferred' form asks for students' perceptions of a preferred classroom environment. Some classroom environment instruments also have teacher versions of the actual, ideal and preferred forms.

Three versions of the CES were developed, the CES R Form which assessed perceptions of an actual classroom environment, the CES I Form which assessed conceptions of an ideal classroom environment and the CES E Form which assessed expectations of a new classroom environment. Moos (1979b) also stated that items in the three forms corresponded to one another and that the forms were scored using identical scoring keys. The CES is most commonly used to assess teachers' and students' perceptions of their own classroom environments.

The validity and reliability of the CES was confirmed by studies in both the United States and Australia. An American study reported by Trickett and Moos (1974) involved 465 students in 22 classrooms completing the actual or real form of the CES. Cronbach alpha reliabilities, using the class mean as the unit of analysis, ranged from 0.67 to 0.86, each scale's mean correlation with the other scales ranged from 0.20 to 0.31 and the ANOVA *eta*^{2} statistic values, indicating each scale's ability to discriminate between classrooms, ranged from 0.21 to 0.48. Test-retest reliabilities, after a six week interval, involving 52 students in four classrooms ranged from 0.72 to 0.90. Fisher and Fraser (1983b, 1983c) reported on an Australian study involving 1,083 students, who completed the actual form of the CES, in 116 junior high school science classes in 33 different schools. Three of the 90 items were omitted from the analysis because they appeared to have low validity. Reported Cronbach alpha reliabilities, using the individual as the unit of analysis, ranged from 0.51 to 0.75, each scale's mean correlation with the other scales ranged from 0.09 to 0.40 and ANOVA *eta*^{2} statistic values, indicating each scale's ability to discriminate between classrooms, ranged from 0.18 to 0.43. The above results confirmed that the CES could confidently be used in future classroom environment studies.

The Science Laboratory Environment Instrument (SLEI)

The *Science Laboratory Environment Instrument* (SLEI) was developed to specifically assess science laboratory classroom environment at the upper secondary and higher education levels where separate laboratory classes exist (Fraser, Giddings, & McRobbie, 1992). Five criteria guided the development of the SLEI. Dimensions considered to be unique in science laboratory classrooms were identified through an extensive literature review. A review of all scales contained in existing classroom environment instruments was undertaken to help with the identification of relevant dimensions. Dimensions chosen provided coverage of Moos' (1974) three general categories of dimensions conceptualising all human environments (Fraser & McRobbie, 1995). Dimension and item salience to teachers and students was ensured through interviewing students and teachers, and their commenting on draft versions of sets of items. Economy of time with regard to answering and scoring of the instrument was ensured by the inclusion of a relatively small number of reliable scales, each containing a small number of items.

The initial version of the SLEI had eight dimensions, or scales, containing a total of 72 items. This initial version was field tested using six sub-samples of upper secondary and six sub-samples of university students in six different countries. Upon data collection and item/factor analyses, the number of scales was reduced to five and the total number of items to 35. The final published version of the SLEI contained five scales and 35 items, with the 35 items being evenly divided amongst the five scales (Fraser & McRobbie, 1995). The items are responded to on a five-point Likert-type scale ranging from almost never to very often. Scoring direction is reversed for approximately half of the items. A class form (measuring a student's perceptions of the class as a whole) and a personal form (measuring a student's perceptions of his/her role within the class) of this instrument exist. Actual and preferred versions of the forms are also available.

SLEI validation statistics that follow are those reported by Fraser and McRobbie (1995) for the class actual form using the student as the unit of analysis. Data for these analyses were collected from 3,727 school students and 1,720 university students in six countries. Reported Cronbach alpha reliabilities, using the class mean as the unit of analysis, ranged from 0.81 to 0.95 for school students and from 0.76 to 0.98 for university students; each scale's mean correlation with the other scales ranged from 0.11 to 0.42 for school students and from 0.19 to 0.28 for university students; ANOVA eta^2 statistic values, indicating each scale's ability to discriminate between classrooms, ranged from 0.19 to 0.23 for school students and from 0.20 to 0.34 for university students. Complete validation and reliability data, for all forms and units of analyses, are available in Fraser, Giddings, and McRobbie (1991). The sample statistics quoted above indicate that the SLEI is a suitable instrument to measure science laboratory classroom environments.

The College and University Classroom Environment Inventory (CUCEI)

The *College and University Classroom Environment Inventory* (CUCEI) was developed in the early 1980s as a response to the lack of a suitable, reliable and practical instrument to measure perceptions of higher education classrooms and the resultant lack of classroom environment research at this level of education (Fraser & Walberg, 1991). The initial development of the CUCEI was guided by four criteria (Fraser, Treagust, Williamson, & Tobin, 1987). Dimension identification was guided by the examination of all dimensions in existing secondary school classroom environment instruments. Dimensions eventually chosen for inclusion had to provide coverage of Moos' (1974) three general categories of dimensions for conceptualising all human environments. Dimension and item salience to students and teachers was ensured through the interviewing of higher education teachers and students, and their commenting on draft versions of sets of items. Economy in answering and processing was ensured by including a small number of scales, with a fairly small number of items per scale.

The trial version of the CUCEI (Fraser & Treagust, 1986; Fraser, Treagust, & Dennis, 1986) contained 12 items per scale and was field tested with a sample of 127 students in ten tutorials or seminars. Data collected were then subjected to item analysis and the number of items was reduced to 49, with the items being evenly divided into seven scales. The final published version of the CUCEI contained seven scales with seven items per scale (Fraser, Treagust, Williamson, & Tobin, 1987). The items are responded to on a four-point scale, with responses ranging from strongly agree to strongly disagree, and approximately half of the items are reverse scored. The CUCEI has four different forms (student actual, student preferred, teacher actual, teacher preferred) and is intended for use in seminar or tutorial-type higher education classes of approximately 30 students.

Detailed validation and reliability statistics can be located in Fraser, Treagust, Williamson, and Tobin (1987). The statistics quoted below are selected from the study quoted and are those reported when the actual form was completed and the individual was used as the unit of analysis. The study sample included 307 students in 30 postgraduate and undergraduate classes in a variety of disciplines in two multi-purpose higher education institutions in Australia and 65 students in four postgraduate and undergraduate education classes in a university in the USA. Reported Cronbach alpha reliabilities ranged from 0.70 to 0.90, each scale's mean correlation with the other scales ranged from 0.34 to 0.47 and ANOVA eta^2 statistic values, indicating each scale's ability to discriminate between classrooms, ranged from 0.32 to 0.47. These sample statistics confirmed that the CUCEI was a valid and reliable instrument that could be used with confidence, to assess classroom environments in higher education classes commonly known as seminars or tutorials.

The My Classroom Inventory (MCI)

The *My Classroom Inventory* (MCI) is a simplified form of the Learning Environment Inventory (LEI). The MCI was developed because children between eight and 12 years old experienced fatigue in answering the LEI's numerous items and the terminology used in many of the items was beyond their comprehension (Fisher & Fraser, 1981; Fraser, Anderson, & Walberg, 1982; Fraser & O'Brien, 1985). The MCI differs from the LEI in four important ways. The LEI's 15 scales were reduced to five in order to reduce student fatigue; the LEI's item wording was simplified to improve readability; the LEI's four-point response format was reduced to a two-point, yes-no format; and the LEI's requirement of recording responses on a response sheet was abandoned in favour of recording responses directly onto the questionnaire sheet.

The original version of the MCI contained 45 items distributed evenly between five scales. Reliabilities of some of these scales proved to be relatively low, thus Fisher and Fraser (1981) undertook an item analysis of data collected from a large student sample with the sole purpose of removing those items that reduced scale reliabilities. The result was a 38-item MCI, with five scales and the number of items per scale varying between six and nine. Fraser, Anderson, and Walberg (1982) reported the following validity and reliability statistics based on a sample of 2,305 students in 100 seventh grade classes in 30 schools in Australia. Cronbach alpha reliabilities, using the individual as the unit of analysis, ranged from 0.62 to 0.78, each scale's mean correlation with the other scales ranged from 0.13 to 0.30 and ANOVA eta^2 statistic values, indicating each scale's ability to discriminate between classrooms, ranged from 0.18 to 0.31. These statistics indicated that the MCI was a valid and reliable instrument that could be used with confidence in measuring perceptions of science classroom environments especially at the elementary school level. This instrument has also proven to be especially useful for use with junior high school students experiencing reading difficulties with the LEI.

The Individualised Classroom Environment Questionnaire (ICEQ)

The Individualised Classroom Environment Questionnaire (ICEQ) was developed to measure those aspects of classroom environments not measured by instruments such as the LEI and CES, but common in classroom settings referred to as individualised, open or inquiry-based (Fraser, 1982; Fraser, 1986b). A study reported by Power and Tisher (1979) evaluating the inquiry-based Australian Science Education Project (ASEP) illustrated some aspects of individualised classrooms not measured by the LEI. Fraser (1980) identified these aspects as being student choice, individual rates of working and involvement in inquiry-based activities, which were design features of the ASEP program.

The initial development of this questionnaire by Rentoul and Fraser (1979) was guided by the criteria that follow. Dimension inclusion was based on extensive literature reviews on individualised/open/inquiry- based classrooms and individualised curriculum materials. Dimension and individual item salience was ensured by extensive interviewing of teachers and secondary school students. Economy in answering and processing was assured by the inclusion of a small number of reliable scales, each containing a fairly small number of items. Final item inclusion was determined by feedback received from selected experts, teachers and junior high school students, including item analysis, after field testing, to determine which items should be removed to enhance scale statistics (Fraser, 1994).

The initial version of the ICEQ long form had five scales with approximately 15 items per scale. After field testing the number of items was reduced to 50 items, evenly distributed across the five scales. The final published version of the ICEQ (Fraser, 1990) retained 50 items evenly distributed across the five scales, of Personalisation, Participation, Independence, Investigation and Differentiation. Fraser (1994), using Moos' scheme of environment classification, classified the Personalisation and Participation scales in the Relationship dimension, the Independence and Investigation scales in the Personal Development dimension and the Differentiation scale in the System Maintenance and System Change dimension. Each item is responded to on a five-point, Likert-type scale ranging from 1 (almost never) to 5 (very often). Scoring is reversed for many of the items. Four forms of the questionnaire exist, two for the measurement of student perceptions of classroom environment and two for the measurement of teacher perceptions of classroom environment. One of the two student perception forms and one of the two teacher perception forms measures actual classroom environment, while the other measures preferred classroom environment.

A short form, of the four questionnaire types, was also constructed (Fraser, 1990). The short form of the ICEQ retained all five scales of the long form along with its balance of positively and negatively scored items within each scale. The short form consists of 25 items evenly divided amongst the five scales.

Validation statistics were obtained for all four long forms of the ICEQ. The sample statistics stated below are for an Australian sample (Fraser, 1986b) of 1,849 grades 7, 8 and 9 students in 150 classes who filled in the 'actual' long form of the ICEQ. Using the individual as the unit of analysis, Cronbach alpha reliabilities ranged from 0.68 to 0.79, each scale's mean correlation with the other scales ranged from 0.07 to 0.28 and ANOVA eta^2 statistic values, indicating each scale's ability to discriminate between classrooms, ranged from 0.21 to 0.43. The statistics were more rigorous when the class was used as the unit of analysis. Validation statistics for all forms of this questionnaire supported its validity and reliability, thus indicating the questionnaire could be used with confidence in classroom environment studies. Detailed reliability and validity statistics for the student actual short form are provided in Chapter 3.

The student actual short form of the ICEQ was the basis for the construction of the Science Classroom Environment Questionnaire (SCES) used in this study. As such, an overview of a sample of studies in which the ICEQ was used to collect quantitative data on student and/or teacher perceptions of science classrooms follows, as further evidence of this instrument's validity and reliability.

Review of Past Studies Using the ICEQ

An exploratory study involving the use of the ICEQ was completed by Rentoul & Fraser (1980), in which they explored the relationships between learning outcomes, classroom individualisation and actual-preferred congruence. Learning outcomes were measured by the administration of one attitudinal and two cognitive test banks, as pretests and posttests, at the beginning and end of the school year. The ICEQ was administered at mid-year. The study sample consisted of 285 students in grades 7 to 9, in 15 junior high school classes, in 15 schools in Sydney. Nine of the classes were science classes and the remainder were social science classes. One of the findings reported was that the Personalisation scale and the Participation scale, both Relationship dimensions in Moos' (1979a) classification scheme, were strongly related to the attitude outcome tested. Other reported findings were that cognitive outcomes were better predicted by actual-preferred (or person-environment fit) interactions and that affective outcomes were better predicted by actual individualisation of the classroom environment. These findings were reported to be similar to those of overseas studies.

Fraser (1980) reported on a study conducted to determine the predictive validity of the ICEQ. A Sydney student sample of 320 students in grades 7 to 9, in 14 science classrooms, was involved in the study. Student outcomes were determined using the seven-scale, Test of Science-Related Attitudes (TOSRA) instrument (Fraser, 1981a), which students responded to at the beginning and the end of a school year. The ICEQ instrument, completed by the students at the mid-year point of that same school year, was used to measure students' perceptions of the classroom environment. Five different methods of data analysis were used to explore the relationship between the end-of-year attitude outcomes and the classroom environment dimensions measured. The predictive validity of student perceptions of classroom environment, as measured by the ICEQ, was solidly supported by the overall results from the five different methods of analyses employed in the study.

Fraser and Butts (1982) report on a study designed to determine the relationship between student perceived levels of classroom individualisation and student science-related attitudes. The sample in this study consisted of 712 grades 7 to 9 science students, in 23 different classes, in eight different Sydney schools. Students' attitudes were measured using the TOSRA (Fraser, 1981a) instrument, which was administered to students at the beginning and end of one school year, and students' perceptions of classroom individualisation were measured using the ICEQ instrument, which was administered at mid-year. Reported Cronbach alpha reliability coefficients, using the student as the unit of analysis, ranged from 0.61 to 0.76 for the ICEQ scales, and each ICEQ scale's mean correlation with the other ICEQ scales, ranged from 0.15 to 0.29. Also reported was the fact that students' perceptions of classroom individualisation, as measured by the ICEQ scales, accounted for a significant amount of increase in the variance of posttest attitude scores. This increase was greater than that attributable to pretest attitude scores and occurred for four of the seven attitude scales.

A study involving 1,083 grades 8 and 9 science students, in 116 classrooms, in 33 different schools in Tasmania, determined the relationships between students' affective and cognitive outcomes and their perceptions of classroom psychosocial environment (Fraser & Fisher, 1982). Affective outcomes were assessed using six of the seven scales found in the TOSRA (Fraser, 1981a) instrument and cognitive outcomes were assessed using three of the nine scales of the Test Of Enquiry Skills (TOES) (Fraser, 1979) instrument. Both instruments were administered as pretests and posttests at the beginning and end of a school year. Classroom environment perceptions were measured using the ICEQ and CES instruments, which were administered at the mid-year point of the same school year. For the ICEQ, using the class mean as the unit of analysis, Cronbach alpha reliabilities ranged from 0.74 to 0.92, each scale's mean correlation with the other scales ranged from 0.16 to 0.36 and ANOVA eta^2 statistic values, indicating each scale's ability to discriminate between classrooms, ranged from 0.20 to 0.40. Six methods of analysis were employed to determine the relationship goals of the study. All six methods yielded consistent support for the existence of overall relationships between students' outcomes and their perceptions of classroom psychosocial environment.

A Fraser, Nash, and Fisher (1983) study explored the relationship between student anxiety and various characteristics of the science classroom, as measured by the ICEQ and CES. Anxiety was measured with a version of Zuckerman's (1960), as cited in Fraser, Nash, and Fisher (1983), *Affect Adjective Checklist*. A total of 2,068 students completed the anxiety instrument. A randomly selected half of the students completed the ICEQ and the other half the CES. The ICEQ randomly selected half, was the sample described in the Fraser and Fisher study above, thus the reliability and validity of the ICEQ instrument has been described. Of the 14 simple correlations possible, between anxiety and the classroom environment instrument scales, nine were found to be significant. With reference to the ICEQ only, anxiety tended to be lower in classrooms perceived to be characterised by greater Personalisation and Participation. When multiple correlation techniques were applied, only the Personalisation scale retained its significance.

Wierstra (1984) and Wierstra, Jörg, and Wubbels (1987) reported on a Dutch study that used mainly items from the two ICEQ scales of 'Investigation' and 'Participation', with some modification, to construct a 20-item classroom learning environment instrument. This instrument consisted of 10 items that measured actual classroom environment and 10 items that measured preferred classroom environment. The study also measured factors such as cognitive achievement, and the affective and attitudinal outcomes of a new physics curriculum (the PLON project) whose main features were context-learning and inquiry-learning by pupils. The study involved nine PLON classes (254 pupils) and six control classes (144 students). The students were 15 to 16 years old, and in their last year of general secondary education, intermediate level. The internal consistency (Cronbach alpha coefficients calculated using the individual student as the unit of analysis) values reported were 0.72 and 0.64 for the actual and preferred learning classroom environment scale respectively. Intra-class correlation, calculated using the general coefficient of Horst (1949), values were calculated to serve as an estimate of class reliability. These values were reported as 0.92 and 0.55 for the actual and preferred scales respectively. Some other findings, based on student perceptions, were that generally PLON classes were characterised by more inquiry-learning, that the more inquiry-based the classroom, the more positive the students' attitude to physics (for both groups), and for the PLON group, the more positive the attitude, the higher the achievement.

Wierstra, Jörg, and Wubbels (1987) also reported on a study, similar to the one above and completed a year later, that involved 1,105 students in 21 PLON curriculum classes and 45 classes using other methods. The student sample involved students from the general secondary intermediate level, general secondary higher level and secondary as preparation for university study level. The classroom learning environment questionnaire was modified to more explicitly differentiate between participation and activity learning, and items about reality learning were added. Students, and teachers, were asked to respond to the resulting 20-item instrument. Students were only asked for their perceptions of the actual classroom environment. Four of the 20 items of the instrument were omitted in the analysis because of their low or ambiguous factor loadings or low contributions to alpha coefficients at the individual level. The resulting Cronbach alpha coefficients ranged from 0.66 to 0.70 using the student as the unit of analysis and 0.80 to 0.86 using the class mean as the unit of analysis, across the three scales of Reality, Participation and Activity Learning.

The above review of a sample of studies completed using the complete ICEQ instrument, or several scales of the instrument in modified form, confirm this instrument's reliability and validity for use in educational research.

The Constructivist Learning Environment Survey (CLES)

The Constructivist Learning Environment Survey (CLES) instrument (Taylor & Fraser, 1991) was developed to help teachers and researchers monitor the development of constructivist approaches to teaching. The instrument had 40 items evenly spread amongst five scales. Studies completed using this instrument (Roth & Roychoudury, 1993, 1994; Watters & Ginns, 1994) have shown the questionnaire to be a valuable instrument in the measurement of learning environment in constructivist-type classrooms, and an analyses of the data collected from a 500 student sample of high school mathematics and science classes found this instrument to be psychometrically sound. An updated version of the CLES, which was strengthened by the incorporation of a critical theory perspective on the socio-cultural framework of classroom environments (Taylor, Fraser, & White, 1994), also featured items testing the same scale arranged in banks, rather than in the traditional cyclic fashion of most previous classroom environment perception questionnaires (Taylor, Fraser, & White, 1994). A refined, economical version of the CLES also has been developed (Taylor, Dawson, & Fraser, 1995; Taylor, Fraser, & Fisher, 1997) which contains only 30 items divided evenly amongst the five scales.

Each scale's mean correlation with the other scales ranged from 0.17 to 0.38 and Cronbach alpha reliabilities ranged from 0.72 to 0.91, in an Australian study involving 494, 13 year old science students.

Other 'special purpose' instruments such as the Geography Classroom Environment Inventory (Teh & Fraser, 1993) and the Computer Classroom Environment Inventory (Maor & Fraser, 1993) have been developed to study specific aspects of classroom environments in specific subjects.

CES, ICEQ and MCI Short Forms

Short forms of the CES, ICEQ and MCI were developed (Fraser, 1982; Fraser & Fisher, 1983) because some researchers expressed a preference for more rapid and economical instruments and because teachers, using these instruments for local/in-house applications, also expressed a desire for instruments that would take less time to administer and score.

The short forms were developed to satisfy three criteria: reduce the number of items per instrument to approximately 25, make the instrument amenable to hand scoring and ensure adequate reliability for uses involving the assessment of class means. (Fraser, 1994).

All three forms were developed mainly by performing several item analyses on data obtained by administering the instruments to large numbers of science students, with particular attention being paid to maximising the internal consistency of each scale and enhancing discriminant validity. Others factors given attention in the development of the short forms were the balance of items positively and negatively scored per scale and the instrument as a whole, and preference was given to items with better face validity.

The short form of the CES contains six of its original nine scales and it has four items per scale. The ICEQ and CES both contain their original five scales and have five items per scale. All items, and space for responding, fit on a single sheet for each instrument thus eliminating the need for a separate response sheet. When all three instruments were administered to a large sample of science classes, the results, for each instrument, supported each scale's internal consistency, discriminant validity, and ability to differentiate between the perceptions of students in different classrooms (Fraser & Fisher, 1986).

Fraser and Fisher (1983) reported validation statistics for both the actual and preferred forms of the ICEQ and CES, and the actual form of the MCI. The ICEQ and CES were administered to a large sample of grades 8 and 9 students and the MCI was administered to a large sample of grade 7 students, in Tasmania, Australia. Statistics quoted below are only for the actual form of all three instruments, using the class mean as the unit of analysis. Correlations obtained between the long and short forms of each environment scale, ranged from 0.84 to 0.97 for the ICEQ, 0.91 to 0.97 for the MCI, and 0.78 to 0.95 for the CES. Reported Cronbach alpha reliability coefficients ranged from 0.69 to 0.85 (short form) and 0.74 to 0.92 (long form) for the ICEQ, from 0.65 to 0.78 (short form) and 0.73 to 0.88 (long form) for the MCI, and from 0.59 to 0.78 (short form) and 0.71 to 0.90 (long form) for the CES. Reported scale mean correlations with other scales ranged from 0.15 to 0.34 (short form) and 0.16 to 0.36 (long form) for the ICEQ, from 0.11 to 0.30 (short form) and 0.13 to 0.30 (long form) for the MCI, and from 0.29 to 0.43 (short form) and 0.29 to 0.42 (long form) for the CES. The above statistics confirmed the predictive validity of the actual short forms of all three instruments and indicated that the short forms could be used with confidence in any classroom environment study where the class mean was to be used as the unit for statistical analyses.

It has been shown that over the past 30 years a variety of classroom environment questionnaires have been developed, some general in nature, some very specific. A meta-analysis completed by Haertel, Walberg, & Haertel (1981) involved 734 correlations based on student perception data collected from 12 investigations of 10 data sets including 17,805 students in 823 different classes in eight subject areas, from four countries. Their findings, amongst others, included consistent enhanced student achievement in classes perceived by students as having greater

Cohesiveness, Satisfaction, Task Difficulty, Formality, Goal Direction, Democracy and Environment, and less Friction, Cliqueness, Apathy, Disorganisation and Favouritism. The findings of another meta-analysis (Fraser, Walberg, Welch, & Hattie, 1987) further support the link between enhanced student achievement and perceived classroom environment.

The review of the numerous instruments developed to measure classroom environment has clearly indicated that this field of study has a strong theoretical grounding and is very well established in educational research. The various instruments have been used to collect students' and teachers' perceptions of their actual classroom environment, their ideal/preferred environment and even their expected environment. In addition, all the instruments have been proven as reliable and valid for collecting student and teacher quantitative data on classroom environments, with most allowing for individual and/or class-based analyses. Initially the various instruments were used mainly to study correlations between perceived classroom environment and student achievement. With time, and the development of new instruments, studies looking into the effects of educational innovations on classroom environment, the effects of various instructional paradigms on classroom environment and the effects of technological innovations on classroom environment became common. However, of all the studies that have been completed using the proven and tested classroom environment questionnaires to determine the effects of computers on science classroom environment, none have been completed in science classrooms where students use their own laptop computer in each lesson.

2.7 AN HISTORIC OVERVIEW OF COMPUTERS IN EDUCATION

2.7.1 Overview of Computer Development and Application in Education

Primitive teaching machines were first invented and utilised by both the Americans and Soviets in the 1920's (Zender, 1975). However, neither group fully exploited the potential of these teaching machines and their potential laid virtually dormant for over three decades. It was not until the late 1950's that the potential of teaching machines (computers) was demonstrated, by the computer industry, when computer companies began using computer-based instruction to train their own personnel (Kulik, Kulik, & Cohen, 1980; Niemiec & Walberg, 1985; Kulik, Kulik, & Shwalb, 1986) and that educators began to exhibit a genuine interest in, and foresee possible benefits of, using computers in the educational process (Kulik, Kulik, & Cohen, 1980; Burns & Bozeman, 1981).

Countries such as France, the United Kingdom, the United States and, to a lesser extent, the Soviet Union all had computer industries and numerous professionals in computer science dating back to the 1950s and early 1960s (Hebenstreit, 1992; Zender, 1975), and it was in these countries that the application of computers in education first occurred to any significant extent. Of the above countries, it appears that the United States led the 'computer revolution in teaching', or at least had its efforts more completely and thoroughly documented than any other country.

The first computers used for educational purposes were huge, expensive mainframe computers locked away in air-conditioned rooms. The PLATO computer developed in the Coordinated Science Laboratory at the University of Illinois in 1960 (Burns & Bozeman, 1981; Alessi & Trollip, 1991) was probably the most publicised of these huge computers. Interaction, if it could be called that, with the computer initially was limited to preparing a set of punched cards that were submitted to the computing centre for entry into the computer. If no errors were made, a print-out was delivered a day or two later (Hebenstreit, 1992). Next it was possible to interact with the computer through a limited number of directly connected print or visual terminals, and eventually on terminals, connected through phone lines, located great distances from the mainframe. However, limited phone ports and heavy demands (time-sharing) still limited access on demand. Instruction was mainly drill and practice or tutorial (Okey, 1985).

With the advent of microcomputers in 1977 (Okey, 1985; Alessi & Trollip, 1985), computer terminals were finally freed of their attachment to a mainframe at some distant location. Cost and size were greatly decreased, while portability and access were greatly increased, so that every school could now own its own computer and enjoy exclusive access. Each microcomputer had its own visual display screen capable of graphic displays, limited only by the operator. Instructional uses expanded to such areas as computer simulations, problem solving and logical thinking exercises (Tinker, 1983).

In the late 1970s and throughout the 1980s, microcomputers (personal computers) became increasingly common in schools and instructional uses diversified to include, for example, diagnostic testing, data bases, algorithmic problem solving, educational games, concept demonstration and development, instructional prescriptions, spread-sheets and electronic mail (Okey, 1985; Hebenstreit, 1992). However, in most schools, the microcomputers were still locked in a room and access had to be planned in advance. Students could not solve problems as they arose, nor could they interact with the computer on demand, in order to view the computer as a 'personal tool', rather than a part of the 'institution' (Hebenstreit, 1992).

The truly portable personal computer, commonly referred to as a notebook or laptop computer, has been the latest development in the permanent tendency, over the past thirty years, to bring the processing power as near as possible to the user (Hebenstreit, 1992). It appears that with the advent of laptop computers the stage was finally set for students to view the computer as a 'personal tool', provided students owned or hired laptops, so as to have immediate access to a computer in each lesson, every day of the week.

2.7.2 A Conceptual Framework Focusing on How the Computer Has Been Used

Computers have been used in a multitude of ways since first being applied to the educational process. The first reported uses were drill and practice or tutorial (Okey, 1985). Other uses such as simulations, word processing, databases, and simple programming (Oliver, 1986) followed, with the most recent uses being interactive video, microworlds, interactive hypermedia, problem solving at a distance using telecommunications and expert tutoring systems (artificial intelligence) (Berger et al., 1994). Taylor (1980) proposed a succinct conceptual framework for classifying all educational computing, based on how the actual hardware, the computer, was used by the learner in the various applications. Taylor's goal was to simplify, for study purposes, this wide variety of uses.

Taylor's (1980) framework consisted of three categories, these being tutor, tool and tutee. When used as a tutor, Taylor believed the computer was programmed by programming 'experts' in a particular subject, and then students were simply tutored, in that particular subject, by the computer executing the program. However, when used as a tool, the computer had some useful capability programmed into it such as word processing or statistical analysis, and students then used the computer to perform mundane calculations or improve presentation. According to Taylor when used as a tutee, students programmed the computer in a language it understood, and 'taught' the computer to perhaps function as a tutor, for others, or perform some algorithmic calculation tasks.

Oliver (1986) explained Taylor's framework in terms of learner control on a continuum ranging from no learner control to total learner control. He posited that when the learner had no control over the computer, the computer was being used as a tutor; however, when the student had total control over the computer, the computer was being used as a tutee. When the computer was being used as a tool, the amount of student control was somewhere between the above two extremes. It follows, that in applications such as demonstration or drill and practice, the computer would be used as a tutor, in applications such as word processing or spreadsheeting, the computer would be used as a tool and that in applications such as hypercard or microworlds, the computer would be used as a tutee.

Okey (1986) preferred to look at the uses of computers in science education, from a teacher's perspective, as 'computer as teacher - for the student', 'computer as tool - for the student', and 'computer as tool - for the teacher'. Okey combined Taylor's (1980) classification of tutor and tutee under the 'computer as teacher - for the student' and introduced the notion of 'tool for teacher'.

Lancy (1987) proposed five models underlying the use of computers in classrooms, they were computer as intelligent tutor, computer as intelligent medium, computer as a tool, computer as a mental gymnasium and computer as activity corner. These five models can all be classified in Taylor's 'tutor/tool/tutee framework' as his description of 'mental gymnasium' allows for the programming of the computer by students.

Whatever the computer application in education, it appears that the 'tutor/tool/tutee' framework is still a valid one, even including today's newest applications. Although not referred to specifically in the remainder of this chapter, it will be helpful to think of the application of computers against Taylor's framework.

2.8 THE FINDINGS OF THE EFFECTS OF COMPUTERS IN EDUCATION/SCHOOLS

2.8.1 Introduction

In the reporting of research on the effects of computer applications in education, it has been more common to have the actual computer application described using such general terms as computer assisted, computer aided, computer augmented, computer administered, computer enhanced, computer managed, computer based and computer simulated.

Acronyms, for the above, such as CAL, CAI, CMI, CML, CSE, CBE, CBI, CEI and CBL (Kulik, Kulik, & Cohen, 1980; Kulik, Kulik, & Bangert-Drowns, 1985; Kulik & Kulik, 1986; Berger et al., 1994) are common in the literature reviewed; however, some of the acronyms have several interpretations, for example, CAI has been used to represent computer-assisted instruction, computer-aided instruction, computer-augmented instruction or computer-administered instruction and CBL has been used to represent computer-based learning or microcomputer-based laboratories.

In the more recent studies reviewed, CBE (computer-based education) appears to have become the most commonly used acronym, describing any educational activity involving the use of computers. CAI is commonly taken to mean computer-assisted instruction, and it is this meaning of CAI that is adopted in this thesis.

Research into the effects of computers in education originated during the late 1960's/early 1970's as a result of the educational application of computers in the early 1960's. Early advocates of computer support in the educational process promised such benefits as "greater student achievement, more efficient use of human and material resources, improved attitudes toward the learning process, and an enhancement of education in general" (Burns & Bozeman, 1981, p. 32). It is no surprise, that Wise and Okey (1983), Okey (1985) and Oliver (1986) state that the earliest studies into the effects of computers in education usually focused on the four factors of achievement, attitudes, time to learn and costs.

It is beyond the scope of this literature review to comment on individual studies conducted into the effects of computer applications in education. This review is limited to reviewing some of the significant 'summaries of studies' that have been conducted from the early mid-1970's onward. The earliest of these studies were descriptive studies, followed by the more quantitative studies applying the meta-analysis techniques pioneered by Glass (1976, 1977) (Berger et al., 1994).

The descriptive studies followed two formats, narrative reviews and box-score reviews. In narrative reviews, a limited number of studies on a particular topic were selected, described and evaluated. Conclusions were then drawn based on these results (Bangert-Drowns, Kulik, & Kulik, 1985). Box-scores reviews on the other hand usually included many more studies, and generally provided a qualitative assessment of the studies under review, in conjunction with a comparison of the number of studies with positive effects, no effects and negative effects (Burns & Bozeman, 1981; Kulik, Kulik, & Bangert-Drowns, 1985).

Meta-analysis reviews are much more quantitative in their approach. Individual studies are located using objective procedures, quantitative or quasi-quantitative techniques are used to describe findings and statistical methods are used to summarise findings and report relationships between study features and outcomes as an effect size (Kulik, Bangert, & Williams, 1983; Bangert-Drowns, Kulik, & Kulik, 1985; Kulik, Kulik, & Shwalb, 1986; Roblyer, Castine, & King, 1988). In these studies, effect sizes were usually calculated by subtracting the mean scores of the experimental and control groups, and dividing the difference by the standard deviation of the control group (Glass, McGaw, & Smith, 1981). Effect sizes of 0.20 or less are considered a small effect, those of 0.50 a medium effect and those of 0.80 or greater a large effect (Cohen, 1977).

2.8.2 Elementary School Findings

Vinsonhaler and Bass' (1972) study is amongst the first of the box-score type reviews conducted on the effects of CAI drill and practice in elementary education, using achievement as the measurement outcome. Their study summarises the results of ten independent studies, involving over 30 separate experiments and over 10,000 subjects in the content areas of language arts and mathematics. The experiments varied in length from three months to ten months and achievement gains were determined using standardised pretests and posttests. For mathematics, a statistically significant gain in achievement, in favour of CAI drill and practice, was reported in a majority of cases and the gains favouring CAI were replicated in most of the independent studies.

A box-score study conducted by Edwards et al. (1975) reviewed studies on different applications of CAI. In these studies, 'CAI as a Supplement to Traditional Instruction' revealed that in all studies CAI supplemented instruction was more effective than normal instruction; 'CAI as a Substitute for Traditional Instruction' revealed that out of six studies, CAI was more effective in two, equally effective in two and indeterminate in two; 'Effectiveness of Different Modes of CAI' revealed that no conclusion could be drawn as to which were the most effective modes; 'Comparison with Other Non-traditional Methods of Instruction' revealed CAI was as effective as programmed instruction and filmstrips; 'Compression of Time' revealed less time was required for similar achievement; 'Retention' revealed material wasn't retained as well; and 'Effectiveness According to Ability' revealed greater effectiveness for lower ability students than either average or high ability students (effectiveness was measured by student achievement as a result of CAI compared with achievement as a result of other forms of instruction).

In an early meta-analysis study, Burns and Bozeman (1981) reviewed 40 studies, which met six pre-established inclusion criteria, of computer-assisted mathematics instruction in elementary and secondary schools where achievement was the outcome variable. The 40 studies yielded 397 drill/practice and 151 tutorial-related effect size measures. Reported effect sizes (*ES*s) for the elementary school studies were 0.35 for drill/practice and 0.43 for tutorial. Other general findings reported were that drill/practice programs were significantly more effective with highly achieving and disadvantaged students than with average students, and that these programs were significantly more effective with intermediate boys. Tutorial programs were found to be significantly more effective among disadvantaged students. Effectiveness was equated with gains in achievement. The researchers ended their report with a caveat that all instructional support systems are influenced by a host of variables, so caution has to be applied when interpreting their findings.

A meta-analysis by Kulik, Kulik, and Bangert-Drowns (1985), conducted on 32 comparative studies of computer-based education in elementary schools, in any subject where computers were used reported significant differences in effect sizes for CAI and CMI (computer-managed instruction) programs. The instructional outcome predominantly measured in the studies was achievement. The average *ES* reported for CMI was 0.07, while the average *ES* reported for CAI was 0.47. Retention results were also provided in five of the CAI studies with a calculated average *ES* of 0.27. One of the CAI studies provided 'attitude toward subject' results in mathematics and its reported *ES* was 0.10. The researchers pointed out that of the studies reviewed, only one examined the effects of a microcomputer-based system. They also suggested one of the areas researchers should examine in the future was that of 'interpersonal outcomes of computer uses in the classroom'.

Niemiec and Walberg's (1985) meta-analysis of the most 'up-to-date' comprehensive reviews of CAI literature at the elementary school level, conducted by the University of Illinois, reviewed the work of 48 separate investigators involving over 200 studies. Their meta-analysis calculated *ES*s for grade levels, achievement, sex, exceptionality, CBI (computer-based instruction) typology, course content, micro or mainframe and year of study. Only relevant *ES*s are reported here. The calculated average *ES* for CMI was 0.03, for CAI drill/practice 0.27, for CAI tutorial 0.34, for mathematics achievement 0.28, for science achievement 0.28, for studies using microcomputers 1.26 and for studies using mainframe computers 0.33. Caution was advised in the interpretation of the *ES* for science and microcomputers as both were based on only two studies.

2.8.3 Secondary School Findings

One of the first box-score reviews supplying data for secondary schools was also that of Edwards et al. (1975) where effectiveness was equated with achievement gains. Amongst their findings for secondary schools, with different applications of CAI, were: 'CAI as a Substitute to Traditional Instruction' revealed that out of six studies, CAI was more effective in four, equally effective in one and indeterminate in one; 'Effectiveness of Different Modes of CAI' revealed that, as at the elementary level, no conclusion could be drawn as to the most effective modes; 'Compression of Time' revealed that, as at the elementary level, less time was required for similar achievement; and 'Retention' revealed that, as at the elementary level, material wasn't retained as well.

In a narrative analysis conducted by Thomas (1979), several dozen studies on CAI were reviewed which examined achievement, attitude, retention, time savings and cost factors. He reported, for CAI students: achievement gains over more traditional methods as most common, including an improvement in attitude toward computers and often toward subject; retention equal to that in traditional instruction; mastery of content in a shortened time period; and that cost associated with CAI instruction appeared to be approaching that of traditional methods.

In the Burns and Bozeman (1981) meta-analysis study described in the elementary school findings, *ES*s for their secondary school sample were 0.24 for drill/practice CAI and 0.52 for tutorial CAI. It appears, based on this study, that drill/practice was slightly more effective, in terms of achievement gains, at the elementary level, but tutorial was more effective at the secondary level.

Kulik, Bangert, and Williams' (1983) meta-analysis, of 51 independent evaluations of computer-based teaching in grades 6 to 12, analysed achievement gains, retention, attitudes and time. In 39 of these studies, CBI students received better examination scores and in 9 of the studies control students received the better scores. The reported average *ES* was 0.32. Five of the studies provided 'retention' data, with four studies favouring CBI and one favouring the control; the average *ES* for retention was 0.17. Ten studies provided 'attitude toward subject matter' data, with eight studies favouring CBI; the average *ES* was 0.12. All four of the studies providing data for 'attitudes toward computers' favoured CBI, with the average *ES* being 0.61. Four other studies provided data for 'attitude toward instruction', with all favouring CBI and an average *ES* of

0.19. Only two studies provided 'time to learn' data, with one reporting a time saving of 39% and the other 88%. The data provided did no allow for an average *ES* calculation. Other interesting findings resulting from this study were that more recent studies reported stronger effects of CBI on student achievement, journal published studies reported stronger effects than did dissertation studies and studies of shorter duration reported stronger effects than studies of longer duration.

Bangert-Drowns, Kulik, and Kulik (1985) conducted a meta-analysis of 42 mainframe computer-based studies occurring between 1968 and 1982, across all subjects, in grades 7 to 12. Computer applications included management, general enrichment, tutorial, drill/practice, programming, simulation, programming with tutorial and simulation with tutorial. For analyses, these computer applications were broken down into the three general areas of CMI (computer-managed instruction), CAI (computer-assisted instruction) and CEI (computer-enhanced instruction). An examination at the end of the instructional period was used to measure achievement and an average *ES* of 0.26 was reported in favour of CBE (computer-based education) students. The reported average *ES*s for the nine CMI, seventeen CAI and sixteen CEI studies were 0.40, 0.36 and 0.07 respectively. The average *ES*s for low aptitude students, average aptitude students and high aptitude students were 0.46, 0.13 and 0.24 respectively. An interesting finding in this study was the fact that CMI had an average *ES* comparable to that of CAI, whereas in elementary reviews the effect of CMI was significantly less than that of CAI.

2.8.4 Combined Elementary/Secondary Findings

Okey (1985) conducted a box-score type analysis of three box score and six meta-analysis research reviews reported between 1972 and early 1985, focusing on four areas of interest: the effectiveness of CBE (computer-based education) in promoting learning, under what conditions CBE had differential effects, whether some forms of CBE were more effective than others and whether any trends in effectiveness of CBE were evident over the years. Five of the studies covered all year levels with one each covering elementary only, secondary only and college only. Five studies covered all subjects, with the remainder covering one or more of mathematics, science or language arts. The conclusions reached were that: CBE was effective in promoting learning; younger children seemed more powerfully affected than older children and low ability children more strongly affected than high ability children; CBE had positive effects in all subject areas; CAI showed a higher impact on achievement than CMI; drill and practice was the most common form of CAI; supplemental CAI appeared to be more effective than replacement CAI; there was a trend to expand computer use to include simulations and problem solving; and microcomputers were becoming more commonly used than mainframe computers and would become dominant in the future.

Roblyer, Castine, and King (1988) adopted two additional criteria to those routinely followed by researchers carrying out a meta-analysis study, in that only studies available after 1980 were included and most were microcomputer based. Thirty-eight studies and reports and 44 dissertations, across all subject areas, were identified as suitable for inclusion in their meta-analysis. Of the studies, 44 were at the elementary level, 22 at the middle/secondary level and 10 at college/adult level. The overall *ES* reported, for achievement, was 0.31, with middle/secondary reporting the lowest (0.19) and college/adult the highest (0.57). When the data were analysed to determine if computer applications were more effective with certain types of content, *ES*s of 0.36, 0.49, 0.26 and 0.35 were reported for mathematics, science, reading/language and cognitive skills respectively. When CBE effectiveness with certain kinds of students was determined, an *ES* of 0.36 was reported for low-achievers and 0.22 for regular-achievers. *ES*s of 0.25, 0.28 and 0.19 were calculated for attitude toward self, school/subject matter, and computer medium respectively.

A meta-analysis conducted by Kulik and Kulik (1991) included the results of 254 studies, covering all subjects and grade levels, focussing on achievement differences between students in CAI and non-CAI classes. Achievement was generally measured by final examinations. The reported *ES* for achievement was 0.30 across the 254 studies. Of the studies, 19 studies examined the effects of CAI on student attitudes towards computers and 34 studies examined the effects of CAI on student attitudes towards the subject being taught. Reported *ES*s were 0.30 and 0.05 respectively.

2.8.5 Science Study Findings

Few meta-analyses evaluating the effects of CBE in science have been completed. However, Aiello and Wolfle's (1980) is one such study where they analysed 115 studies of individualised type instruction in science, in which this method was compared with traditional instruction. Most studies were published between 1970 and 1976, were introductory in nature, were mainly in the subjects of biology, chemistry or physics and were carried out mainly at secondary schools or four year schools. The findings of interest to this research are the only ones reported here. Of the studies reviewed, 11 evaluated CAI in science and the reported *ES*, for effectiveness as measured by achievement gains, was 0.42. Only four of the 11 studies occurred in secondary schools and the reported *ES* for this sample was only 0.08. The *ES* reported for supplementary CAI was 0.65 while that for replacement CAI was only 0.05.

Willett, Yamashita, and Anderson (1983) reported an overall *ES* of 0.13 for CBE on achievement, based on 14 studies. However, the five studies using CAI had an average *ES* of only 0.01 and the eight studies using CMI had a average *ES* of only 0.05. The one study using CSE (computer-simulated experiments) had a calculated *ES* of 1.45, thus producing a strong bias of the overall average in favour of CBE. The meta-analysis covered both elementary and secondary science.

Of the studies reviewed under 'secondary school findings' earlier, several studies reported achievement effect sizes for science as a part of their overall results. The Kulik, Bangert, and Williams (1983) meta-analysis reported an *ES* of 0.31 for the 11 science studies in grades 6 to 12. The Bangert-Drowns, Kulik, and Kulik (1985) study reported an *ES* of 0.13 for the 11 science (physical and biological science) studies included in grades

7 to 12. Roblyer et al.'s (1988) meta-analysis reported an *ES* of 0.49 for the four science studies in secondary schools and colleges. This reported *ES* was increased to 0.64, if the one study using drill/practice CAI was excluded from the other three that used simulations.

Wise (1989) located 26 CBE published science reports, between 1982 and 1988; however, he used much broader criteria on what constituted a CBE science study than did Roblyer et al. (1988). Wise reported an average *ES* of 0.34 for achievement based on 51 studies found in the 26 published findings. Twenty-four studies provided data on microcomputer-based simulations, eleven on videodisk-based lessons, seven on tutorials, six on microcomputer-based labs and three on microcomputer-based diagnostic testing. The reported *ES*s were 0.18, 0.40, 0.45, 0.76 and 0.28 respectively. The *ES*s for grade level were highest for grades 9 to 12, and 5 to 8 at 0.40 and 0.39 respectively, and lowest for grades K - 4 at 0.12. Wise stated that CBE student motivation and interest were higher than that of the control group.

2.8.6 Laptop Study Findings

With the appearance of 'low cost' truly portable personal computers in the late 1980's, schools in Australia and overseas began introducing laptop computers into the classroom. Students were either provided with a class-set of computers which individual students then 'owned' for some predetermined length of time, or a decision was made that the entire school would become a 'laptop school' with the introduction of laptops, initially, at certain year levels. In this latter scenario, schools provided the opportunity for students to purchase or lease a laptop, usually at a reduced price, through contracts schools were able to negotiate with suppliers. Research on the effects of laptop computers in education is a new area of research and, as such, published case studies/reports are few.

It is plausible to believe that if every student in a class had a laptop computer, and the teachers of these students were reasonably computer literate, students would use a high level of information technology in their daily learning. Based on acceptance of this assumption, the ImpacT study completed by Watson (1993), and summarised by and cited in Johnson, Cox, and Watson (1994), is included here, even though the students in the study did not use laptops *per se*.

The ImpacT study compared secondary classes having high access to information technology (IT) with those having low access to IT. For students to be classified as having high access, the teacher was to be experienced in using IT, the teacher had to intend making regular use of computers in the classroom in the particular subject, there was to be a sufficient number of computers in the classroom or there was to be regular access to a networked classroom, there was to be access to a range of appropriate software and a curriculum plan to integrate IT in lessons. Low IT classes, the 'control group', were those where teachers were innovative, good practising teachers who had little or no intention of making substantial use of IT during the two-year period of the study.

The ImpacT study involved 2,300 students from 87 elementary and secondary schools in England and Wales during the two-year period 1989-1991, focussing on the subjects of mathematics, science, geography and English. Data were collected using a range of assessments and methodologies including specially designed 'reasoning in subject' assessments, 'topic specific mini-studies' and a test of IT concepts and skills (secondary sample only). Where possible, data were analysed through a statistical comparison of high IT with low IT classes, otherwise qualitative methods were employed.

In answering the most general of questions, 'Did IT make a contribution to pupils' learning?', the conclusion was 'yes', but with the caveat that a range of factors, not the least being the role of the teacher, made an impact on the achievement of pupils (Johnson et al., 1994), and that the contribution was not consistent across subjects or age groups. Summary results for secondary students in the 'reasoning in science tests' proved inconclusive on favouring high IT classes.

Amongst the positive findings of case study classes were: increased motivation of students; increased concentration by focussing pupils' attention to the task at hand resulting in an increase in the quality of work; increased sustainment of activities with regard to time; increased number of open-ended activities/assignments; increased student pride and presentation of work; and increased understanding of conceptual misunderstandings through interaction with a computing environment. Negative findings included: difficulties in using the software package provided; teacher lack of understanding of the philosophy behind a particular software package and/or the pedagogical implications for effective software use; time constraints due to 'content needed to be covered' as specified by the curriculum; and student inability to work effectively in collaborative surroundings. The report also suggested that, in order for IT to make an impact on student learning, perhaps there exists some minimal threshold of access to IT.

Rowe's (1993) SUNRISE project, which was sponsored by the Queensland Department of Education and the Australian Council for Educational Research, focused on the attitudes, knowledge, abilities and achievements of 56 grade 6 and 59 grade 7 students who worked with their own laptops. The descriptive study took place in Queensland, Australia where students were provided with a laptop for use at school and at home. In-class computer use was reported as drill and practice, tutorial, simulation, microworlds and games. Data were collected and analysed in 1991 when the grade 7 classes were completing their second year of laptop use and the grade 6 classes their first. Data were collected using open-ended interviews, observation, structured tasks, questionnaires containing multiple choice and open-ended questions, case studies and teacher judgments.

Rowe reported that students with above average abilities and knowledge of computers/computing, and with positive attitudes towards computers, used their laptops more effectively as a tool for problem solving, as a tutee for programming and occasionally as a tutor for drill and practice. Conversely, students with opposing characteristics used their laptops mainly as a tutor for drill and practice. Analyses of the attitude data collected, revealed that most students felt laptops were as important as books and were positively inclined towards computers. Students indicated that once they started working with computers it was difficult to stop. A majority of below average ability/achievement students reported using computers as fun. Not having to use pencil and paper, and ease of erasing, was a most common response to the question of what students liked best about using their laptops. Just over half the students indicated there was a greater chance for social interaction when the laptops were in use. Peer tutoring was reported as common, but troublesome if engineered. The most common usage of the laptop at home was homework, followed by typing practise.

Competence in the four 'subject' areas of typing, writing procedures, databases/stories and mathematics was assessed by asking students to indicate if they were doing well or not. A majority of students indicated they believed they were doing well in all subject areas. Students were unanimous in their view that using laptops did not prevent discussing work with peers. It was also found that by the end of 1991, the second year of laptops for the grade 7s, almost half of the students were starting to do things without their laptops. Rowe concluded that 'the novelty had certainly run out'. In addition, there was widespread unhappiness amongst the grade 7s about the prospect of continuing in the project in grade 8; however, the realism of these feelings was not determined. The students simply felt they were missing out on learning and social activities that their non-SUNRISE friends were enjoying.

At Methodist Ladies' College in Melbourne, Australia, a decision was taken in 1989 (Loader, 1993a), after a successful 1989 pilot program where one grade 7 class had access to lots of computers, that the school would become a 'laptop school'. In 1990 all grade 5 students were required to have personal laptop computers. The school negotiated a maintenance and price contract for the supplying of laptops, which allowed for parental purchase or lease of the machines at reduced cost (Dedman, 1993). Staff were offered some financial assistance in purchasing a laptop and funds were made available for appropriate professional development. The grade 5 pilot program was expanded during 1990 and by the end of 1991 there were 15 laptop classes in grades 5, 6 and 7 (Loader, 1993b).

After the first year of laptop use in grade 5, the Junior School Head, using anecdotal evidence, identified the following advantages of each student possessing a laptop computer (Dettman, 1993). Enhanced learning because of computer availability at exact time and place of need; greater exposure, and in a variety of environmental settings, because of portability; greater freedom in classroom arrangements because of laptop unobtrusiveness; and a greater feeling of control by students of their own learning situation.

At the end of 1992, 215 grade 7 students each completed a 45-statement questionnaire designed to assess their views and opinions with regard to using laptop computers. An analysis of these data (McDonald, 1993) revealed that 95% of the students like using their laptop; 86% described learning as fun; 98% felt learning was not easier, but that they had learned new skills; 88% indicated they could now do things that were once impossible; 89% were confident programming had taught them a lot; 89% appreciated its portability; 93% used it for recreational purposes during free time; 81% felt more organised; 90% preferred the appearance of their work completed on the laptop; and 85% preferred using it to pen and paper. On the negative side, 60% complained about the weight of machine and 83% indicated annoyance of being disrupted when the battery ran flat.

Analysis of questions focussing on teachers and teaching styles, revealed that 85% of students described their learning as more independent; 82% felt they were more able to learn at their own pace; 93% felt they were given more responsibility; 95% felt teachers 'trusted' them to work alone on projects; 86% felt they helped each other more in class than last year; and 87% accepted that their teachers were learning about Logo writer with them. However, 89% felt strongly that teachers should know enough to appreciate student work.

McMillan and Honey's (1993) Project PULSE (Pupils Using Laptops in Science and English) involved 25 grade 8 students at a school in New Jersey, USA during the 1991-1992 school year. The students were each supplied with a laptop computer and the timetable was arranged so that these students came together for their science and English lessons daily. The students were encouraged to take their laptops to others classes and use them as they saw fit; however, the study was restricted to the experiences in science and English only. The study was sponsored by a systems and communications company and strongly supported by senior school administration, the school's computer supervisor and the cooperating teachers.

The overall purpose of this study was to "explore the process the teachers and students went through as they appropriated this particular technology and integrated it into a specific set of classroom circumstances" (McMillan & Honey, 1993, p. 3). Data were collected through teacher interviews, classroom observations, samples of project-based work, writing samples and projective tests.

The teacher interviews revealed that the use of laptops developed and refined student writing skills, facilitated and fostered both inquiry and research-based tasks, developed an unexpected intimate telecommunications relationship between students and teachers, and when used as a tool, improved student performance. Classroom observation data were coded along seven dimensions as either positive or negative assessment. The seven dimensions used were 'making things work', 'student collaboration', 'teacher collaboration', 'role of the teacher', 'motivation', 'know-how' and 'expectations'. The most frequently occurring theme was positive 'motivation', followed by positive 'role of the teacher', positive 'know-how' and positive 'making things work'. Within each of the seven dimensions, the dimensions with the highest negative-to-positive ratios (greatest percentage of disagreement within a dimension) were 'making things work', followed by 'role of the teacher', 'know-how' and 'student collaboration'.

Collaborative project-based work in science brought with it unexpected difficulties because for the first time in the students' educational history, they were required to apply inductive reasoning and observation rather than simply produce accurate reports or show mastery of material. Marking these individually produced, collaborative reports, with the above scenario in mind, also presented a totally new challenge for the teacher. In English, writing sample analysis proved somewhat easier; however, frustration was encountered when 'exchange stories' were attempted via the telecommunication system because of technical difficulties plus poor quality work and a lack of follow-up by the 'exchange school'. Writing samples were analysed three times during the year and the mean scores improved from 58.7% to 79% to 81.3% across the three samples. The improvement was attributed to ease of editing and laptop portability, which provided additional flexibility over pen and paper.

The most common use of the telecommunication system was private e-mail. The system was also used for teleconferencing (study-related and personal), posting/receiving special interest group information, posting of classified ads and directory information surveying. PULSE students accounted for approximately two-thirds of the system use, with less than half the class members accounting for the majority of the log-ins. Students were given a projective test to determine what was distinctive about the PULSE system and how it fit into the choices they made about what medium to use to communicate certain information to their teachers. The results indicated that students did perceive the PULSE system as a viable alternative to communicating with the teacher and their choice of using/not using the system, for communicating particular information, was determined upon an assessment of factors such as honesty, self-efficacy, directness and efficiency.

A study, sponsored by the Department of Education for Northern Ireland, into the potential of laptop computers in schools (Gardner et al., 1993) as cited in (Gardner, Morrison, & Jarman, 1993) involved students in nine schools during the 1991-1992 school year. Seven of the schools were secondary schools, one was an elementary school and one was a special education school. Five experimental/control class groups were selected and matched for age, gender and ability. There were 235 students in the experimental group and 191 students in the control group. Students in the experimental group were provided with laptop computers for the school year. The main type of software used was a word processing package, a database and spreadsheet package, a LOGO-like package and a *Sense and Control* package for science. Students were encouraged to use their laptops throughout the curriculum; however, monitoring only occurred in the subjects of mathematics, English and science.

The overall purpose of the study was to evaluate the impact and role of information technology in education, focussing on laptop computers. Two aspects of the study, of interest to this research, were the assessment of the use of laptops on students' learning and the assessment of the use of laptops on students' attitudes to their school and the subjects mathematics, English and science, focussing on science. Data were collected through classroom observations, 'action research' (in particular the use of diaries), interviews, questionnaires and achievement tests.

Performance differences between the experimental and control groups in mathematics, English and science were measured using standardised pretests and posttests approximately eight months apart. An analysis of covariance (ANCOVA), with pretest results as the covariate, was completed to ensure maximum reliability of comparison between pretest and posttest results. The conclusion reached, for the secondary groups, was that the use of laptop computers had no significant effect on students' achievement, in all three subjects. Of the five matched pairs, across the three subjects, only one significant effect ($p<0.05$) was reported and this was for the 'high ability' matched pair in science. It was concluded "that the impact of high access to computers on learning in mathematics, English and science was at best marginal" (Gardner, Morrison, & Jarman, 1993, p. 2).

Students' attitudes toward the three focus subjects were measured by a study specific, 25-item, five-point semantic differential questionnaire, with bipolar statements identified through a careful examination of students' diaries (Morrison et al., 1993). Students completed three copies of this questionnaire, one for each focus subject. A 28-item Likert scale was used to measure students' attitude to school life in general. Student results were analysed in two groups, experimental and control. The results from the two questionnaires were factor analysed, with four factors identified for 'attitude to discipline' and four for 'attitudes to school'. An analysis of variance (ANOVA) was performed on the regressed factor scores arising from the factor analysis of the questionnaire data, leading to following conclusions. The only significant differences between the experimental and control groups, for the attitude to discipline questionnaire, occurred in English for the 'enjoyment' factor, in mathematics for the 'relevance' factor and in science for the 'performance' and 'responsible approach' factors. All were in favour of the experimental group. Of the four 'attitudes to school' factors of 'work in class', 'school', 'security' and 'teachers', the only significant difference recorded between the experimental and control groups, and in favour of the experimental group, was that for the 'work in class' factor. It was concluded "that positive impacts of high access to IT upon the attitudes of pupils was relatively marginal and confined to instances where the pupils' process-based IT work transferred to the content domains in their disciplines" (Morrison et al., 1993, p. 130).

The final laptop study reviewed occurred in the latter part of 1994 and first part of 1995 (Shears 1995). Shears secured the cooperation of a major computer manufacturer, the Australian Council for Educational Research, the Victorian Directorate of School Education and a number of Victorian Independent schools for the project. There were seven independent and three government schools involved in the study. Each school purchased a class set of laptop computers and the students of a selected class, mainly upper elementary/lower secondary, were provided with a laptop for use at school and at home. Each school decided on the time block a particular class would 'own' the computers, how the computers would be used and how the school-based research project would be conducted. Of the schools involved, some already had an operating laptop program while others still considered themselves as relatively deficient in computer hardware and use.

The major objectives of the project were to describe the present position of computer use, the current situation with laptop computer use, possible effective uses of laptops and draw conclusions/principles from the findings. The emphasis was on teachers and schools and their development and implementation of a 'laptop program'. The results were collected in the form of ten case studies, which included experiments and surveys conducted using either a sample of those involved, or by all those involved in the experiment. Responses were sought from students, staff and parents. Factual and/or attitudinal information was also collected and presented in each case study.

Positive points expressed by the students included work became neater and changes were easily made, motivation increased, attitude to homework increased, group became more cohesive, laptops were interactive and provide for independent and discovery learning and increased scope of data searching and holding. On the negative side, students included equipment failure, weakness in touch typing, erosion of 'basic skills', printing time was excessive, incompatibility of laptop with home desktop, games were a strong influence and less time spent reading.

Teachers expressed the positive points as more involvement of students in work, increased presentation quality, effective peer tutoring/student cooperation, portability, enhanced teaching of the subject, broadening of staff horizons resulting in extension of the curriculum, teachers becoming facilitators and mangers rather than presenters, a breakdown of barriers between subjects and the creation of positive changes in the learning environment. On the negative side of the ledger, teachers said they lacked confidence/knowledge, lacked a lot of technical expertise, class control decreased, more disruptions occurred, plagiarism was easier, good software was difficult to locate and was expensive, students read less, teaching methods did not change much and it was difficult to tell if students learned better.

Parents felt that student learning and development improved, that younger siblings with laptop experience were significantly advanced in computer know-how compared to older non-laptop siblings and parents were enthusiastic, supportive and pleased with the outcomes. The only negative points made by parents were cost being a real problem, security concerns and inability to assist students with homework.

This overview of computer use in education/schools has indicated that there is no strong theoretical basis or instrument, with proven validity and reliability, which researchers can use when evaluating the effects of computers on education. It appears that researchers review previous research and then attempt to replicate it, usually with incorporated 'improvements' to meet their particular needs. Narrative, box score and meta-analysis reviews of the numerous studies on the effects of computers in education have been undertaken to find 'common threads' in studies that are similar, or meet certain minimum criteria. It is from these reviews that general conclusions have been drawn about the effects computers have had on education over the past three decades. However, even the results of these reviews were presented with caveats and often did not support each other.

What most early studies had in common was the examination of the effects computers had on student achievement, student attitude, student retention, learning time savings and cost effectiveness. Later studies addressed the areas of effectiveness of different modes of CAI, effectiveness of supplemental CAI compared to replacement CAI, effectiveness of CAI on students with different abilities and effectiveness of CAI compared to CMI. Recent studies completed on the effects of the newest of computer innovations, the laptop, have concentrated on the effect laptops (saturated computer access) have had on student learning and achievement, presentation and quality of work, motivation, learning activities and experiences, students of different abilities, teacher reactions to laptop presence, the teacher's role in the classroom, and physical and social classroom changes. No studies have been reported on the effects of laptop computers on teacher-student interpersonal behaviour or classroom environment in science, or any other subject area.

2.9 SUMMARY

The literature reviewed in this chapter covered three areas, the conceptual framework on which teacher interpersonal relationships research is based, the development of the QTI and an overview of studies completed using the QTI; the conceptual framework on which classroom environment research is based, the development of the various classroom environment questionnaires and an overview of studies completed using the ICEQ; and an historic overview of computers in education, including a general overview of research findings from the late 1960s onward and a review of published laptop studies. Considerable research has been completed in each of the three areas, measuring the effects of a plethora of educational factors on students in classrooms around the world, be they actual effects on the students or student perceptions of effects. Recent research in the field of teacher interpersonal relationships, for example, has indicated that student perceptions of various student-teacher interpersonal behaviours may actually have a greater bearing on student performance, than the actual teacher-student interpersonal behaviours.

None of the research reviewed in these three areas revealed any studies completed where the QTI was used in conjunction with the ICEQ to assess what effect computers have had on students in science classrooms. With a 'new' generation of computers (laptops) being released on the market and increasingly adopted as necessary requisites by schools, a study into the effects of laptop computers on teacher interpersonal relationships and classroom environment in science classrooms is timely. This research will attempt to partially fill this void in the research.

The next chapter reports on all aspects of the methodology used to plan and complete the study. It also provides the rationale for the selection of the instruments used to collect the quantitative data and the reliability and validity data for the QTI and ICEQ. A description of the development of the SCES also appears in the chapter.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The theoretical framework on which both student-teacher interpersonal relationships research and classroom environment research is based was reviewed in Chapter 2, along with instrument development for research use, in each area. A review of studies completed using the QTI and the ICEQ was also included as the QTI, and a modified version of the ICEQ, were the main questionnaires used to collect data for this study. The chapter concluded with an overview of computers in education over the past three decades and a review of published studies on the effects of laptop computers in education.

This chapter begins with a brief overview of the rationale for engaging in this research and the subsequent decision to collect both quantitative and qualitative data, including the rationale for using student perceptual data questionnaires for quantitative data collection. Section 3.3 explains the rationale for the selection of the two major questionnaires, the QTI and ICEQ, as well as the Test of Enquiry Skills (TOES) instrument, as three of its nine scales were used to collect student cognitive achievement data.

In Section 3.4 the development of the Science Classroom Environment Survey (SCES) is explained in detail. Section 3.5 provides detailed reliability and validity data for the economical, short, forms of the QTI and ICEQ, and Section 3.6 gives an overview and a summary of the validation statistics for the TOES, TOSRA and CLES questionnaires, parts of which were used in this research.

In Section 3.7 the selection process used to identify the study sample is reviewed and a description of the final sample is given. Section 3.8 deals with data collection, both quantitative and qualitative, and Section 3.9 describes the process followed to analyse the data, including the units of analyses.

3.2 INITIAL PREPARATION

Upon being first intrigued as to what effects laptop computers would have on the science classroom environment, the learning of science and the teaching of science, the researcher undertook a general 'computers in science education/classroom environment' literature review to determine these effects. This review resulted in two important discoveries. First, there were numerous studies into the effects of computers in science education, but they mainly focussed on student achievement gains, and other factors such as learning efficiency, cost and attitudes. Second, there was a variety of reliable and valid instruments that were routinely utilised to determine the effects of a wide variety of educational innovations on teacher interpersonal relationships and general science classroom environment. Through a more in-depth literature review, and discussions with experts in science classroom environment research, several instruments were identified as being suitable for use in a study that would partially address the void in research identified above.

Moreover, the literature review also indicated that there were various approaches to studying classroom environments, such as the 'objective' approach where observers describe the environment, or the 'subjective' approach where the milieu inhabitants provide perceptions of the environment, or case studies, or ethnographies or naturalistic inquiries (Fraser, 1994). It has been recognised that the 'subjective' approach to human environment research, described as *beta press* by Murray (1938) and *high inference* by Rosenshine (1970), provides a much more psychosocial significance to events in the environment. In classroom environment studies, this dimension is significant in predicting student outcomes. The following five arguments were presented by Fraser and Walberg (1981) in favour of using student perceptual measures, the 'subjective' approach, over direct observation by researchers, the 'objective' approach. One, student paper-and-pencil perceptual measures were far more efficient and economical, two, student perceptual measures were reflections of numerous lessons, three, student perceptual measures formed a 'pool of perceptions', four, since student behaviour is influenced by student perceptions their perceptions were probably of more importance, and five, perceptual measures accounted for considerably more variance in student learning outcomes than did directly observed variables.

Many of the computers in education studies reviewed combined both the 'objective' and 'subjective' type methods described above, and articles by Fraser and Tobin (1991), Fraser (1992), and Fraser and Fisher (1994) describe the desirable aspects of combining quantitative and qualitative techniques in research. For example, these researchers found that the pools of data collected by each method, basically reinforced each other, and often the data of one pool was useful in elucidating the data of the other pool. The above led to this researcher's decision to collect quantitative student perceptual data through the use of questionnaires, and qualitative data, through student and teacher interviews. Furthermore, the researcher's own experience in a science laptop classroom was used to support and enhance the findings of the student perceptual and interview data.

3.3 RESEARCH INSTRUMENT SELECTION

3.3.1 Questionnaire on Teacher Interaction (QTI)

The Questionnaire on Teacher Interaction (QTI) was selected to measure teacher-student interpersonal behaviour because it is most likely the best instrument available and it was specifically designed for that purpose. The 48-item economical version of the QTI, developed in Australia (Wubbels, 1993), was used in this study. Wubbels' validation of this 48-item economical form of the instrument indicated insignificant losses in the reliability of each of the scales in the form, especially if the class mean was used as the unit of analysis.

The 48-item version of the QTI was used in unaltered form, except that students were requested to provide a few personal details on the 'instructions' side of the questionnaire. A copy of this questionnaire, as presented to students, appears as Appendix A.

3.3.2 Individualised Classroom Environment Questionnaire (ICEQ)

The ICEQ was chosen as the instrument for determining the effects of laptop computers on the science classroom environment for two reasons. Firstly, it was generally felt that laptop computers in the science classroom had the potential of creating a much more individualised environment. Whether the laptop was used in the most traditional sense, as a tutor, for drill and practice or tutorial (Okey, 1985); as a tool for doing word processing or spreadsheets (Hebenstreit, 1992); or as a tutee, with simple programming applications such as hypercard or microworlds (Berger et al., 1994), all of these applications involve a considerable degree of student choice, independent rate of task completion and inquiry-based learning activities. These factors were identified by Fraser (1980) as not being tested by classroom environment instruments such as the LEI or CES.

Secondly, a recommended use of the ICEQ is evaluating the effects of educational innovations, and it has been used successfully in evaluating innovations in classroom individualisation (Fraser, 1990). The short form of the student-actual version of the ICEQ was used in this research because student actual perceptions were required and the total time required to complete a total of three questionnaires had to be kept to a minimum.

3.3.3 Test of Enquiry Skills (TOES)

The TOES instrument was designed to test non-content specific inquiry skills of students in grades 7 to 10 (Fraser, 1979), and was thought to be ideal for gathering cognitive information on grades 8 and 9 students attending different schools across Australia. One area of inquiry skills that could be influenced, by the presence of personal laptop computers in the science classroom, is that of information processing and interpretation. The TOES instrument contains a section designed to measure 'interpreting and processing information skills', and three of the four scales present in this section were selected. The three scales selected were 'Scales', 'Charts and Tables' and 'Graphs'. These three scales were used intact as presented in the Test of Enquiry Skills Handbook (Fraser, 1979). This instrument was named the 'Student Cognitive Achievement Measurement Instrument' and is included as Appendix B.

3.4 SCIENCE CLASSROOM ENVIRONMENT SURVEY (SCES) DEVELOPMENT

This questionnaire was developed after an in-depth literature review on classroom environment and computers in education, and discussions with experts in the field of science classroom environment research. It was decided that none of the classroom environment instruments available for research would, if used in their original form, provide the data necessary to meet the goals of this study. Furthermore, Fraser and Tobin (1991) indicated that the construction of a 'study specific' questionnaire, using only scales perceived to be salient for particular study, was an acceptable procedure to follow.

The SCES was developed by adopting the short form of the student-actual version of the ICEQ. The major change made to this form of the ICEQ was that the items were reworded, as necessary, to ensure each one was written in the personal form. For example, items such as, 'Students find out the answers to questions from textbooks rather than from investigations' and 'The teacher is unfriendly to students' were reworded to read, 'I find out the answers to questions from textbooks rather than from investigations' and 'The teacher is unfriendly to me', respectively. This was done to elicit students' perceptions of their own experiences, rather than their perceptions of the class or group experience. That perceptions of persons within the same group are different, was recognised over four decades ago when Stern, Stein, and Bloom (1956) differentiated between *private beta press*, unique individual perceptions, and *consensual beta press*, group perceptions. It was felt the personal form, which elicited unique personal perceptions, would provide a more accurate reflection of the classroom environment for the purposes of this study. A description of the SCES scales used in this study and sample items appear in Table 3.1.

The deficiency of the 'class form' (group perceptions) was highlighted when differences between subgroups within a class were to be explored (Fraser & Tobin, 1991). Fraser and Fisher (1994) pointed out that in studies completed using both the 'class' and the 'personal' form of the SLEI, one of the findings was that students' scores on the class form were systematically more favourable than their scores on the personal form. It appears that students could easily give a much more favourable/unfavourable perception of their environment. For example, a student might find the teacher generally unfriendly to the class, but very friendly towards him/her, and thus record an 'unfriendly' response on a 'class' form. However, the same student would record a 'friendly' response on the 'personal' form, a much more accurate description of that student's perception.

However, the ICEQ did not address some aspects of the classroom environment that were of interest, these being, did the laptop science classroom allow for more student interaction and peer learning/teaching, and were there differences in the way boys and girls were treated in laptop science classrooms compared to non-laptop science classrooms.

Various classroom environment instruments were reviewed to identify scales that could be used to meet the above needs.

Table 3.1
Descriptive Information for SCES Scales

Scale	Description	Sample item
Personalisation	Emphasis on opportunities for individual students to interact with the teacher and on concern for the personal welfare and social growth of the individual	The teacher helps me if I'm having trouble. (+)
Participation	Extent to which students are encouraged to participate rather. than be passive listeners.	I ask the teacher questions. (+)
Independence	Extent to which students are allowed to make decisions and have control over their learning and behaviour.	The teacher decides which students I work with. (-)
Investigation	Emphasis on the skills and processes of inquiry and their use in problem solving and investigation.	I explain the meaning of statements, diagrams and graphs. (+)
Differentiation	Emphasis on the selective treatment of students on the basis of ability, learning style, interests, and rate of working.	I move on to other topics if I work faster than other students. (+)
Negotiation	Emphasis on opportunities for students to explain and justify to other students their newly developing ideas; reflect self-critically on the viability of their own ideas.	Other students ask me to explain my. ideas. (+)

Adapted from Fraser (1990) and Taylor, Dawson, & Fraser (1995)
(-) Reverse scoring for this item

The Constructivist Learning Environment Survey (CLES), reviewed in Chapter 2, (Taylor, Fraser, & White, 1994; Taylor, Dawson, & Fraser, 1995) contains a scale known as the 'Student Negotiation' scale, that addresses the student interaction and peer learning/teaching interest. The rationale for the inclusion of the Student Negotiation scale was that some of the 'tool' uses, and most of the 'tutee' uses of laptop computers in science classrooms would create the opportunity "for students to explain and justify to other students their newly developing ideas, to understand other students' ideas and reflect on their viability and, subsequently, to reflect on the viability of their own ideas" (Taylor, Fraser, & White, 1994, p. 4). The only change necessary for the inclusion of this scale in the SCES, was reducing the number of items in the scale to five, to match it with the other scales in the SCES. The items were already written in the personal form. The term 'Student' was dropped from the name Student Negotiation, and the scale is referred to as the 'Negotiation' scale in the SCES.

The Geography Classroom Environment Inventory (GCEI) (Teh & Fraser, 1993) contained a scale, the Gender Equity scale, that addressed boy/girl treatment in class. However, this scale proved to be of no value in the SCES and this study because of the nature of the final sample in that mainly single gender classes were obtained. This scale was discarded in the data collection phase of the research.

An 'attitude to subject' scale, simply referred to as the Attitude scale, was attached to the SCES. It was adopted from the Test of Science-Related Attitudes (TOSRA) (Fraser, 1981a). As each of the seven scales of the TOSRA has ten items, once again items were omitted so that the scale conformed to the structure of the SCES. The five items included in the Attitude scale were all taken from the 'Enjoyment of Science Lessons' scale of the TOSRA. The selected items were rewritten in the personal form.

The final version of the SCES contains seven scales, and the Attitude scale, each with five items per scale. The seven SCES scales are: Personalisation, Participation, Independence, Investigation, Differentiation, Gender Equity and Negotiation. However, as stated earlier, the Gender Equity scale was eventually discarded. The reason for this is further explained in Section 3.7 of this chapter. The instrument has been designed so that students answer the questions directly on the questionnaire, next to each question. Students respond to each item in the SCES scales, and the Attitude scale, on a five-point, Likert-type scale ranging from 1 (Almost Never) to 5 (Very Often).

The balance of 'positively and negatively' scored items on the short form of the ICEQ was preserved in this questionnaire. The SCES appears as Appendix C.

3.5 RELIABILITY AND VALIDITY OF MAIN QUESTIONNAIRES

3.5.1 The QTI

The theoretical framework on which the QTI was developed and the initial reliability and validity statistics for the instrument, reported by Wubbels, Créton, and Hooymayers (1985), appear in Chapter 2. Since then, the instrument has been used repeatedly in many studies and a new set of statistics have been adopted as the reliability and validity benchmark of this instrument.

Table 3.2
Reliability (Cronbach Alpha Coefficients) for QTI Scales, Student Actual Form, Individual and Class Mean Level Units of Analysis, for American (US), Australian (A) and Dutch (D) Samples of Students

	Student Level			Class Mean Level		
Scale	US	A	D	US	A	D
Leadership	0.80	0.83	0.83	0.94	0.94	0.94
Helping/Friendly	0.88	0.85	0.90	0.95	0.95	0.95
Understanding	0.88	0.82	0.90	0.94	0.94	0.96
Student Respon-sibility/Freedom	0.76	0.68	0.74	0.86	0.80	0.85
Uncertain	0.79	0.78	0.79	0.96	0.92	0.92
Dissatisfied	0.83	0.78	0.86	0.90	0.93	0.92
Admonishing	0.84	0.80	0.81	0.92	0.92	0.90
Strict	0.80	0.72	0.78	0.95	0.90	0.89

n = 1606 US students in 66 classes
n = 792 A students in 46 classes
n = 1105 D students in 66 classes
Source: Wubbels & Levy (1993)

An important feature of a quality classroom research instrument is that each scale within the instrument has high internal consistency. Scale internal consistency requires each item within a scale to measure the same aspect of behaviour every time the instrument is used. Cronbach's (1951) alpha coefficient, using either the student or the class mean as the unit of analysis, is calculated to determine if a scale has sufficient internal consistency for inclusion in an instrument. According to Nunnally (1967), a sufficient scale internal consistency is 0.60, for instruments used in research. The Cronbach alpha coefficients in Table 3.2 are based on the actual form of the QTI completed by students in The Netherlands, the United States and Australia. Cronbach alpha coefficients were calculated using the student and the class mean as the unit of analysis. As expected, the calculated values were higher when using the class mean as the unit of analysis (Haertel, Walberg, & Haertel, 1981), on average about 0.1 of a unit. The internal consistencies of the QTI scales, when used with the Australian sample, were all well above the 0.60 value established by Nunnally (1967).

Table 3.3
Ability to Differentiate Between Classrooms for the QTI Scales for Dutch and Australian Student Samples

	ANOVA Results (*eta*²)	
Scale	Dutch	Australian
Leadership	0.59*	0.33**
Helping/Friendly	0.48*	0.35**
Understanding	0.43*	0.32**
Student Responsibility/Freedom	0.36*	0.26**
Uncertain	0.59*	0.22**
Dissatisfied	0.39*	0.23**
Admonishing	0.39	0.31**
Strict	0.45*	0.23**

*$p<0.01$ **$p<0.001$ n = 1606 Dutch students n = 3994 Australian students
Source: Wubbels & Levy (1991), Fisher, Fraser, & Rickards (1997)

Another important feature of a quality classroom research instrument is its capacity to measure that differences in student perceptions are more a result of class differences than student differences. (Fraser, McRobbie, & Giddings, 1993). One-way analysis of variance (ANOVA), using class membership as the main effect, is commonly applied to determine an instrument's capacity to differentiate between classes. The calculated ANOVA eta^2 statistic represents the proportion of variance of scores accounted for by class membership. Table 3.3 indicates the eta^2 statistic ranged from 0.39 to 0.59 for The Netherlands' benchmark sample and that each scale of the QTI differentiated significantly ($p<0.01$) between students' perceptions in different classrooms. Table 3.3 also indicates that the ANOVA eta^2 statistic, for a very large Australian sample, ranged form 0.22 to 0.35 and that each scale of the QTI differentiated significantly ($p<0.001$) between student perceptions in different classrooms. The Horst's (1949) general coefficient, for intra-class correlations, can also be used to determine an instrument's ability to differentiate between classrooms, with large values indicating instrument strength in this area. Horst values for the QTI reported in a 1987 Wubbels, Créton, Brekelmans, and Hooymayers' study, cited in Wubbels and Levy (1993), were generally all above 0.80, a large intra-class correlation.

A third feature of a quality classroom research instrument, is that each of the instrument's scales measure a different dimension than that measured by any other scale of the instrument. It follows then, that in a quality instrument, each scale of the instrument should have a very small, or negative correlation, with all other scales in the instrument. However, because the eight scales of the QTI are represented by eight sectors arranged in circular fashion, so that one type of teacher behaviour 'fades' into another, it is not unreasonable to expect two adjoining scales to have medium to large positive correlations. Table 3.4 illustrates this was indeed the case for the QTI, with the scales adjacent to each other having the largest positive correlations. For example, the correlation between DC and CD was 0.61 for the student sample and 0.48 for the teacher sample. Conversely, the scales opposite each other had the largest negative correlations. For example, the correlation between DC and SO was -0.72 for both student and teacher samples.

Table 3.4
Correlations Between the Scales of the QTI

Scale	Unit of Analysis	DC	CD	CS	SC	SO	OS	OD	DO
Leadership	Student	1.00	0.61	0.50	-0.12	-0.72	-0.48	-0.33	0.02
(DC)	Teacher	1.00	0.48	0.35	-0.41	-0.72	-0.40	-0.17	0.34
Helping/	Student		1.00	0.86	0.38	-0.34	-0.68	-0.60	-0.42
Friendly (CD)	Teacher		1.00	0.76	0.09	-0.37	-0.47	-0.44	-0.19
Understanding	Student			1.00	0.44	-0.23	-0.69	-0.63	-0.49
(CS)	Teacher			1.00	0.30	-0.15	-0.45	-0.57	-0.29
Student Resp./	Student				1.00	0.34	-0.24	-0.33	-0.48
Freedom (SC)	Teacher				1.00	0.52	-0.08	-0.40	-0.64
Uncertain	Student					1.00	0.44	0.29	-0.03
(SO)	Teacher					1.00	0.49	0.15	-0.19
Dissatisfied	Student						1.00	0.76	0.53
(OS)	Teacher						1.00	0.60	0.44
Admonishing	Student							1.00	0.58
(OD)	Teacher							1.00	0.54
Strict	Student								1.00
(DO)	Teacher								1.00

n = 2407 students and 91 science teachers
Source: Wubbels, Creton, & Hooymayers (1985)

These data confirmed that the QTI is a reliable and valid questionnaire, and could be used with confidence in this study.

3.5.2 The ICEQ

The theoretical framework on which classroom environment instruments were developed and the reasoning behind the development of the ICEQ are provided in Chapter 2. A summary of the reliability and validity statistics for the long form of the student actual version are also provided in that chapter. Since the short form of the student actual version was the basis for the development of the Science Classroom Environment Survey (SCES) used in this study, detailed reliability and validity statistics for the short form of the student-actual version are provided here.

Table 3.5
Internal Consistency (Cronbach Alpha Coefficients), Discriminant Validity (Mean Correlation with other Scales) and Ability to Differentiate Between Classrooms for the ICEQ

Scale	Classroom	Alpha Reliability	Mean Correlation with other Scales	ANOVA (eta^2)
Personalisation	Actual	0.83	0.30	0.29*
Participation	Actual	0.73	0.29	0.21*
Independence	Actual	0.70	0.15	0.28*
Investigation	Actual	0.69	0.34	0.22*
Differentiation	Actual	0.85	0.25	0.39*

*$p<0.001$ n = 116 classrooms Source: Fraser (1990)

As already discussed in Section 3.1, quality classroom research instruments are those whose scales have high internal consistencies, can differentiate strongly between classes and do not measure, to any significant extent, the same dimension of the classroom environment. Table 3.5 provides the reliability and validity statistics for the student-actual short form of the ICEQ and are based on an Australian sample of students. The figures in the table are calculated using the class mean. The internal consistency, differentiation and discriminant validity, of each scale, are all satisfactory indicating this version of the ICEQ can be used with confidence in classroom environment research.

3.5 OVERVIEW AND SUMMARY VALIDATION STATISTICS FOR THE TOES, TOSRA AND CLES

3.6.1 Test of Enquiry Skills (TOES)

The TOES was designed to measure inquiry skills of grades 7 to 10 students studying science and social science (Fraser, 1979), as a result of the early 1970s trend toward inquiry-based, individualised instruction. Because inquiry-based, individualised instruction allowed for students to progress at different rates, often using different content material, this instrument was designed to measure skill achievement, independent of content material. The instrument contains three sections, testing the areas of using reference materials (two scales), interpreting and processing information (four scales) and critical thinking in science (three scales).

The final version of the instrument was administered to a large Australian sample of grades 7 to 10 students and the three main scale statistics of mean, standard deviation and reliability were calculated (see Fraser, 1979 for details). The data collected at each grade level were analysed separately. Means of results, over the nine scales and across grade levels, ranged from 5.3 to 8.2 for scale means (maximum obtainable mean score 9.7), 1.5 to 2.5 for scale standard deviations and 0.59 to 0.72 for scale reliabilities, using the student as the unit of analysis. The scale reliabilities were calculated by Fraser (1979) using the Kuder-Richardson Formula 20 (KR-20). For the three scales used in this study (Scales, Charts and Tables, and Graphs), the means of results, across grade levels, ranged from 5.8 to 9.0 for scale means (maximum obtainable mean score 10.3), 1.5 to 2.7 for scale standard deviations and 0.64 to 0.76 for the scale KR-20 reliabilities.

3.6.2 Test of Science-Related Attitudes (TOSRA)

Fraser (1981a) designed the TOSRA instrument to measure attitude to science, using Klopfer's (1971) six conceptually different categories of classifying attitudinal aims in science, as the basis for developing the seven scales in the instrument. Fraser's rationale for the construction of the TOSRA instrument was the growing consensus amongst educators in Australia and overseas that the achievement of positive science-related attitudes was one of the most important aims of science education.

The final version of the TOSRA instrument was administered to a large Australian sample of grades 7 to 10 students. The data were collected and analysed in grade levels, and Cronbach alpha reliabilities and scale mean correlations were calculated. Results, over the seven scales and across grades levels ranged from 0.80 to 0.84 for the Cronbach alpha reliabilities, and each scale's mean correlation with the other scales ranged from 0.13 to 0.40. For the attitude scale used in this study, Cronbach alpha reliabilities across grade levels ranged form 0.92 to 0.93, and the scale's mean correlation with the other scales ranged from 0.13 to 0.40. A Fraser and Butts (1982) study involving 712 grades 7 to 9 science students, reported Cronbach alpha reliabilities, using class means as the unit of analysis, ranging from 0.62 to 0.91, and each scale's mean correlation with the other scales ranging from 0.23 to 0.43, across the seven scales.

3.6.3 Constructivist Learning Environment Survey (CLES)

The CLES was designed to enable teacher-researchers to monitor their development of constructivist approaches to teaching (Taylor & Fraser, 1991). The 1991 version was strengthened by the incorporation of a critical theory perspective on the socio-cultural framework of classroom environments (Taylor, Fraser, & White, 1994). A refined version (Taylor, Dawson, & Fraser, 1995) containing five scales, with six items per scale, was trialed with an Australian sample of 494, 13 year old science students. The reported Cronbach alpha reliability coefficients, calculated using the class mean as the unit of analysis, ranged from 0.72 to 0.91. The reported reliability for the Student Negotiation scale which was used in this study was 0.89. Each scale's mean correlation with the other scales ranged from 0.17 to 0.38. When the CLES was used in an American study of over 1,600 grades 9 to 12 science students in 120 classes (Dryden & Fraser, 1996 as cited in Taylor, Fraser, & Fisher, 1997), Cronbach alpha reliabilities, using the class mean as the unit of analysis, ranged from 0.64 to 0.95.

3.7 SAMPLE SELECTION AND DESCRIPTION

This study was designed to evaluate the effectiveness of laptop computers in science classrooms in grades 8 and 9 in Australian Independent schools. In the first half of 1994, the names of independent schools using laptop computers were obtained through various school contacts and through contact with major laptop computer suppliers. A list of over 30 independent schools, that used or probably used laptop computers, was compiled as a result of this action. As a control group was required for the study, and it was unknown if each of the schools above had laptop and non-laptop classes, a list of 'non-laptop' schools in the immediate area of each 'laptop' school was also compiled.

In mid-1994, a letter written by the researcher's supervisor introducing the researcher and his research, along with 'An Evaluation of the Use of Laptop Computers in Science Education' questionnaire (Appendix D) was mailed to the principal of each of the 'laptop' and 'non-laptop' schools identified. The questionnaire was designed to determine if laptop computers were used in the science classroom and if they were, at what grade level; if the school was willing to participate in the research; if the school had a minimum of two classes in a grade level; and if the school was willing to participate in some qualitative data collection as well. After two rounds of follow-up phone calls, just over 80% of these questionnaires were returned.

Upon an analysis of the returned questionnaires, 16 laptop schools were identified as willing to participate; however, only 11 of these had science classes using laptops at the grades 8 and 9 levels. Most non-laptop schools indicated they were willing to participate in the research. Ten non-laptop schools were selected on the basis of location and similarity to the laptop schools.

In February, 1995, the school principals of the 11 laptop schools and the 10 selected non-laptop schools were contacted, and a school contact person who the researcher could communicate with directly regarding questionnaire distribution and data collection, was named. Because of staff changes during the 1994/1995 summer break, the number of laptop schools still willing to participate was reduced to ten.

In April, 1995, a questionnaire entitled 'Questionnaire Re: Students to Participate in Research' (Appendix E) was mailed to each school's contact person. The purpose of this questionnaire was to identify the classes that were to participate in the completion of the questionnaires, the number of students per class, whether the students used laptops in science and how each school wished to deal with the 'Permission to Participate in Research' form (Appendix F). This form was designed to comply with the Ethics in Research policy of Curtin University. A copy of the 'Permission to Participate in Research' form was included in this mailing.

As a result of this action, one of the laptop schools decided to withdraw from participating in this research because they felt if a 'Permission to Participate in Research' form had to be signed by a parent, in order for the student to complete the questionnaires, then the research was of a nature that would breach the school's strict confidentiality policy. Direct contact with the school failed to resolve this problem and the school was dropped from the participation list.

Upon receipt and analysis of the 'Questionnaire Re: Students to Participate in Research', it was determined that five of the nine laptop schools could supply both laptop and non-laptop data. To match the laptop and non-laptop data as closely as possible, five non-laptop schools, of the ten written to earlier, were selected to provide the additional non-laptop data. It was ensured the five non-laptop schools were very similar to the four 'laptop only' schools in terms of school population base and location. The remaining five 'non-laptop' schools were written a letter explaining why they were no longer required to participate in this research, but that they would still be mailed an executive summary of the findings, as an indication of appreciation for their willingness to participate in the research.

The final sample consisted of 863 students in 44 classes of grades 8 and 9 science classes in 14 independent schools, in four states, across Australia. Of the 863 students, 433 used laptops in 23 different laptop science classrooms. The non-laptop sample consisted of 430 students in 21 non-laptop science classrooms. The number of classes per school ranged from a high of five classes to a low of two classes. Two of the laptop schools, that had both laptop and non-laptop classes, were approached regarding the collection of qualitative data through interviews with science laptop students and science laptop teachers. Both schools agreed to participate in this data collection exercise.

Of the nine laptop schools in the research sample, seven were single sex schools. It was because of this that the Gender Equity scale, included in the SCES, had to be discarded. This scale was designed to measure equity in classes containing both boys and girls, not equity in different schools.

3.8 DATA COLLECTION

3.8.1 Quantitative Data

In early July, 1995, class sets of the three questionnaires and 'Permission to Participate in Research' forms, along with instructions for the contact person and classroom teacher, were mailed to the contact person in all 14 schools. Each class set was clearly labelled with the teacher's class code and contained the appropriate numbers of each of the three questionnaires.

The questionnaires included in each class set were the QTI to gather student perceptual data on teacher-student interpersonal behaviour, the SCES to gather student perceptual data on classroom environment, including the Attitude scale to collect student attitudinal data, and the Student Cognitive Achievement Measurement Instrument to determine student cognitive achievement in selected inquiry skills.

Schools were requested to have the questionnaires completed by students in one or two classroom sessions, and to have the completed sets of questionnaires returned to the researcher by no later than September. After several phone calls to some schools, all questionnaires were returned by early November. Eight hundred and sixty-three complete, useable sets of responses were returned, 433 from laptop students and 430 from non-laptop students.

3.8.2 Qualitative Data

In late 1995, the two schools that had earlier agreed to qualitative data collection, were contacted requesting researcher access in early 1996; both schools granted access.

In early 1996, the contact persons at both schools were contacted and asked to identify science laptop students who had completed all three questionnaires in 1995, and who would be willing to be interviewed. The contact persons were also asked to identify the teachers who taught the science laptop classes that completed the questionnaires in 1995, and to ask them if they would participate in an interview. Upon dong this, the contact persons also set up an interview schedule that suited the school, teachers and students. Two weeks before the interview date, an appropriate number of 'Permission to Participate in Research' forms were sent to each contact person so that the forms could be distributed to students, signed by parents, and returned to school before the interview date.

In one school, a group of eight students were interviewed during one session. In the other school, two groups of four students were interviewed in two different sessions. In both cases, this was determined by timetable constraints and student availability. The students were interviewed using pre-set questions, with some impromptu questioning to further explore student answers to the pre-set questions. A group of three teachers was interviewed in one school and a group of two teachers in the other school. Student and teacher responses were recorded on audio cassette.

The questions asked to students, explored their feelings about having their own laptops in the science classroom, how they felt the presence of the laptops affected their learning, the classroom environment, teacher interpersonal behaviour, what they mainly used the laptop for in science, and, as some preliminary analysis of the quantitative data was completed, students were asked for their opinions about these results.

Teachers were asked questions that explored their feelings on the effect the laptops had on classroom environment, their own role in the classroom, their teaching style, their confidence, what were the main student uses of the laptop in science, and what they saw as the greatest advantages and disadvantages of laptops in the science classroom. As with the students, the teachers were asked their opinions about the quantitative data. Teachers also were asked what advice they would give a school that was considering the introduction of laptop computers. In answering this, teachers were asked to focus on the use of laptops in science.

The researcher's perceptions and experiences of coping with introduction of laptop computers at a school, and teaching a science laptop class, were also recorded as qualitative data. These perceptions and experiences were thought important as they provided a third strand of information, which could be used to lend further support to the quantitative and/or qualitative interview data collected.

3.9 DATA ANALYSIS

3.9.1 Quantitative Data

Upon receipt of the class sets of student responses from all schools, the responses from each student were examined, and if one part of a student's set of questionnaires was missing, or was unintelligible, then that student's other two questionnaires were removed and no responses were recorded for that student.

Upon completion of this verification process, the student responses were entered, class-by-class, into a PC Microsoft Works Version 4.0 Spreadsheet. Data transfer was checked for errors after the entry of every second class, and a spreadsheet cell check was performed daily as a double check on the data transfer process.

Before the data for each student were entered on the spreadsheet, each student was assigned a reference number which included a student number, school number, class number, teacher number, grade level and laptop or non-laptop user (1 for laptop, 2 for non-laptop).

Responses to the QTI were entered without any transposing necessary. If a student did not provide an answer for a question, a mid-scale response was recorded. For the QTI this was a 2, as responses ranged from 0 (Never) to 4 (Always) on a five-point Likert-type scale. Because the SCES scales, and Attitude scale, contained items which were reversed scored, responses were first transposed for reversed-scored items and then entered into the spreadsheet. A mid-point scale response of 3 was recorded for non-responded to items, as responses ranged from 1 (Almost Never) to 5 (Very Often) on a five-point Likert-type scale for the SCES and Attitude scales.

Cognitive achievement test responses to the 'Student Cognitive Achievement Measurement Instrument' were transposed, for each student, using a '0' for the incorrect answer and a '1' for the correct answer, provided to each question. Any omitted questions were treated as incorrect answers and a '0' was recorded for the response to the question.

Once all the data were entered onto the spreadsheet and the researcher was confident there were no data entry errors, the spreadsheet containing all the data was transferred to SPSS Version 6.1 and class means and standard deviations were calculated for each scale of the QTI and SCES, the Attitude scale and the cognitive achievement test. These calculations were carried out for both the laptop sample and the non-laptop sample.

Scale reliability, differentiation and discriminant validity statistics were carried out, using the individual and class mean as the units of analysis, for all scales of the QTI and SCES, for the laptop sample only. Simple correlation and multiple correlation (standard regression weights) analyses were also completed with each scale of the QTI and SCES and each of the laptop students' outcomes of attitude and cognitive achievement.

3.9.2 Qualitative Data

The qualitative data collected from students and teachers on audio cassette were transcribed using pen and paper. It was later typed and categorised in a form the researcher considered favourable for analysis and interpretation. The researcher's self-reflection was recorded and categorised in the same manner as the interview data. When all quantitative analyses were completed and conclusions drawn, the qualitative data were analysed and interpreted.

3.10 SUMMARY

This chapter has described how this study was initiated and completed. It has provided the rationale for the collection of both quantitative and qualitative data, the rationale for the selection of the quantitative data collection instruments along with their reliability and validity statistics, and it has described the 'development' of the SCES. The chapter also detailed the sample selection and data collection processes. It concluded with a description of the procedures followed to analyse both the quantitative and qualitative data.

About a third of the independent schools identified as using laptop computers agreed to take part in the study. The main reason more schools did not participate was that laptops were not used in grades 8 and 9 science, which was the area of interest in this study. Other schools were already involved in studies and felt another study, albeit different from the one taking place, would be too much to expect from students and teachers.

The next chapter provides the descriptive statistics, using only the laptop sample, to confirm the reliability and validity of the QTI, SCES and the Attitude scale. Scale reliabilities are provided for the three scales of the cognitive achievement instrument.

CHAPTER 4

RELIABILITY AND VALIDATION OF THE QTI AND THE SCES

4.1 INTRODUCTION

As discussed in Chapter 3, a quality multi-scale classroom environment research instrument is one in which each scale has a high internal consistency (high Cronbach alpha coefficients), each scale measures a dimension of the classroom environment not measured by the other scales (low scale correlations), and each scale of the instrument measures differences in students' perceptions that are more a result of between class differences than within class differences (low ANOVA eta^2 coefficients).

However, because of the circumplex nature of the QTI (see section 2.3), the scales adjacent to one another do measure quite similar dimensions of teacher-student interpersonal behaviour, and thus strong scale correlations are expected. The further apart any two scales are on the circumplex model, the weaker their correlations should be, with negative correlations being recorded between scales diametrically opposed on the model.

In this chapter, descriptive statistics are used to confirm the reliability and validity of the QTI, the SCES and the Attitude scale, and the reliability of the cognitive achievement instrument. The data used for the descriptive statistics were those collected from the sample of grades 8 and 9 science students who used laptop computers in the science classroom.

4.2 RELIABILITY AND VALIDITY OF THE INSTRUMENTS

4.2.1 The QTI

Table 4.1 and Table 4.2 report the reliability and validity statistics for the 48-item, student actual version of the QTI. Statistics are reported using the individual student and the class mean as the units of analyses. Scale internal consistency, and scale differentiation are reported in Table 4.1 and scale intercorrelations are reported in Table 4.2.

Table 4.1.
Internal Consistency (Cronbach Alpha Coefficients) and Ability to Differentiate Between Classrooms for the QTI Using Two Units of Analysis

Scale	Unit of Analysis	Alpha Reliability	ANOVA(eta^2)
DC Leadership	Individual	0.87	0.40*
	Class Mean	0.94	
CD Helping/Friendly	Individual	0.88	0.41*
	Class Mean	0.95	
CS Understanding	Individual	0.87	0.36*
	Class Mean	0.97	
SC Student Responsibility/Freedom	Individual	0.59	0.14*
	Class Mean	0.55	
SO Uncertain	Individual	0.77	0.31*
	Class Mean	0.91	
OS Dissatisfied	Individual	0.81	0.31*
	Class Mean	0.94	
OD Admonishing	Individual	0.84	0.44*
	Class Mean	0.93	
DO Strict	Individual	0.80	0.33*
	Class Mean	0.80	

*$p<0.001$ n = 433 students in 23 science laptop classrooms

Scale internal consistencies were confirmed by the calculation of Cronbach (1951) alpha coefficients for each scale. Calculations are reported using the individual student and class mean as the units of analysis, in order to be consistent with previous classroom learning environment research. As expected the alpha coefficients calculated using class means are, on average, about 0.1 of a unit higher than those calculated using the individual as the unit of analysis, except for the Student Responsibility and Freedom scale. For this scale the alpha coefficient value decreases from 0.59 to 0.55 when using the individual and the class mean as the unit of analysis respectively. A similar decrease for this scale was reported, for the student ideal version, in a study by Henderson (1995), with the alpha coefficient value decreasing from 0.70 (individual as unit of analysis) to 0.67 (class mean as unit of analysis). However, because of the low Cronbach alpha coefficients of 0.59 and 0.56 reported for the Student Responsibility and Freedom scale, caution will need to be taken when interpreting findings associated with this scale.

Table 4.1 reveals that the Cronbach alpha coefficient values ranged from 0.59 to 0.88 and 0.55 to 0.97 when the individual student and the class mean were used as the unit of analysis respectively. Wubbels and Levy (1993) reported alpha reliability values ranging from 0.68 to 0.85 and 0.80 to 0.95 when the individual and the class mean were used as the unit of analysis respectively. A recently reported study by Fisher, Fraser, and Rickards (1997) reported alpha coefficient figures ranging from 0.63 to 0.88 when the individual was used as the unit of analysis and from 0.78 to 0.96 when the class mean was used as a unit of analysis respectively. The values obtained in this study confirm that the scales within the QTI are reliable, that either the individual student or class mean can be used as the unit of analysis and that the values obtained are very similar to those obtained in other Australian studies. However, the Cronbach alpha coefficients reported for this study are the first reported reliability statistics for the 48-item student actual form of the QTI, when used in science laptop computer classrooms.

The other characteristic of the QTI that was checked in this study, was each scale's ability of differentiating between the perceptions of students in different classrooms. This was confirmed by calculating one-way

ANOVAs for each scale, using class membership as the main effect. The ANOVA eta^2 statistic calculated for each scale, representing the proportion of variance due to class membership, was significant at the $p<0.001$ level. For the laptop student sample in this study, the eta^2 values ranged from 0.14 to 0.44. These values compare favourably with one of the first Australian studies (Fisher, Henderson, & Fraser, 1995) providing this statistic for the 48-item student actual version (eta^2 values from 0.20 to 0.48, $p<0.001$), and a recent Australian study (Fisher, Fraser, & Rickards, 1997) which also reported this statistic for the 48-item student actual version of the QTI (eta^2 values from 0.22 to 0.35, $p<0.001$). Again, the ANOVA eta^2 statistics reported for this study, are the first reported one-way ANOVA eta^2 statistics for the 48-item student actual form of the QTI, when used in science laptop computer classrooms.

Table 4.2
Correlations Between the Scales of the QTI

Scale	Unit of Analysis	DC	CD	CS	SC	SO	OS	OD	DO
Leadership (DC)	Individual	1.00	0.77	0.81	0.00	-0.65	-0.62	-0.60	-0.20
	Class Mean	1.00	0.86	0.86	-0.14	-0.91	-0.75	-0.69	-0.27
Helping/ Friendly (CD)	Individual		1.00	0.83	0.24	-0.54	-0.69	-0.67	-0.41
	Class Mean		1.00	0.93	0.23	-0.80	-0.88	-0.83	-0.62
Understanding (CS)	Individual			1.00	0.20	-0.54	-0.70	-0.73	-0.43
	Class Mean			1.00	0.19	-0.78	-0.91	-0.91	-0.65
Student Resp./ Freedom (SC)	Individual				1.00	0.24	0.05	-0.04	-0.21
	Class Mean				1.00	0.28	-0.20	-0.25	-0.57
Uncertain (SO)	Individual					1.00	0.63	0.56	0.21
	Class Mean					1.00	0.76	0.69	0.31
Dissatisfied (OS)	Individual						1.00	0.74	0.53
	Class Mean						1.00	0.89	0.69
Admonishing (OD)	Individual							1.00	0.56
	Class Mean							1.00	0.75
Strict (DO)	Individual								1.00
	Class Mean								1.00

n = 433 students in 23 science laptop classrooms

As discussed in the introduction of this chapter, because of the circumplex nature of the QTI, adjacent scales should register the strongest correlations and diametrically opposed scales should register negative correlations. The data in Table 4.2 confirm the circumplex nature of the QTI, as each scale correlates most strongly with one or two adjacent scales, but correlates most weakly with the scale diametrically opposed in the model. A good example of this is illustrated by the Helping/Friendly scale. Using the individual student as the unit of analysis, this scale is most strongly correlated with its adjacent scales of Leadership (0.77) and Understanding (0.83) and it is most weakly correlated with its diametrically opposed scale of Dissatisfied (-0.69). The circumplex nature of the QTI was also demonstrated by Henderson (1995) and Rawnsley (1997).

The Cronbach alpha coefficients and one-way ANOVA eta^2 statistics calculated for the QTI, based on the laptop sample of students in this study, confirm the instrument's reliability and validity for use in classroom research. The correlation data confirm the circumplex nature of this instrument.

4.2.2 The SCES

As the SCES contained the five ICEQ scales of the student-actual short form, and one scale from the CLES instrument, comparisons of the reliability and validity statistics of the SCES scales are made with the corresponding scales in the ICEQ and CLES instruments. The items of the five scales of the ICEQ were rewritten in the personal form, thus the reliability and validity statistics calculated for this study are the first reported for a 'personal form' of the ICEQ, as well as being the first reported for the instrument's use in science laptop computer classrooms.

Table 4.3 reports the three statistics generally used to confirm a classroom environment research instrument's reliability and validity. The statistics are reported using the individual and the class mean as the units of analysis for scale internal consistency and scale mean correlation with other scales. Class membership, as the main effect, is used to determine scale differentiation of students' perceptions between classrooms.

Scale internal consistencies were confirmed by calculating Cronbach (1951) alpha coefficients for each scale. As with the QTI, in order to be consistent with previous research, calculations were done and are reported using both the individual and the class mean as the unit of analysis. As expected, values calculated using the class mean as the unit of analysis are higher than the values calculated using the individual as the unit of analysis, except for the Independence and Investigation scales where the two values are identical.

Table 4.3.
Internal Consistency (Cronbach Alpha Coefficients), Discriminant Validity (Mean Correlation with other Scales) and Ability to Differentiate Between Classrooms for the SCES

Scale	Unit of Analysis	Alpha Reliability	Mean Correlation with other Scales	ANOVA (*eta*²)
Personalisation	Individual	0.81	0.34	0.34**
	Class Mean	0.93	0.45	
Participation	Individual	0.67	0.32	0.15**
	Class Mean	0.80	0.40	
Independence	Individual	0.65	0.08	0.39**
	Class Mean	0.84	0.08	
Investigation	Individual	0.67	0.23	0.11*
	Class Mean	0.73	0.23	
Differentiation	Individual	0.52	0.10	0.19**
	Class Mean	0.77	0.25	
Negotiation	Individual	0.72	0.21	0.11**
	Class Mean	0.87	0.34	

*$p<0.01$ **$p<0.001$ n = 433 students in 23 science laptop classrooms

As recorded in Table 4.3, the Cronbach alpha coefficients ranged from 0.52 to 0.81 and from 0.73 to 0.93 using the individual student and the class mean as the unit of analysis respectively, for the five scales

(Personalisation, Participation, Independence, Investigation, Differentiation) from the ICEQ questionnaire. However, because of the low Cronbach alpha coefficient of 0.52 reported for the Differentiation scale, caution will need to be taken when interpreting findings associated with this scale. Fraser (1990) reported alpha reliabilities ranging from 0.69 to 0.85 using the class mean as the unit of analysis in an Australian study involving the student-actual short form of the ICEQ.

The Cronbach alpha coefficient for the Negotiation scale was 0.72 using the student as the unit of analysis and 0.87 using the class mean as the unit of analysis. Taylor, Dawson, and Fraser (1995) reported an alpha reliability value of 0.89 for this scale using the student as the unit of analysis for an Australian sample. Alpha reliability values of 0.89 and 0.94, using the student and the class mean as the unit of analysis respectively, were reported by Taylor, Fraser, and Fisher (1997) for the Student Negotiation scale when the CLES was used in an American study.

The discriminant validity of the SCES was ensured by calculating the mean correlation of each of the instrument's six scales with the remaining scales. The mean correlation values obtained ranged from 0.08 to 0.34 using the individual student as the unit of analysis and from 0.08 to 0.45 using the class mean as the unit of analysis. Fraser (1990) reported mean correlation values for the ICEQ's five scales, using the class mean as the unit of analysis, ranging from 0.15 to 0.34. When a scale intercorrelation matrix (which provides a measure of the extent to which scores of each scale are independent of those of the other scales) was calculated for each of the scales in the CLES instrument, the Student Negotiation scale result (ranging from 0.27 to 0.38) indicated a satisfactory degree of independence in relation to the CLES's other scales (Taylor, Dawson, & Fraser, 1995). The values reported for this study are similar to those reported by Fraser et al., and indicate that each of the six scales in the SCES do measure distinct classroom environment aspects, even though there is some overlap between scales. Although the correlations reported for the SCES were not completed between the same scales, or the same number of scales as present in the ICEQ and the CLES, comparisons are justified in order to provide some notion of replicability of each scale's mean correlation with the other scales in the instrument.

The other characteristic of the SCES that was confirmed in this study, was each scale's ability of differentiating between the perceptions of students in different classrooms. This was confirmed by calculating one-way ANOVAs for each scale as described previously. The ANOVA eta^2 statistic calculated for each scale was significant at the $p<0.01$ level for the six scales. For the laptop student sample in this study, the eta^2 values ranged from 0.11 to 0.39. Fraser (1990) reported ANOVA eta^2 values ranging from 0.21 to 0.39 for the five ICEQ scales at the $p<0.001$ level. No ANOVA eta^2 statistics have been reported for the scales of the CLES instrument, thus a comparison of this statistic for the SCES Negotiation scale is not possible. The eta^2 statistics calculated compare very favourably with those reported for the student-actual short form of the ICEQ, and indicate that the SCES's scales do differentiate significantly between students' perceptions of classroom environment in different classes.

The reliability and validity of the SCES, for use in classroom research, are confirmed based on the reliability and validity statistics calculated for the instrument using the laptop student sample of this study. The calculated reliability and validity statistics are very similar to those quoted for several previously competed studies using the ICEQ and CLES.

4.2.3 The Attitude Scale

The reliability and validity of the Attitude scale, in terms of the scale's internal consistency (Cronbach alpha coefficient) and ability to differentiate between students' perceptions in different classrooms, (ANOVA eta^2) were calculated. The alpha coefficients calculated were 0.88 and 0.96, using the individual student and the class mean as the unit of analysis respectively. Fraser (1981b) reported alpha reliabilities, for this scale in the TOSRA instrument, ranging from 0.92 to 0.93 across four year levels, using the class mean as the unit of analysis. In another study using the TOSRA, Fraser and Butts (1982) reported an alpha reliability of 0.91 for this particular attitude scale using the class mean as the unit of analysis.

The Attitude scale's ability to differentiate between students' perceptions in different classrooms was confirmed by the calculation of the one-way ANOVA eta^2 statistic. The obtained value of 0.27, at $p<0.001$, indicated that students in the same class are likely to have similar attitudes. The reliability and validity statistics for the Attitude scale, based on this study sample, confirmed it could be used with confidence for classroom research purposes.

4.2.4 The Student Cognitive Achievement Measurement Instrument

Cronbach alpha coefficients, for the three scales of Scales, Charts and Tables, and Graphs, used in this study, ranged from 0.64 to 0.86 using the individual as the unit of analysis and from 0.63 to 0.94 using the class mean as the unit of analysis. These values compare favourably with the reliability values for these three scales, using the KR-20 formula, of 0.64 to 0.76 reported by Fraser (1979) using the student as the unit of analysis. The reliability statistics, based on this sample, confirmed that the three scales could be used confidently in classroom environment research to measure student cognitive achievement in science.

4.3 SUMMARY

This chapter presented the reliability and validity statistics for the QTI, the SCES and the Attitude scale, and the reliability statistics for the Student Cognitive Achievement Measurement Instrument. The statistics were calculated using the data collected from 433 grades 8 and 9 students in 23 science laptop computer classrooms. The reliability and validity of the two instruments, the Attitude scale and the student cognitive achievement instrument were confirmed, indicating that all four could be used with confidence in future studies of this nature.

The QTI has not been used previously in classrooms where students use their own laptop computer in science. Therefore, the reliability and validation statistics presented here, lend further support to this instrument's robustness in measuring the effects of a variety of educational innovations on teacher-student interpersonal behaviour in the science classroom.

A similar comment, to the one made above regarding the QTI, can be made regarding the student-actual short form of the ICEQ, as it was the main component of the SCES instrument used in this study. In addition to this, the items of the ICEQ were rewritten from the traditional 'class form' into the more recently accepted 'personal form'. As such, the reliability and validation statistics presented for the SCES, are the first such data for a personal form of the student-actual short form of the ICEQ.

The next chapter of this thesis presents the findings based on the analyses of the quantitative data collected. The analyses explore laptop students' perceptions of teacher-student interpersonal behaviour and classroom environment, differences of laptop and non-laptop students' perceptions of these two areas, associations between laptop students' perceptions of teacher-student interpersonal behaviour and science classroom environment and both outcome areas, and differences in both outcome areas between laptop and non-laptop science students.

CHAPTER 5

THE QUANTITATIVE FINDINGS - ASSOCIATIONS BETWEEN MAJOR INSTRUMENTS AND ATTITUDE/ACHIEVEMENT

5.1 INTRODUCTION

This chapter reports on the analysis and findings of the quantitative data collected in this study. First the quantitative data collected indicated what laptop students' perceptions are of teacher-student interpersonal behaviour and science classroom environment. Second, it showed the differences in perceptions between laptop and non-laptop students, of teacher-student interpersonal behaviour and science classroom environment. Third associations between the laptop students' outcomes and their perceptions of both teacher-student interpersonal behaviour and science classroom environment are reported. Fourth, any differences between the student outcomes of attitude to science and cognitive achievement due to students using laptop computers in the science classrooms are determined.

5.2 LAPTOP STUDENTS' PERCEPTIONS OF TEACHER-STUDENT INTERPERSONAL BEHAVIOUR AND CLASSROOM ENVIRONMENT IN THE SCIENCE CLASSROOM

One of the objectives of this study was to examine the perceptions of teacher-student interpersonal behaviour and classroom environment, as perceived by grades 8 and 9 students, in science classrooms where the students use their own laptop computers. As discussed in previous chapters, such perceptions have not been examined in science, even though it was suggested over a decade ago, that one of the areas researchers examine in the future was that of "interpersonal outcomes of computer uses in the classroom" (Kulik, Kulik, & Bangert-Drowns, 1985,

p. 72). The authors do not explain their meaning of interpersonal outcomes; however, it can be assumed that it is either teacher-student or student-student, and if it is the former, then this is the first reported study, for science classrooms where laptop computers are used, exploring an area recommended for study over a decade ago.

Table 5.1
Scale Means and Standard Deviations for the Laptop Study Sample for the QTI Scales

		Laptop Study Group	
Scale	Unit of Analysis	Scale Mean	Standard Deviation
Leadership	Individual	2.73	0.89
	Class Mean	2.71	0.56
Helping/Friendly	Individual	2.67	1.00
	Class Mean	2.67	0.64
Understanding	Individual	2.72	0.92
	Class Mean	2.71	0.56
Student Responsibility/Freedom	Individual	1.66	0.64
	Class Mean	1.66	0.25
Uncertain	Individual	1.01	0.82
	Class Mean	1.04	0.45
Dissatisfied	Individual	1.14	0.89
	Class Mean	1.17	0.49
Admonishing	Individual	1.51	0.99
	Class Mean	1.56	0.68
Strict	Individual	1.95	0.74
	Class Mean	1.94	0.43

n = 433 students in 23 classes max = 4 min = 0

The Australian version of the QTI, as described in Chapter 3, was used to determine student perceptions of teacher-student interpersonal behaviour. Items in each of the QTI's eight scales were responded to on a five-point scale (from 0 to 4) and the scale means appear in Table 5.1. The scale means for each scale reveal that laptop science students perceived their teachers as strongest on leadership behaviour, followed closely by understanding and then helping/friendly behaviour, using either unit of analysis. The students perceived their teachers exhibiting least uncertain behaviour, with slightly more dissatisfied and admonishing behaviour.

Table 5.2
Scale Means and Standard Deviations for the Laptop Study Sample for the SCES Scales

		Laptop Study Group	
Scale	Unit of Analysis	Scale Mean	Standard Deviation
Personalisation	Individual	3.26	0.85
	Class Mean	3.27	0.50
Participation	Individual	3.45	0.71
	Class Mean	3.46	0.27
Independence	Individual	3.58	0.77
	Class Mean	3.57	0.49
Investigation	Individual	2.89	0.71
	Class Mean	2.88	0.23
Differentiation	Individual	1.99	0.65
	Class Mean	1.97	0.29
Negotiation	Individual	3.02	0.72
	Class Mean	3.04	0.25

n = 433 students in 23 classes max = 5 min = 1

These results are very similar to other reported science students' perceptions of teacher-student interpersonal behaviour reported in other science classroom studies, (eg., Henderson, 1995; Fisher & Rickards, 1997), except for the following difference. Whereas science students in the other studies perceived their teachers as exhibiting the greatest amount of helping/friendly behaviour, the laptop science students perceived their teachers as exhibiting the greatest amount of leadership behaviour (notice what's happening, lead, organise, give orders, set tasks, determine procedure, structure the classroom situation, explain, hold the attention); however, differences between the groups is minimal. Perceptions of the laptop sample in this study is compared with a non-laptop sample in section 5.3 of this chapter.

Laptop students' perceptions of science classroom environment were determined using the SCES. Items in each of the SCES's six scales were responded to on a five-point scale (from 1 to 5) and the scale means appear in Table 5.2. The scale means indicate that laptop students perceived their science classroom environment as being characterised most strongly by the factors measured by the Independence scale, followed by the scales of Participation, Personalisation, Negotiation, Investigation and Differentiation, at both the individual and class mean unit of analysis. Caution is advised in the interpretation of the results associated with the Differentiation scale because of this scale's low internal consistency reported in Chapter 4.

Using the class mean as the unit of analysis, Fraser (1990) reported that students in 116 science classrooms, at the grades 8 and 9 levels, perceived their classroom environment as being characterised most strongly by those factors measured by the Participation scale, followed by the scales of Personalisation, Independence, Investigation and Differentiation. The most striking difference in this comparison, is that laptop students perceive their science classroom environment as being characterised most strongly by independence (extent to which students are allowed to make decisions and have control over their own learning and behaviour), while the students in Fraser's study perceived their science classroom to be characterised most strongly by participation (extent to which students are encouraged to participate rather than be passive listeners). Comparisons between the laptop and non-laptop samples, in this study, are discussed in section 5.3 of this chapter.

5.3 DIFFERENCES IN LAPTOP AND NON-LAPTOP STUDENTS' PERCEPTIONS OF TEACHER-STUDENT INTERPERSONAL BEHAVIOUR AND CLASSROOM ENVIRONMENT

One of the major objectives of this study was to ascertain what differences, if any, laptop computers have had on students' perceptions of teacher-student interpersonal behaviour, and the classroom environment, in science classrooms. These differences were explored in two ways. The first involved determining if the differences between the scale means, of student perceptions, for the laptop and non-laptop groups were statistically significant. The second involved calculating effect sizes for each of the scales, to indicate the degree and direction of effect, laptop computers have had on students' perceptions on each scale of the two instruments. Effect sizes provide a more unrestricted representation of the impact laptop computers have had on students' perceptions, as they show the size of the effect, without the caveat of whether the calculated statistic is significant or not. Often non-significant statistical data is ignored, for this simple reason alone, and the reported findings of the study are not as rich as a consequence.

The difference in scale means, for each scale, was calculated by subtracting the non-laptop mean from the laptop mean for each scale. Therefore, a positive difference indicates that the scale mean for the laptop group was higher than the scale mean for the non-laptop group, for that particular scale, based on students' perceptions. A similar procedure was employed in the calculation of effect sizes, where the non-laptop mean was subtracted from the laptop mean and the difference was divided by the pooled standard deviation for that scale, Cohen's *d* (1969). Thus a calculated positive effect size, indicates that laptop computers had a positive effect on the factors measured by that particular scale, and vice versa.

5.3.1 Laptop/Non-laptop Differences of Students' Perceptions of Teacher-Student Interpersonal Behaviour

The differences in scale means between laptop and non-laptop students' perceptions, for the QTI scales, are reported in Table 5.3.

Table 5.3
Scale Means and Standard Deviations for Laptop and Non-laptop Samples for the QTI Scales

		Scale Mean			Standard Deviation	
Scale	Unit of Analysis	Laptop	Non-laptop	Difference[a]	Laptop	Non-laptop
Leadership	Individual	2.73	2.87	-0.14**	0.89	0.71
	Class Mean	2.71	2.86	-0.15	0.56	0.38
Helping/Friendly	Individual	2.67	2.83	-0.16*	1.00	0.95
	Class Mean	2.67	2.82	-0.15	0.64	0.61
Understanding	Individual	2.72	2.83	-0.11	0.92	0.86
	Class Mean	2.71	2.80	-0.09	0.56	0.50
Student Responsibility/Freedom	Individual	1.66	1.55	0.11*	0.64	0.66
	Class Mean	1.66	1.56	0.10	0.25	0.35
Uncertain	Individual	1.01	0.84	0.17**	0.82	0.72
	Class Mean	1.04	0.87	0.17	0.45	0.35
Dissatisfied	Individual	1.14	1.08	0.06	0.89	0.86
	Class Mean	1.17	1.10	0.07	0.49	0.44
Admonishing	Individual	1.51	1.48	0.03	0.99	0.90
	Class Mean	1.56	1.54	0.02	0.68	0.54
Strict	Individual	1.95	1.96	-0.01	0.74	0.75
	Class Mean	1.94	1.98	-0.04	0.43	0.47

* $p<0.05$ n = 433 in 23 laptop classrooms
**$p<0.01$ n = 430 in 21 non-laptop classrooms

[a] difference was calculated by subtracting the non-laptop scale mean from the laptop scale mean

An examination of the differences of scales means indicates that the laptop group scale means were lower than the non-laptop group scale means on four of the eight QTI scales, these being Leadership, Helping/Friendly, Understanding and Strict. Of these, only the differences for the Leadership and Helping/Friendly scales were statistically significant, both at the student unit of analysis. For the remaining four scales of Student Responsibility/Freedom, Uncertain, Dissatisfied and Admonishing, where the laptop group had the higher scale means, the differences were only significant for the Student Responsibility/Freedom and Uncertain scales, again only at the individual student unit of analysis. No significant scale mean differences occurred when using the class mean as the unit of analysis.

The magnitude of the significant differences, whether positive or negative, are not large. However, the differences do indicate that at least to some extent laptop students, compared with non-laptop students, perceive their science teachers as exhibiting more uncertain and student responsibility/freedom behaviour and less leadership and helping/friendly behaviour. Possible reasons for these differences in perceptions are explored in Chapter 6.

Table 5.4 indicates the magnitude and direction of effect, the daily use of personal laptop computers have had, on science students' perceptions of teacher-student interpersonal behaviour as measured by the QTI scales. An examination of the 'direction' (positive or negative) of effect size, indicates that laptop computers have had a positive effect on science students' perceptions on those factors measured by the scales of Student Responsibility/Freedom, Uncertain, Dissatisfied and Admonishing teacher-student interpersonal behaviour, and a negative effect on those factors measured by the scales of Leadership, Helping/Friendly, Understanding and Strict.

Table 5.4
Effect Sizes (ES) for Laptop Computers on Teacher-Student Interpersonal Behaviour as Measured by the QTI Scales in Science Classrooms

Scale	Unit of Analysis	Effect Size - *ES*[a]
Leadership	Individual	-0.17
	Class Mean	-0.31
Helping/Friendly	Individual	-0.16
	Class Mean	-0.24
Understanding	Individual	-0.12
	Class Mean	-0.17
Student Responsibility/ Freedom	Individual	0.17
	Class Mean	0.33
Uncertain	Individual	0.22
	Class Mean	0.42
Dissatisfied	Individual	0.07
	Class Mean	0.15
Admonishing	Individual	0.03
	Class Mean	0.03
Strict	Individual	-0.01
	Class Mean	-0.09

[a] *ES* was calculated by subtracting the non-laptop mean from the laptop mean and dividing the difference by the pooled standard deviation, Cohen's *d* (1969)

Interpretations on the magnitude of effect size, are based on Cohen's (1977) operational definitions of 0.20, 0.50 and 0.80 as being small, medium and large effect sizes respectively. Examination of effect size data in Table 5.4 reveals that, at the individual student unit of analysis, the effect sizes were in the 'small' category for all scales except the Dissatisfied, Admonishing and Strict scales where the effect sizes were considerably less than the small operational definition of 0.20. At the class mean unit of analysis, the effect sizes for the scales of Leadership, Student Responsibility/Freedom and Uncertain approach the 'medium' category, while the effect sizes for the scales of Helping/Friendly, Understanding and Dissatisfied are small.

This analysis indicates that, at the individual student unit of analysis, laptop computers in science classrooms have a small, positive effect on students' perceptions of teacher-student interpersonal behaviour on those factors measured by the Student Responsibility/Freedom and Uncertain scales. The effect is also small, but negative on those factors measured by the scales of Leadership and Helping/Friendly. The effects, at the class mean unit of analysis, are similar to the individual student unit of analysis, except that effects are considerably stronger for the Leadership, Student Responsibility/Freedom, Uncertain, Dissatisfied and Strict scales.

A comparison of findings, using the two methods of analysing the differences of laptop and non-laptop students' perceptions of teacher-student interpersonal behaviour, discloses that effect size calculations provide a more complete picture of the findings. The 'effect size' method confirms the findings of the 'statistical significance' method, at the individual student unit of analysis. In addition, this method of analysis indicates that the laptops had an even greater effect on students' perceptions, at the class mean unit of analysis, for the three scales of Leadership, Student Responsibility/Freedom and Uncertain.

5.3.2 Laptop/Non-laptop Differences of Students' Perceptions of Science Classroom Environment

An examination of scale mean differences for the SCES scales, calculated by subtracting the non-laptop students' perceptions from the laptop students' perceptions, indicates that all laptop scale means are higher than the non-laptop scale means, except for two scales, both at the individual student unit of analysis. The two scales are the Personalisation and the Participation scales. The results, in Table 5.5, indicate that the magnitude of the differences, whether positive or negative, are quite negligible, ranging from 0.00 to 0.07 for all scales except one.

Table 5.5
Scale Means and Standard Deviations for Laptop and Non-laptop Samples for the SCES Scales

Scale	Unit of Analysis	Scale Mean: Laptop	Scale Mean: Non-laptop	Difference[a]	Standard Deviation: Laptop	Standard Deviation: Non-laptop
Personalisation	Individual	3.26	3.28	-0.02	0.85	0.80
	Class Mean	3.27	3.26	0.01	0.50	0.40
Participation	Individual	3.45	3.48	-0.03	0.71	0.66
	Class Mean	3.46	3.46	0.00	0.27	0.23
Independence	Individual	3.58	3.57	0.01	0.77	0.72
	Class Mean	3.57	3.50	0.07	0.49	0.44
Investigation	Individual	2.89	2.82	0.07	0.71	0.71
	Class Mean	2.88	2.83	0.05	0.23	0.28
Differentiation	Individual	1.99	1.83	0.16*	0.65	0.62
	Class Mean	1.97	1.85	0.12	0.29	0.24
Negotiation	Individual	3.02	3.00	0.02	0.72	0.69
	Class Mean	3.04	3.00	0.04	0.25	0.23

*$p<0.01$

n = 433 in 23 science laptop classrooms
n = 430 in 21 science non-laptop classrooms

[a] difference was calculated by subtracting the non-laptop scale mean from the laptop scale mean

Of all the scale mean differences, at both units of analysis, only one is statistically significant, this being the scale mean difference calculated for the Differentiation scale using the individual student as the unit of analysis. As such, laptop and non-laptop students perceive their science classroom environments in very similar ways, except laptop students feel their classrooms are characterised by a greater emphasis on the selective treatment of students on the basis of ability, learning style, interests and rate of working, those factors measured by the Differentiation scale.

Looking at effect sizes, by first examining their direction, Table 5.6 indicates that the effects laptop computers have had on science students' perceptions of their classroom environment, have all been positive, except for the scales of Personalisation and Participation at the individual student unit of analysis. At this unit of analysis, the magnitude of the effect sizes is very small, except for the Differentiation scale which has a reported effect size of 0.25. The effect sizes for the scales of Independence, Investigation, Differentiation and Negotiation, at the class mean unit of analysis, are small except for the Differentiation scale where the value of 0.45 approaches the medium definition of 0.50.

Table 5.6
Effect Sizes (ES) for Laptop Computers on Classroom Environment as Measured by the SCES Scales in Science Classrooms

Scale	Unit of Analysis	Effect Size - *ES*[a]
Personalisation	Individual	-0.02
	Class Mean	0.02
Participation	Individual	-0.04
	Class Mean	0.00
Independence	Individual	0.01
	Class Mean	0.15
Investigation	Individual	0.10
	Class Mean	0.20
Differentiation	Individual	0.25
	Class Mean	0.45
Negotiation	Individual	0.03
	Class Mean	0.17

[a] *ES* was calculated by subtracting the non-laptop mean from the laptop mean and dividing the difference by the pooled standard deviation, Cohen's *d* (1969)

This analysis reveals that laptop computers have had an overall positive effect on students' perceptions of the science classroom environment, especially at the class mean level of analysis. At this level of analysis laptop computers have a very small, to small, positive effect on students' perceptions of science classroom environment on those factors measured by the scales of Independence, Investigation and Negotiation. The effect rises to near medium for those factors measured by the Differentiation scale. It is also for this scale, at the individual unit of analysis, that a small, positive effect is also evident. As indicated in section 5.2 of this chapter, caution is advised in the interpretation of the results with respect to the Differentiation scale.

Greater effect sizes at the class mean unit of analysis likely indicate a greater perceived effect between classrooms, than between individuals in a classroom. Logically, this should be the case, as students' perceptions of effects between classrooms are influenced by different teachers in the classrooms.

Based on the positive effect sizes calculated in Table 5.6, using the class mean as the unit of analysis, laptop students perceive their science classrooms as places where they enjoy more decision making, more control over their own learning, more skill and process inquiry learning, more selective treatment on the basis of personal study characteristics, and more opportunities to explain/justify their ideas to other students and understand/reflect on other students ideas, than do their non-laptop counterparts in their science classroom.

Again, as for the QTI analysis, the effect size calculations confirmed the 'statistical significance' findings, and provided a more complete picture of the effects laptop computers have on students' perceptions of science classroom environment. There were effects at the class mean unit of analysis, and the effects were even stronger, and across more scales, than at the individual student unit of analysis, indicating that as classes, students perceived greater effects due to laptops than they did as individuals. The significance of scale mean differences did not allow for the drawing of these observations.

5.4 ASSOCIATIONS BETWEEN LAPTOP STUDENT OUTCOMES AND TEACHER-STUDENT INTERPERSONAL BEHAVIOUR, AND SCIENCE CLASSROOM ENVIRONMENT

The associations between students' perceptions of teacher-student interpersonal behaviour and students' attitudinal and cognitive achievement outcomes, and students' perceptions of science classroom environment and their attitudinal and cognitive achievement outcomes, were investigated by analysing the data using both simple and multiple correlations. The simple correlation (r) describes the bivariate association between a selected outcome and each scale of the instrument, the QTI and SCES in this study. The multiple correlation, as expressed by the standardised regression weight (β), describes the multivariate association between an outcome and particular scale, when all other scales are controlled. The latter test provides a more conservative indication of outcome-scale correlation.

5.4.1 Outcomes Associations with Teacher-Student Interpersonal Behaviour

Students' perceptions of teacher-student interpersonal behaviour were measured using the 48-item student-actual form of the QTI. Attitudinal outcomes were determined using the five-item 'Attitude' scale and students' cognitive achievement was assessed administering the three-scale Student Cognitive Achievement Measurement Instrument. Details of the methods employed to assess student outcomes appear in Chapter 3.

Examination of the simple correlation results in Table 5.7 discloses that of the 16 possible relationships between teacher-student interpersonal behaviour and the outcome variables of attitude and achievement, 14 are statistically significant ($p<0.05$). This is 17 times that expected by chance alone. However, a similar examination of the multiple correlation (β) weights reveals that out of the 16 possible relationships only four relationships are statistically significant ($p<0.05$). This is still five times that expected by chance alone. Both multiple correlation (*R*) statistics, between the set of QTI scales and each of the outcomes, are statistically significant.

Table 5.7
Associations Between QTI Scales and Laptop Students' Attitudinal and Cognitive Achievement Outcomes and in Terms of Simple Correlations (r) and Standardised Regression Coefficients (ß)

	Strength of Classroom Environment - Outcome Association			
	Attitudinal		Achievement	
Scale	*r*	*ß*	*r*	*ß*
Leadership	0.57***	0.25**	0.23***	0.04
Helping/Friendly	0.58***	0.24**	0.19***	-0.07
Understanding	0.56***	0.02	0.22***	0.06
Student Responsibility/ Freedom	0.05	-0.02	-0.08	-0.03
Uncertain	-0.41***	0.03	-0.30***	-0.22**
Dissatisfied	-0.51***	-0.08	-0.27***	-0.11
Admonishing	-0.51***	-0.14*	-0.21***	0.07
Strict	-0.27***	0.00	-0.17***	-0.10
Multiple Correlation, *R*		0.63***		0.33***
R^2 Coefficient		0.40		0.11

*$p<0.05$ **$p<0.01$ ***$p<0.001$ n = 433

Attitudinal Outcome Associations

The simple correlation (*r*) data in Table 5.7 indicate that all associations between students' attitudinal outcomes and the QTI scales are quite large and statistically significant, except for the Student Responsibility/ Freedom scale. The data also indicate that of the significant associations, the associations for the scales of Leadership, Helping/Friendly and Understanding are positive, while those for the scales of Uncertain, Dissatisfied, Admonishing and Strict are negative. These findings suggest that positive students' attitudes to science are promoted in science laptop classrooms where students perceive teacher-student interpersonal behaviour as being strong on leadership, helping/friendly and understanding behaviour. On the other hand, students' attitudes to science decrease in science laptop classrooms where students perceive teacher-student interpersonal behaviour as being strong on uncertain, dissatisfied, admonishing and strict behaviour.

The multiple correlation (R) statistic at 0.63 ($p<0.001$), suggests that there is a strong association between students' perceptions of teacher-student interpersonal behaviour in science laptop classrooms, as measured by the QTI, and students' attitude to science. The R^2 statistic indicates that 40% of the variance in students' attitude to science in science laptop classrooms is explained by students' perceptions of teacher-student interpersonal behaviour.

When an examination, like that completed for the simple correlations, is completed looking at the standard regression weights (β) (correlations between the attitudinal outcome and each QTI scale when all other QTI scales were controlled) it is evident that only three of the seven scales retain their statistical significance. Of these, the associations for the Leadership and Helping/Friendly scales are positive associations and the association for the Admonishing scale is a negative association. This more conservative analysis suggests that of the teacher behaviours earlier identified as promoting positive students' attitude to science in science laptop classrooms, it is the leadership and helping/friendly teacher behaviours that are most influential. This analysis also suggests that of the teacher behaviours identified as having a negative effect on students' attitude to science, it is the admonishing type of behaviour that is most influential.

Cognitive Achievement Outcome Associations

In relation to cognitive achievement, the following observations are noted in Table 5.7. The simple correlation (r) data reveals that seven of the eight scales are statistically, significantly correlated with the cognitive achievement outcome, with the Student Responsibility/Freedom scale being the exception. All of the statistically significant correlations are small at best. Of the significantly correlated scales, the scales of Leadership, Helping/Friendly and Understanding are positively correlated while the scales of Uncertain, Dissatisfied, Admonishing and Strict are negatively correlated. These data suggest that students' cognitive achievement is higher in science laptop classrooms where students' perceive their teachers exhibiting more leadership, helping/friendly and understanding behaviour. Conversely, students' cognitive achievement is lower when students perceive their teachers exhibiting more uncertain, dissatisfied, admonishing and strict behaviour in science laptop classrooms.

At 0.33 ($p<0.001$) the multiple correlation (R) statistic indicates that there is an association between laptop students' perceptions of teacher-student interpersonal behaviour in science classrooms, as measured by the QTI, and students' cognitive achievement. The R^2 statistic indicates that 11% of the variance in students' cognitive achievement can be explained by students' perceptions of teacher-student interpersonal behaviour.

An examination of the standard regression weights (β), indicates that only one of the seven scales retains its statistical significance. The scale is the Uncertain scale which has a negative correlation. This suggests it is the perception of teacher uncertain behaviour that is most influential in having a negative effect on student cognitive achievement.

The data in Table 5.7 indicate that of the two student outcomes of attitude and cognitive achievement, the strength of the association between laptop students' attitudinal outcomes and their perceptions of teacher-student interpersonal behaviour is nearly twice that between laptop students' cognitive achievement outcomes and their perceptions of teacher-student interpersonal behaviour, based on the multiple correlation (R) statistic. The R^2 statistic indicates that the variance in laptop students' attitudinal scores, as explained by students' perceptions of teacher-student interpersonal behaviour, is approximately four times that for laptop students' cognitive achievement outcome variance explained by students' perceptions of teacher-student interpersonal behaviour.

5.4.2 Outcomes Associations with Science Classroom Environment

Chapter 3 provides a description of the collection of laptop students' outcomes data and their perceptions of science laptop classroom environment. The statistical methods deployed to investigate associations between students' perceptions of their science classroom environment and their attitudinal and cognitive achievement outcomes, are described in section 5.3. The results of the analyses of the associations are presented in Table 5.8.

Table 5.8
Associations Between SCES Scales and Laptop Students' Attitudinal and Cognitive Achievement Outcomes in Terms of Simple Correlations (r) and Standardised Regression Coefficients (ß)

	Strength of Classroom Environment - Outcome Association			
	Attitudinal		Achievement	
Scale	*r*	*ß*	*r*	*ß*
Personalisation	0.65**	0.52**	0.22**	0.12
Participation	0.47**	0.01	0.19**	0.08
Independence	0.11*	0.02	0.13*	0.08
Investigation	0.47**	0.24**	0.05	-0.02
Differentiation	-0.10*	-0.02	-0.26**	-0.22**
Negotiation	0.33**	0.07	0.08	0.01
Multiple Correlation, *R*		0.69**		0.33**
R^2 Coefficient		0.48		0.11

*$p<0.05$ **$p<0.001$ n = 433 (laptops)

An examination of the simple correlation (*r*) results in Table 5.8 indicates that of the 12 possible relationships between science classroom environment and the outcome variables of attitude and achievement, 10 are statistically significant ($p<0.05$). This is over 16 times that expected by chance alone. However, a similar examination of the multiple correlation beta weights (β) reveals that only three of the 12 possible relationships, between science classroom environment and the variables of attitude and achievement, are statistically significant ($p<0.05$). This is still five times that expected by chance alone. Both multiple correlation (R) statistics, between the set of SCES scales and each of the outcomes, are statistically significant.

Attitudinal Outcome Associations

The simple correlation (r) data in Table 5.8 indicate that all the associations between students' attitudinal outcomes and the SCES scales are statistically significant. The associations for the scales of Personalisation, Participation and Investigation are quite large, while the association for the Negotiation scale is somewhat smaller. The associations for the Independence and Differentiation scales are small. All of the associations are positive, except for the Differentiation scale. These findings suggest that positive student attitudes to science are promoted in science laptop classrooms where students perceive the science classroom as being characterised by personalisation, participation, independence, investigation and negotiation. In contrast, student attitudes to science decrease in science laptop classrooms where students perceive the science classroom as being characterised by differentiation, an "emphasis on the selective treatment of students on the basis of ability, learning style, interests, and the rate of working" (Fraser, 1990, p. 5). As noted earlier, this is a small association, and because of this scale's low internal consistency, caution must be taken in the interpretation of the findings associated with it.

The multiple correlation (R) statistic, 0.69 ($p<0.001$), suggests that the association between students' perceptions of classroom environment in science laptop classrooms, as measured by the SCES, and students' attitude to science is a strong one. Furthermore, the R^2 value indicates that

48% of the variance in students' attitude to science is explained by students' perceptions of classroom environment in science laptop classrooms.

An examination of the associations between students' attitudinal outcomes and their perceptions of science classroom environment, but focussing on the more conservative standard regression weights (*ß*) data, indicates that only two of the six scales retain their statistical significance. Both of the scales, Personalisation and Investigation, are positively correlated with attitude. This more conservative analysis suggests that of the science laptop classroom characteristics earlier identified as promoting positive laptop student attitudes to science, it is the classroom characteristics of personalisation and investigation that are most influential.

Cognitive Achievement Outcome Associations

Another examination of the simple correlations (*r*) data presented in Table 5.8 indicates that four of the six correlations between students' cognitive achievement and the SCES scales are statistically significant. Of the four scales, the Personalisation, Participation, and Independence scales are positively correlated and the Differentiation scale is negatively correlated. The correlation values can generally be described as small. These data suggest that laptop students' cognitive achievement is higher in science laptop classrooms where students' perceive the classroom as being characterised by personalisation, participation and independence. Students' cognitive achievement is decreased in science laptop classrooms where students' perceive the classroom as being characterised by differentiation.

The multiple correlation (*R*) statistic value of 0.33 ($p<0.001$) indicates that there is an association between science classroom environment, as measured by all the SCES scales, and laptop student cognitive achievement. Moreover, the R^2 statistic indicates that 11% of the variance in laptop students' cognitive achievement can be attributed to students' perceptions of their classroom environment.

Achievement outcome association standard regression weights (β) data in Table 5.8 indicate that only one scale retains its statistical significance. This is the negatively associated Differentiation scale. This statistic suggests that of the classroom characteristics that promote higher student cognitive achievement, all are equally influential. The only classroom characteristic that promotes poor student achievement is increased differentiation. However, it needs to be acknowledged that the reliability of this scale is somewhat lower than desired.

The Table 5.8 data indicate that of the two student outcomes of attitude and cognitive achievement, the strength of the association between students' attitudinal outcomes and students' perceptions of classroom environment in science laptop classrooms is just over twice as strong as that between students' cognitive achievement outcomes and their perceptions of classroom environment in science laptop classrooms, based on the multiple correlation (R) statistic. The percentage of variance in students' attitudinal scores, as explained by students' perceptions of science laptop classroom environment, is over four times that, as shown by the R^2 statistic, for students' cognitive achievement and their perceptions of science laptop classroom environment.

5.5 DIFFERENCES IN STUDENTS' ATTITUDINAL AND COGNITIVE ACHIEVEMENT OUTCOMES IN LAPTOP AND NON-LAPTOP SCIENCE CLASSROOMS

Another of the major objectives of this study was to determine if there were any differences in students' attitudinal and cognitive achievement outcomes between students in laptop science classrooms and students in non-laptop science classrooms at the grades 8 and 9 levels. The existence of any significant differences was explored by determining if the differences between the mean scores, in each of the two outcome areas, were statistically significant. Effect sizes were also calculated to allow for a confirmation of any differences and a convenient means of indicating the effect laptop computers had on the two student outcome areas of attitude and cognitive achievement.

Table 5.9
Scale Means and Standard Deviations for the Attitudinal and Cognitive Achievement Student Outcomes for Laptop and Non-laptop Students

Student Outcomes	Unit of Analysis	Scale Mean			Standard Deviation	
		Laptop	Non-laptop	Difference[a]	Laptop	Non-laptop
Attitude	Individual	3.38	3.29	0.09	0.99	0.88
	Class Mean	3.36	3.29	0.07	0.52	0.38
Cognitive Achievement	Individual	23.86	24.21	-0.35	5.63	4.85
	Class Mean	23.78	23.90	-0.12	2.26	2.10

n = 433 in 23 laptop classrooms n = 430 in 21 non-laptop classrooms

[a] difference was calculated by subtracting the non-laptop scale mean from the laptop scale mean

5.5.1 Comparison of Attitudinal Outcomes in Laptop and Non-laptop Classrooms

Table 5.9 reports the differences in scale means between the laptop and non-laptop student groups for the student outcome of attitude to science. The difference at both the individual student and class mean unit of analysis is positive, indicating that students' attitude to science is higher in laptop science classes than in non-laptop science classes However, neither of the differences are statistically significant suggesting that although the relationship is positive in nature, it is not possible to indicate that laptop computers actually do have a positive effect on students' attitude to science.

The effect sizes in Table 5.10 indicate that laptops do have a positive effect on students' attitude to science. The magnitude of the effect size data indicates that the effect of laptops on students' attitude to science is very small at the individual student unit of analysis and small, at best, at the class mean unit of analysis. The effect size data verify that laptop computers appear to have positive effects on students' attitudes to science, but that the effects are small.

Table 5.10
Effect Sizes (ES) for Laptop Computers on Attitudinal and Cognitive Achievement Outcomes

Scale	Unit of Analysis	Effect Size - *ES*[a]
Attitude	Individual	0.10
	Class Mean	0.22
Cognitive Achievement	Individual	-0.07
	Class Mean	-0.06

[a] *ES* was calculated by subtracting the non-laptop mean from the laptop mean and dividing the difference by the pooled standard deviation, Cohen's *d* (1969)

5.5.2 Comparison of Cognitive Achievement Outcomes in Laptop and Non-laptop Classrooms

The data in Table 5.9 indicate that student cognitive achievement was higher in non-laptop classes that in laptop classes, at both the individual student and class mean unit of analysis. However, as with the earlier analysis of the attitude outcome, neither of the differences are statistically significant, indicating that it cannot be concluded that laptop computers have a negative effect on students' cognitive achievement outcomes.

An examination of the effect sizes for the cognitive achievement outcome in Table 5.10, also reveals that with either unit of analyses the effect of laptop computers as negligible. The effect size data confirm the statistical significance data that the effects of laptop computers appear to be negative in nature, but no firm conclusions can be drawn because of the extremely small magnitude of the calculated values at both units of analyses.

5.6 SUMMARY

This chapter reported on the findings of the analyses of the quantitative data collected in this study. These quantitative data consisted of QTI data, SCES data, attitude data and cognitive achievement data collected from both the laptop and non-laptop samples.

The findings, with respect to how grades 8 and 9 laptop science students perceive teacher-student interpersonal behaviour, indicated that students perceived teacher-student interpersonal behaviour as strongest on leadership behaviour, very closely followed by understanding and helping/friendly behaviour. In terms of classroom environment perceptions, laptop science students perceived their classroom environment being characterised most strongly by independence, followed very closely by participation and then personalisation.

Comparisons between laptop and non-laptop students' perceptions of teacher-student interpersonal behaviour, indicated that laptop students perceived significantly more student responsibility/freedom and uncertain behaviour in their teachers, while non-laptop students perceived significantly more leadership and helping/friendly behaviour in their teachers. The differences in perceptions of science classroom environment, between the two groups of students, were minimal with laptop students only perceiving their classroom environment as being characterised by significantly more differentiation.

The exploration of associations between laptop students' perceptions of teacher-student interpersonal behaviour and the two student outcomes of attitude and cognitive achievement, indicated that there were associations with both outcomes. Moreover, the association with attitude was approximately twice that with cognitive achievement. The findings were similar between the associations of laptop students' perceptions of classroom environment and the two student outcomes. However, the associations between teacher-student interpersonal behaviour perceptions and the outcomes was stronger than that between classroom environment perceptions and the outcomes.

A comparison between laptop and non-laptop science students in the two student outcome areas of attitude and cognitive achievement, revealed that laptop science students had a slightly better attitude to science, but performed slightly worse on the cognitive achievement instrument.

Neither of the scale mean differences were statistically significant indicating definitive statements are not possible. However, the effect size data, for the attitudinal outcome at the class mean level of analysis, indicate that laptops do have a small positive effect on students' attitude to science when classes of laptop students are compared with classes of non-laptop students.

It appears that laptop computers, in grades 8 and 9 in science, have led to teachers exhibiting more uncertain behaviour, giving their students more responsibility and freedom and having classrooms that are characterised by increased differentiation.

The next chapter reports on the qualitative data collected through interviews of students and their teachers in two laptop schools. The results of the analysis of these qualitative data are used to confirm the quantitative findings and provide a plausible explanation for some of the expected and unexpected quantitative findings.

CHAPTER 6

QUALITATIVE DATA ANALYSIS AND INTERPRETATIONS

6.1 INTRODUCTION

This chapter is an analysis and interpretation of the qualitative data collected through interviewing laptop students and their teachers in two of the laptop schools that participated in this study. Details on the collection of the qualitative data appear in Chapter 3.

The analysis and interpretation of the qualitative data is a synthesis of the data collected from laptop students and teachers reflecting their opinions and experiences on using laptop computers in science classrooms. The first section of this chapter concentrates on the students' perceptions, the second on the teachers' perceptions, and the final section highlights the common perceptions between the two groups.

Students were asked a series of questions dealing with science classroom environment and teacher-student interpersonal behaviour. Students were also asked about their attitudes toward science and their perceptions of the association between attitude and achievement. Teachers were asked similar questions, including a question asking for advice they would offer a school contemplating the introduction of laptops in their science program.

6.2 STUDENT EXPERIENCES AND OPINIONS

6.2.1 Questions on Classroom Environment

When students were asked the question, 'Do you think the classroom environment or atmosphere, the way the classroom feels, changes when laptops are being used compared with when they are not being used?' they generally responded that they did not perceive a great change. Comments such as, "I think it's really much the same" and, "No not really. Didn't really change just by having the laptop there because you still have discussions and everything, just take notes on the laptop and discuss", were most common. However, two students did make the following comments

> I think, you know, that the classroom is less friendly because people are focused on the screen and don't communicate as much - you talk more when you are handwriting things.

> I think it's really much the same, after what Kathryn said about anti-social or whatever. And I mean you aren't supposed to be talking in class anyway.

A follow-up confirmatory question of, 'Do you think there is actually less talking between people when you have your own laptop?' resulted in the following response

> Yeah, yes. Well it depends on exactly what you're doing because sometimes you have to concentrate more than others. And sometimes people don't know what to do and they say, do I press File or whatever and there is all this yelling all over the classroom...

The question of, 'Do you help each other - like if one of you knows how to do something and the other is struggling, can you get up and go and help?' resulted in the following student responses

> Yeah, yes, but it gets a bit frustrating though because like you get left behind because you have to help others, but sometimes it's all right...
>
> Even with your friends, they find out things and tell you how to do things and you tell them how to do things.

The answers provided to the other 'classroom environment' related questions appeared to support this feeling of no major change. However, there are some exceptions.

In response to the question of whether students did more individual or small group work in class when laptops were being used, all the students in one school said, "No - used for pracs only where we are always in small groups. Perhaps assignments, but then this would be the same too." Some students in the other school interpreted the question in a different way and one student answered, "I think computers are more individual, like when you are writing down people put in their own ideas more, but when you're in front of the screen it's more self, because only one person can do it."

When students were asked for their perceptions on whether they thought the teacher had more time to provide individual help to students, when laptops were being used, students generally felt this was not the case. Students also interpreted the question as being specific to individual help with laptop problems. Comments made included

> No, not really. In labs the teacher would walk around and ask how things were going but not otherwise. Also if you had a problem you would just ask a friend or the person next to you because the teacher wouldn't know.
>
> The teacher would try and help but they didn't really know what they were doing, so it would just be easier to ask a friend.
>
> I think the teachers don't really know much about it, they often say I don't know how to do it, ask your classmates. It's often the teacher asking for help, than you asking the teacher.

> They generally don't know how to use the laptop.
>
> They generally spend much more time with students trying to use the laptops. The problem is, is that you have some people who can use the laptop and some that can't or they can't type, so you just sit there and rest while the teacher helps the others.

The above comments suggest that laptop computers have led to some changes in the science classroom environment, but that these changes, as perceived by students, have been minimal. Of these minimal changes, the greatest occurred in the areas of students being more responsible for their own learning, thus helping each other and sharing information to a greater extent, and the perceived amount of teacher individual help. The latter appears to have decreased because of teachers' limited expertise and experience in using laptops. This does parallel the quantitative findings to some extent as students perceived their classroom environment as being strongest on independence (make decisions, have control over learning) and somewhat lower in personalisation (individual interaction with teacher).

6.2.2 Questions on Teacher-Student Interpersonal Behaviour

Preliminary analysis of the QTI data revealed that laptop students perceived their teachers as exhibiting strong leadership behaviour, that is control, organise, set tasks, determine procedures, explain and so on. When asked to comment on this statement, students agreed that teachers showed much of this behaviour. Some typical comments were

> Well, teachers using laptops give you a sheet of paper that tells you exactly how to do it, you know like in graphs, and then they tell you to do it.
>
> We were always told, write in your book now, use your laptops now and stuff like that.

This preliminary analysis also showed that students perceived less student responsibility and freedom than expected. Student comments in response to this statement indicated that they did not really expect anything else. Students made comments like

> Well teachers are strict and they are not going to change just because there is a laptop in the class.
>
> Like other things would happen when we were using the laptops - some students would be looking at something else, or some would start playing games and when they got caught the teacher would yell and we'd all have to put away our laptops and get our books out.
>
> I think teachers were a bit scared of the laptops at the start, they were not confident and felt a bit intimidated.
>
> I think some of the teachers are really, really strict because they think you might be playing games, that's why they walk around and check more.
>
> Sometimes I think they are just curious and they wander around and just check because they can't see what you're doing from the front.

Another area that was explored with students was whether they perceived a difference in the confidence level and the stress level in their teachers, in classes where laptop computers were used. Generally all students agreed that they perceived less confidence and more stress in their teachers when the laptops were in use. The following comments were common and reflect general student opinion.

> Yeah, I think they get short tempered - like they can't help or don't know what to do.
>
> And also like when, they get really frustrated when all these students come up and say my computer wouldn't print or it broke down and like they get all the work.
>
> A couple of teachers were very nervous when we used them, they were afraid we didn't know what to do or that they would break.

> Some teachers made us feel that they didn't want us to use them a lot because they weren't confident and didn't want us to use them because they didn't know what we were doing.
>
> Yeah, often when we had trouble with them they got all upset because they couldn't fix it. Also, if we would ask to go print it, they would say no and then get upset that we couldn't hand it in and say you should have used your book. They would yell, why did you use your laptop if you knew you had to print it out. But, that's what you have to do when you use laptops.
>
> It's the people that can't use the graphs and the teachers can't really explain it to them, so everyone else has to like explain it to them and it gets really confusing.

These comments provide considerable support for the preliminary findings of teachers exhibiting more leadership behaviour and considerably less student responsibility/freedom behaviour. They also suggest that perhaps teachers did not have the expertise and/or experience to use the laptops with confidence in class. As a result, it appears teachers may have reacted by becoming more authoritarian and thus exhibited behaviour characterised by controlling, checking, directing, ensuring proper use of laptops and so forth; therefore, not allowing students much responsibility and freedom.

6.2.3 Questions on Attitude and Achievement

Analysis of the quantitative data indicated that laptop students had a better attitude to science than did their non-laptop counter parts, but that they scored at about the same level, if not slightly lower in cognitive achievement. A variety of questions was asked of students in order to determine possible causes for these observations.

In reply to the question, 'Do you think laptops have made it easier for you to learn some of the things in science?' students indicated laptops helped them with things such as making tables, spreadsheets, graphing, presentation, getting work done faster, editing of work, projects, note taking, writing up investigations and organisation, but it really didn't make it easier to learn. One of the students commented "The graphing took a long time to learn, but once you know how to do it, it saves a lot of time and stuff."

When students were asked, 'Do you think laptops affected the way you learn science, or did laptops help you understand science?' their responses indicated that basically they did not think laptops did either. They felt that laptops were only used as tools for graphing, note taking and so on; they were not used to 'teach' any of the science materials or topics. Comments such as the following support this observation.

> Not really in science - it did in other subjects. In science you can't use it to do experiments and stuff but you can use it to do notes.

> Laptops don't really help with our knowledge of science, except for our knowledge of computers.

> It's made a lot of things easier, like reports, and labs and things - it just makes things easier.

> Perhaps if we had a science program in it we could go home and look at it and learn more from it. It would be good if you could put encyclopedias, Encarta and stuff like that on them but they are too small for that.

When students were asked why they thought laptop students appeared to have a better attitude toward science, the following reply perhaps best summarises a majority of student perceptions. "Easier, different, new, a bit more fun, doing neat graphs, it's not such a drag and everything." All students felt their work looked better when done on the laptop and they were proud of their presented work. However, some students felt that their attitude to science was not affected at all and made comments such as, "I think it really depends on the student - those that can use the laptop well, like it (science)... and, "I don't think it influences me at all. Maybe they get better marks because their work is better and they find that they have a better attitude." These comments would indicate that if students have mastered using the laptop, they are finding their experiences of using laptops in science stimulating/fun and have positive attitudes towards science; however, the opposite is also true so that it appears that perhaps attitude to science is more related to mastery of the laptop for use in the science classroom, than merely the presence/use of the laptop itself.

When asked the question, 'If you were to name one advantage of having a laptop computer in science, what would it be?' students gave the following responses

> With writing when you make a mistake you often have to rip out the whole page and rewrite everything. With the laptop you just correct the mistake and you're done.
>
> Being able to generate the graphs for investigations.
>
> Writing up investigations - a lot quicker and neater.
>
> It's quicker to copy notes, but I don't know if that's a bigger advantage than doing graphs, hard to say.
>
> For assignments - it looks better and it's easier to change things around.
>
> Yeah, I reckon presentation as well. It's easier to change things - you can add, delete without having to white out or rewrite and there's a spell check and thesaurus - you write it out and then you just go through the thesaurus changing all the words.

When asked, 'How about the biggest negative of having a laptop in science?' students gave the following responses

> Yeah, say if we have to do an investigation, like sometimes the teacher revs us because we're taking time to do the graph and everything, and then we have to go to the printing room for printing it out whereas, like if we just wrote it out it would be done.

> Just the weight of it I think, and it always needs repairing, well mine does, it always has got some kind of problems - maybe lose files and stuff like that.
>
> And also when you take it to the tech centre it takes ages to get fixed and then you get into trouble with the teacher because you don't have your laptop.
>
> They're heavy, when you have those long 'start ups', when it goes wrong and you lose all your work, and when you don't know how to do things and you ask your teacher, and they don't know either - it's really annoying fiddling around and because then you lose time.
>
> Also having to print is a real problem - it would be nice to have a printer in the classroom.
>
> And also having to recharge all the time, like when you run out of power it's really annoying. And there isn't enough places, in science classes, to plug in, so you have to switch to paper.

The above comments regarding the advantages of using a laptop in science indicate that generally science students perceive the laptop as a time-saving device that allows them to do their work more quickly and present it in a more professional manner, especially if they can use the computer competently. The negative comments regarding laptop use in science tend to focus on the mechanical and logistical aspects of laptop use. It would be fair to say that these student comments lend further support to the earlier observation that it is perhaps mastery of using the laptop in the science classroom, that plays a more important role on students' attitude towards science, rather than simply the presence/use of the laptop.

The laptop students were also asked to comment on the fact that preliminary analysis of cognitive achievement results revealed that laptop students may have actually scored slightly lower than did their non-laptop counterparts. Their responses included the following

> The laptop didn't help us learn more stuff in the subject, like we learned a lot about computers but not science.
>
> It makes doing notes and stuff a lot faster, so it might give you more time to study and help in that way.
>
> It's still up to you to study, like you can finish a lot of work quicker with the laptop so you have more time to study, if you want to.
>
> I also find I do not pay as much attention in class when the teacher is talking and I'm taking notes on the laptop because I'm concentrating on typing (others in group nodded their heads in agreement).
>
> Like they expect you to know everything on the computer and if you don't then you have to waste time to find out how to do it, and you miss out on class things.

Although the cognitive achievement instrument was a non-content specific instrument and tested topics such as graphing, it appears that students may have become too involved in learning to use the laptop and to do this work on the laptop. Consequently, they do not gain as good an understanding of graphing, for example, as do their non-laptop counterparts. Some of the comments made by students led to the question, 'Do you think you are more computer literate or confident in using computers than non-laptop students, even if they have access to a desktop at home?' This question was met with an overwhelming yes. Some of the student comments follow

> It depends, like my sister she just got her laptop now and she knew nothing and we have a computer at home.
>
> Yes, because working at school you do like quite a bit and you learn to face the problems as you come across them because you have to actually get it done....If you're struggling with something at school you actually have to overcome it, instead of just not worrying about it. I think at school you have a lot more people to help you...

> Yeah, yes definitely more computer literate. I knew a lot about computers before I got the laptop, but now I'm learning heaps more all the time because I always have it here.

> I think it really helps with the literate bit because I remember last year after I got my computer I didn't know how to do anything and my Dad showed me everything because he uses his computer every day at work, and by 6 months I was showing him how to do things. Because you learn every day with the laptop. You find out how to do new things with it just by pressing something accidentally or something.

These comments provide some explanation as to why science students, using laptops, did not show better mastery of the topics tested by the cognitive achievement instrument, even though it was thought laptops would promote a better understanding of the concepts tested by this instrument. The comments also indicate that laptop students perceive themselves as having made great strides in their knowledge about computers.

Finally, students were informed that most research shows a direct relationship between attitude and achievement, that is the better the attitude, the higher the student achievement. Students were then asked for their insights on possible reasons why laptop students had the better attitude when compared with non-laptop students, but not the better achievement scores. Generally students felt that if a good attitude existed then they studied more, and thus understood better and so on. One student commented, "But you also find the brighter students in class tend to work more and do more on the computer." This comment seems to suggest a complex relationship where cognitive achievement is dependent on attitude which is dependent on computer literacy, which itself may be dependent, perhaps, on being bright. However, students did not offer any explanation for the fact that laptop students generally had a better attitude to science than their non-laptop counterparts, but may not achieve better.

6.3 TEACHER EXPERIENCES AND OPINIONS

6.3.1 Questions on Classroom Environment

Teachers provided the following responses when asked the question, 'Do you feel that the science classroom environment changed when laptops were introduced?'

> I feel it did change a lot, it became much more relaxed and informal because you had to run around and help individual students and also I found the students became more interactive because they had to ask questions.
>
> Yes I agree initially that was the case, but because we strictly controlled when the laptops were used we also maintained the normal interactive classroom as well. Also I found that once they had coped with the laptop and whatever new thing that was taught they actually became less communicative, that is they talked less to me and each other because they were into their machines.
>
> I think we maintained good communication on the long run because we controlled the way we used the laptops. Also I found that when we were using them as a word processor I had to ask students to close the lids so that they would think and learn and listen because when they have the laptop open they don't.
>
> The logistics of managing the laptop in the classroom were a whole new area. And the general management of the classroom became different.
>
> There is more cooperation where the students help each other and that's quite good.

Teachers generally felt that there was a change in the classroom environment, but the perceived degree of change varied between teachers. Other classroom environment related questions were raised with the teachers to further explore their perceptions in this area.

When asked the question, 'Do you spend more time with individuals or small groups when laptops are being used?' teachers provided the following responses

> No - it's much the same as I always teach - I always walk around and talk to students individually.
>
> It really depends what you're doing, like earlier with Year 8 we were doing Hypercard Stacks and slide shows - the initial part I had to set up, say 20 minutes of the first period, and the rest of the time they worked completely by themselves and I could wonder around and talk to them all and see what they were doing. So, I think if it's projects, where you set it up, and then they work alone, yes there is much more interaction.
>
> It really depends why you're using the laptop, and I guess too the amount that you're required to help them decreases as the year progresses. This frees you up more to give individual help.
>
> I think that giving out sheet instructions on how to do things is much better than trying to do it with the whole class, for example, doing a table. If you have a sheet that has all the steps then they can do it so long as your instructions are really good, that is really the best way to show them how to do a table, do a graph. Just a simple straight forward sheet - do this, click on this, click on that etc. Then the one next to the one having trouble helps and so on.

These responses indicate that the introduction of laptops in science classroom has not led to a great increase in the amount of individual/small group help teachers provide to students. It appears that generally, as in a non-laptop classroom, the amount of individual/small group help depends more on the activity being undertaken than the presence of a laptop computer.

Teachers were also asked how they felt about not always having all the answers in class, with regard to the laptops, and that perhaps they had to be learners alongside the students or actually learn from the students about different aspects of computing in science. Teachers generally had no difficulty with this rather different role in the classroom. Other than saying it was not a problem, little comment was offered. Examples of comments made follow

> I accepted that as the way it was going to be and I didn't mind that - I found that it helped the situation in the classroom (yes, I'd agree with that from others).
>
> As long as you went along, I think if you fought that you would have problems. You have to accept that some of those kids are far more advanced than you are.

It would appear that laptops have had an impact on the science classroom environment, from the teacher perspective, but that the impact has not been a large one. Perhaps the greatest change perceived by teachers, based on the above comments was that students participated more in their learning experience, at least in the area of learning to use the laptop.

6.3.2 Questions on Teacher-Student Interpersonal Behaviour

When asked to comment on the observation that preliminary analysis showed that students perceived teachers of laptop science classes as exhibiting less student responsibility/freedom type behaviour (give opportunity for independent work, give freedom and responsibility) than the researcher expected, teachers provided the following comments

> Well we had to control their (laptop) use because it was all new - we weren't sure what to do, how it would go and the students would just do anything they found interesting on them [interjection: this finding is not based on this school, but the overall sample]. We didn't know enough about microworlds for example to set open-ended questions - we were still writing things down step-by-step for us.
>
> Another thing it could be is students' misconception - maybe they thought once they had the laptop they could do anything, yet they needed to learn the methods just as much as we did, in fact more.

> I think a lot of students think they know a lot more than they do. And also, if we just let them work on their own, at their own pace they would never get through the work.
>
> I think I started off holding the reins fairly tight, but now after I've done it for a couple of years, I tend to give students a sheet with instructions and just let them go. But they are still following your instructions? (teacher 2) Yes. So they haven't got the freedom really have they? (teacher 2). No I guess not, to work at their own pace they do, but not on their own material. Yes but I mean that's because you have to teach them and you want a particular format for a particular thing - for ease of teaching I guess.

These comments seem to indicate that teachers did not have enough expertise and experience with laptops to allow students the freedom to learn through trial and error. It appears teachers felt pressured to ensure that all traditional learning still occurred, plus they had to incorporate the laptop into the course in some way that was beneficial to the students' learning of science.

Teachers were also asked if they felt less confident during lessons in which the laptops were being used. They were also asked to comment on the students' perception that "teachers were a bit up-tight whenever laptops were being used." Teachers' responses included

> Well of course we were less confident, we hadn't had laptops, that was the first time we were using them. We didn't have any expertise, guidance etc. We had to do it ourselves.
>
> In microworlds I didn't feel confident at all - I had to get lessons and spend hours on it and still didn't know if it would work in class.
>
> I'm not surprised they felt that we were stressed. They got that impression because we didn't have time to learn all that and nobody really told us what to do to make us confident. But I think as time went on we got very confident with graphing and spreadsheeting and had no problems.

> It's different this year though, I was a lot more confident and I was able to walk in and say this is how and when we are going to use the laptop. I'm much more positive now and know what is going to be done.

> Probably a couple of years ago I wouldn't have been as confident but now I am quite happily using them. I think the first couple of years are the hardest and then it gets much better from there.

These comments lend support to the earlier observation that perhaps teachers did not have the expertise and experience to use laptops confidently. It would be fair to say this lack of expertise and experience resulted in teacher behaviour students described as up-tight, and teachers recognising increased stress level in laptop classes. In an attempt to reduce stress and increase confidence, it seems a logical reaction could be to become more authoritative and to allow students less responsibility and freedom.

6.3.3 Questions on Attitude and Achievement

When teachers were asked to comment on the preliminary finding that laptop students appeared to have a better attitude to science than their non-laptop counterparts, teachers made the following comments

> Of course it is - there is always something different/exciting every week. I don't know if it was the laptop or not, but we injected a lot of other activities because we felt we had to revamp this course and this together would interest the kids more.

> Hmmm - that's interesting. I think they really enjoy the challenge - it's something new. Yes they really enjoy it overall.

These were the only specific comments related to attitude provided by teachers. They indicate that some uncertainty exists in teachers' minds on the direct association between laptop presence and student attitude to science.

Teachers were then asked attitude-related type questions to further explore their perceptions of the relationship between attitude and the use of laptops in the science classroom. Two of the questions asked teachers were, 'Are there any specific areas in science where you felt laptops really helped you teach certain materials?' and 'What has been the greatest advantage of teaching with the laptops in science?' Typical responses to these two questions were

> Averaging, spreadsheets, graphing, statistics - all that early stuff. It came alive - it was fantastic. The collection and presentation of data. It's such a good standard that the kids enjoy doing it.
>
> And, at the stage where there wasn't much statistics or data involved, they just enjoyed writing it up on the laptop so it looked like a nice scientific report (prac report) was a great bonus to them and helped them take an interest in what was going on.
>
> Usually the work handed in is much, much easier to mark and read. Perhaps maybe the enthusiasm the kids do have - they are quite happy to do the work because they can do it on the computer.
>
> One of the other things naturally is the kids work together a lot more and help each other a lot. Kids that have done some computing before help those that haven't so in terms of classroom cooperation it has really helped.

These comments reveal that teachers did perceive a better attitude to science, especially in those areas where the laptops were of most benefit to the students. For example, teachers felt that graphing 'came alive' and students were enthusiastic about writing up their work on the laptop to produce 'nice' scientific reports.

Teachers were also asked for their perceptions of some of the difficulties they encountered while teaching using laptops and what they thought were some of the greatest negatives of using the laptop in the science classroom. Typical comments in this area included

Time, I think would be one. Also discipline, the discipline side. Some of the boys really lost it - playing games and fooling around. And reconfiguring all the time - yes, yes. So you really had to be on top of them. But at times they weren't.

What I found difficult was I had to be really aware of what every student was doing when they were working on them - walking behind a lot. Another big problem is not having printing facilities in the room - it wastes so much time having to take the whole class over to print and then bring the whole class back.

That was a logistics nightmare and the discipline of students, being able to find the correct files, and have the laptops up and running very quickly at the start of a lesson. Kids not having them, laptops broken. Five kids come to a lesson without laptops - what do they do? Sometimes the laptop would be off at repairs for a month and you just cannot provide alternative activities for that length of time. It just becomes such a problem.

Also the problem of their batteries running down and then their cords being across the isles. I've tripped on them and kids have pulled laptops down off desks. It's just such a problem.

When kids lose their work. They come to class and have to be sent to the technology centre, they don't have their work on disk and don't have it in class to mark. And, last year they didn't have a built-in disk, they had to go to the library, plug the computer in and get it on disk - a real bother.

Also, when they have saved it and they can't find where they've saved it. But they're usually just initial problems.

Often they don't bring them to class which causes problems. Also they are all at such varying levels and to find the best method to actually give them some skills in class and also covering some content, to me, is most challenging. I'm often doing more on computing and less on science than I would like to be doing.

The main difficulties of using laptops in science, as perceived by teachers, are of a mechanical/logistical nature, that is, getting the laptop operating, finding files, printing and so on. Interpretation of these comments with respect to student attitude, would indicate that students without the problems identified by teachers would have positive attitudes to science and vice versa. Thus student competency in laptop use, once again, appears to be more significant in determining student attitude to science than simply laptop presence in the classroom.

Teachers were informed that most research shows a direct relationship between attitude and achievement, that is the better the attitude, the higher the student achievement. Teachers were then asked for their insights on possible reasons why laptop students had the better attitude when compared with non-laptop students, but not the better achievement scores. Teachers responded with comments such as

> Ah, I think that to start with the information they are putting in the computer, they don't actually take notice of. But later when this becomes second nature and they know how to get it all set up and ready to go then perhaps the information you are actually teaching them is becoming more important to them.
>
> I guess what I'd say is that there are more questions about the actual computing than science which is maybe a bit of a worry. This could actually detract from the learning of science - they are so busy trying to learn how to do a table they actually don't pay attention to the information going in.
>
> We were teaching a lot of computer skills, like graphing which they then used later - it was an unknown situation.

These comments indicate that students are perhaps so preoccupied with learning how to use their laptops for these new purposes, such as graphing for example, that the learning about graphing becomes secondary. This is a plausible situation and perhaps is the main reason why laptop students did not outperform their non-laptop counterparts.

The above teacher comments led to one more question to teachers in this area, 'Do you feel laptop students have a better understanding of computers and are more computer literate than non-laptop students?'

Teachers responded with an emphatic "Absolutely, no doubt, yes. It makes school a lot more relevant for them," and "I think a lot of them, by the end of grade 8, really are quite competent and are really quite happy to use computers for all sorts of things."

6.3.4 Questions on the Introduction of Laptop Computers into Science Classrooms

The teacher interviews were concluded with the following question to teachers, 'Based on your experience, what advice would you give anyone contemplating the introduction of laptop computers in their school science program?' The most directly related responses made to this question follow

> You need a lot of instruction and opportunity for staff to work together and make it possible so it doesn't become such a huge responsibility for you all at the one time. We were only given two days of time to prepare for the next term with laptops - I hadn't even put my hand on a laptop!
>
> We really need some time set aside each week for this. It just cannot be done - keep up with all your normal teaching and learn a whole new area at the same time.
>
> We need a lot of time together like half a day a week over a semester to prepare all the resources and learn how to use equipment. We should be provided with laptops (we weren't) and you cannot expect people to just buy them. And how do you learn without having them? Now we have one laptop to share with three or four of us and that helps but you still can't take it home and practice all the time. Staff should be provided with everything they need if something like this is to happen. You can't do it on a shoe-string budget.
>
> We should have had someone (the technology person) producing all the booklets for the different uses of the laptop and it should have been all ready for when the laptops were introduced. Perhaps there should be a team of really competent people doing all the research and preparation of resources - maybe a consultant should be brought in. Get consultants to

> write a book on microworlds or Windows 95, even if it costs $2,000-$3,000, it would be worth it.
>
> Classrooms should be redesigned for it - they are putting technology into an archaic setting.
>
> Definitely in-service of staff to start with and perhaps, depends on really what you're teaching - here at #2 we've integrated computing skills in science, maths, English, so there needs to be lots of communication between who's covering what sorts of areas. If you had a separate computing class that would make it easier because they would learn all the computing skills before coming to class, so you're not teaching them right from scratch. So that would be something you would have to consider too - how you were to implement computers.
>
> You would also need a person who would review all the software, employ a software person, because we don't really have the time. Need this person to make suggestions as to how the laptop could be used.
>
> Maybe the parents should be given an in-service just so they know a little about the machines and what the students should and shouldn't be doing with them at home. Also the expectations of the school re the student use of laptops should be made clear to parents.

The following supplementary questions were then asked. 'How about just hardware, laptops and things like that - as far as staff are concerned. Has there been a problem - like you having to own your own laptop? Do you have to buy your own or does the school provide it?'

> No, the school provides one for every staff member. I think we're very appreciative of them, not necessarily just for teaching but all the other things we can do with them. Recording all of the marks, doing our reports on them. And we have e-mail through the school as well so the other side of it is it's fantastic for us - yes it is marvellous for us.

The final question then followed. 'So all of these benefits for you - do they make you more enthusiastic about using the laptops for teaching and putting in the extra time and effort necessary for success?'

> Yes, I guess so, but then again, it takes up a lot of time to do all those things that were once sent to the office. We now do all our own typing, yes, and it is quicker actually than sending to the office.
>
> Yes, I mean I think it's great in that the kids come away experienced in computers and technology and that sort of thing, really they have the confidence to just get on to any computer and just use it. I mean we've got scanners and computer cameras in the library - no problem, they just figure out how to work them because they are happy they can have a go and not be scared to use them, whereas the Year 12s who didn't go through the laptop program, most of them don't really have a clue about what's there or how to use it. I was in the library yesterday and absolutely none of them could help me with something I needed help with because they knew absolutely nothing about it. They never used it - they were afraid to use it. I think it's the same with staff, once you've had a go, you really realise it's not so hard.

These comments suggest, that from the teachers' point of view, the following are necessary for the smooth introduction of laptop computers into science classrooms. Firstly, a well thought-out master implementation plan needs to be developed, with the aid of consultants, and adopted well before the introduction of laptops. This plan should include, at a minimum: what skills students and staff will have to acquire to make effective use of the laptops in science, the most appropriate training, in-service and lead time necessary for staff to gain the expertise and experience needed to become confident laptop users, how and by whom students will be taught the laptop skills necessary for the studying of science, and provision for the continual upgrading of teacher skills as new programs and updated models of laptops find their way into the science classroom. Secondly, resident specialists or consultants need to be hired to prepare materials for classroom use, review and suggest appropriate software and provide total support for teachers. This would be to ensure that minimal teacher time is lost to extra preparation, as teachers still have all their normal duties and responsibilities. Thirdly, staff need to be provided with laptops as this motivates staff to 'give back' to the school, with extra work, effort and a positive attitude. Fourthly, classrooms need to be redesigned to be conducive and practical for laptop use.

6.4 SUMMARY

Of the perceived changes in science classroom environment, both groups interviewed felt that students probably participated more and were more interactive when laptops were being used. Students also perceived that teachers generally provided less individual help when laptops were being used; however, teachers did not perceive this to be the case, generally indicating the amount of individual help depended on the activity taking place in the classroom. Of the two groups, teachers perceived a greater change in the classroom environment than did the students.

The responses to questions on teacher-student interpersonal behaviour indicated that both teachers and students perceived that laptops caused a lack of confidence and increased stress levels for teachers. This appeared to account for teacher behaviour perceived by students as strong on controlling, directing, checking and weaker on student responsibility and freedom, the type of teacher behaviour laptops were expected to elicit from teachers. Generally, there were no major differences between students' and teachers' perceptions in the area of teacher-student interpersonal behaviour. Teachers were 'forced' to change their behaviour in order to cope with their lack of expertise and experience in using laptops, whereas students did not really expect change, and simply noticed changes in their teachers' interpersonal behaviour when laptops were used.

Both students and teachers felt that generally laptops instilled a better student attitude to science because laptops were new, provided for a different way of doing things, made doing some things easier and so forth. However, comments made by both groups also appeared to indicate that positive attitudes were probably more strongly related to laptop competency, than merely the presence of laptops in the science classroom.

With regard to achievement, the comments made by both students and teachers indicate that the finding that laptop students did not out-perform their non-laptop counterparts on cognitive achievement, is what the researcher could have expected. Both groups indicate that the laptop led to much learning in the area of computers and computing, but that the learning of science was probably not enhanced. Teachers actually expressed concern about laptops perhaps detracting from the learning of science, especially during the period students are mastering the computer skills necessary in science.

Students offered no insight into why laptop students had a better attitude to science, but did not out perform non-laptop students in cognitive achievement. However, their comments in each area of attitude and cognitive achievement, indicate that although laptop students had a better attitude to science, they felt that the laptops helped them most in learning about computers, not science. Teachers expressed concern about students concentrating on learning how to use the computer to do the various tasks in science and paying less attention to the actual science being taught. Teachers were not surprised that laptop students did not outperform non-laptop students in cognitive achievement.

Teacher responses to the query of what advice they would provide someone contemplating the introduction of laptop computers in science classrooms, indicated that extensive teacher training and preparation had to be a priority, followed by the preparation of materials/provision of advice by competent individuals. Teachers also felt the provision of all materials and equipment, including a laptop, were mandatory for teacher motivation and positive attitude.

In the next chapter, the researcher provides a reflection on his perceptions and experiences with the introduction of laptops at a school, focussing on the science classroom. Also included in this chapter will be the researcher's experiences of teaching science in a science laptop classroom for the very first time.

CHAPTER 7

A SELF-REFLECTION ON LAPTOPS IN THE SCIENCE CLASSROOM AND SCHOOL

7.1 INTRODUCTION

This chapter reports the researcher's experiences of teaching science, at the grade 8 level, in an Independent school where all science students had their own laptop computer. As the researcher was at the school when the decision was made to make laptop computers compulsory for all students, these perceptions and experiences are relevant to the research questions posed in this study.

7.2 THE ACCEPTANCE OF THE DECISION BY STUDENTS AND TEACHERS

The decision to make laptop computers compulsory at the grade 8 level, for the following school year, was finalised early in the last term of the preceding year. Rumour of the decision beforehand, had created considerable discussion amongst students and staff. A full range of emotions was expressed by both groups on the issue, ranging from anticipation and excitement to anxiety and apprehension.

7.2.1 The Students

Generally students were enthusiastic about the prospect of having their own laptop computer which they could use each lesson throughout the day. Some students were eager to find out how the laptops would be used in science, exactly what would be taught using the laptops and whether they could use them for notes and so forth, totally replacing the need for an exercise book, pen and pencil.

Many students had concerns about having the extra responsibility of looking after a $3,000.00 laptop, especially getting it to and from school on public transport. A number of students also expressed concern about perhaps having to leave the school because of the extra financial burden the laptops would place on their parents. Some of these students actually did leave the school for this reason; however, others left because parents were unconvinced that laptops would live up to their heralded benefits.

7.2.2 The Teachers

The staff were unenthusiastic about the final decision for three main reasons. First, because of their interaction with students, staff felt that a considerable number of students would leave the school because of the reasons stated above, and that this would jeopardise course offerings and so forth. Secondly, staff were very anxious about how they would incorporate laptops into the science program and when they would get the time needed to master the computer skills necessary to use the laptops in the teaching of science. Thirdly, the school's decision to not provide staff with laptops, but only a small concession in the lease cost of a laptop and free lease for the last six months of a three year contract, caused considerable negative feelings amongst staff. It must be pointed out that there was a small group of staff who were totally convinced that laptops were great, and were prepared to do anything necessary to see the program succeed.

Of these three reasons, it was probably the second that caused the most anxiety, and with staff resentment at not being provided with a laptop, there was little enthusiasm in the preparation of the science laptop program for the following year. In addition, an earlier decision had been made to combine the science and mathematics programs at the grade 8 level, so that these two subjects had to be integrated as much as possible and be adapted for teaching using laptops.

Fairly late in the term, interested science and mathematics staff, and the two heads of department, were allocated several days off to combine the two curriculum areas and integrate the laptops in the 'new' maths-science course. The time allocation was not sufficient and only a skeleton plan was put together for the first term of the following year. The first term's program was finalised during out-of-school hours by the 'volunteer' group referred to above. No laptops were available during this term for staff in-service as the machines were not being delivered to the school until early the following year.

7.3 THE FIRST SEMESTER

The next school year started full of anticipation and excitement as the laptops had arrived at the school and even the 'unconvinced' were caught up in the euphoria. The school was at the forefront of the laptop revolution, both staff and students were leaders in the field. The media were invited into the school and the school made headlines.

Student enrolment was down in grade 8 and staff were still anxious about their lack of skills in using the laptop to teach science, exactly how they would use the laptops and simply how the whole program would proceed. However, this was not a major concern as both staff and students were reassured that appropriate in-service was planned and would be available to deal with all problems and concerns. Staff were given the challenge of ensuring the program's success. Once this occurred, it followed that enrolments would recover and all concerned would greatly benefit from the experience of being leaders in this field.

7.3.1 The Students

Students could not contain their excitement and enthusiasm of coming to science with their own laptop. Approximately half the students had just learned how to turn the laptops on, while the other half arrived with varying degrees of computer literacy; several regarding themselves as 'experts'. This unreserved enthusiasm was great, but the chaos it caused in the classroom was unexpected. The students wanted to learn how to use their laptops - science was not very high on the agenda. When students were asked to put away the laptops because they did not know how to use them, even simply as word processors, this was usually met with disdain and the call of 'show us how.' Initially students also reminded staff quite regularly, that there was the expectation of daily use of the laptops in science.

As the first term progressed and students learned how to use the word processing package, how to make a table, how to use the spreadsheet and how to produce a graph, the chaos of the classroom did not appear to decrease. The great enthusiasm of the students, combined with the huge range of student computer literacy skills combined to produce this seemingly chaotic classroom. There was great student interaction and peer teaching/learning occurring, in the area of computing, but this classroom was very different from the orderly and quiet 'non-laptop science classroom' when giving lectures or doing investigations. As already stated, students were learning much about computers, and it was assumed, much about science in the area of data processing and interpretation.

The second term progressed in much the same manner as the first, except that some of the general enthusiasm of using laptops started to wane as the term continued. Also, students started to complain about not using the laptops enough and that they were not really learning any science using the laptops. Other students, who struggled with using the laptop in terms of saving, filing and printing for example, were beginning to get disenchanted and simply wanted to revert to pen and paper because, for them, this was easier and it avoided confrontation with the teacher. Students still felt any work produced on the laptop was great - it was neat, professional looking and they felt proud of what they had produced. Despite some students feeling incompetent and stating that they could not learn how to use the computer, generally they did make great strides in their knowledge of how to use computers. These were the students who could not turn the machines on several months ago.

7.3.2 The Teachers

Except, perhaps, for the total initial student enthusiasm and resulting classroom chaos, there were not many other really unexpected experiences with teaching science using laptops. Generally teachers felt overwhelmed by all the extra preparation they needed to do in the area of learning to use the computers themselves.

Teachers were offered general and science-specific in-service, but this was almost always after school. The in-service sessions were good, but did not, and probably could not, cover those problems and areas of concern raised most days in class by students, such as, 'I lost my work, can you find it?' 'Why won't my computer start up?' 'It's all gone dead, what do I do?' 'It won't print' 'It won't copy to my disk.' This led to much frustration and the feeling of incompetence. Even worse, the students perceived the teacher as incompetent, because they expected the teacher to be able to deal with any problem that arose.

In addition to the anticipated fear of not having the expertise and experience to deal with all the problems that arose with the laptops, was the unexpected problem of printing and batteries running flat. The whole class often had to make the trip to the printing room and print their work. Once there, rarely was it a simple process. Usually a significant number of students' laptops would not print and often one or more of the printers would be down. Thirty minute time allocations for printing became full hour sessions. An hour of standing around was long enough to cause even

and how much easier some of the tedious tasks, such as graphing, became when simple procedures were mastered on the laptop.
This computer literate group of students created opportunities for themselves to extend the work done in the classroom and became much more involved in their actual learning. Solving other students' problems often resulted in them learning new things themselves as they would often rush back to their laptops, after helping someone, and try something they had just discovered. All students, even those experiencing considerable difficulty, were thought to have had increased opportunity to solve problems and work things out for themselves when the laptops were being used.

The great range of abilities in using the laptops also resulted in a great range of relationships/treatments of various students. Some demanded and received much individual help and became very dependent on the teacher, others received very little attention and help and were totally independent, while still others were somewhere in the middle. This 'middle' group of students appeared to never get enough teacher help and appeared to perceive the teacher as only helping those students that were most demanding and/or those that had grown most dependent on the teacher to do even the simplest of tasks.

Overall, a fairly regimented routine was followed when laptops were used. Students were not encouraged to experiment as the teacher did not have the expertise or experience with laptops to allow anything more to occur than that planned for that particular lesson. Furthermore, students were often encouraged to do things quickly and move on to new work as the extra 'content' of teaching how to use the laptops, made less time available for teaching the science content. Moreover, science content was not reduced as a result of laptops being introduced into the science classroom. Most lessons were rushed and there was little time for enjoyment of this new experience.

Laptops appeared to influence the classroom environment in two major ways, first by increasing the amount of student involvement in the learning process, especially with respect to learning how to use laptops; and secondly, by forcing the teacher to provide a great amount of individual help to some students, not enough to others and no help to some. This latter change was due to the huge range of computer competence amongst the students. Because the laptop problems were much more student machine specific, the teacher could provide very little group help. The result of this was that demanding students monopolised teacher time and other students simply missed out. However, the students that received no help were usually the 'experts' that did not require help.

7.5 TEACHER-STUDENT INTERPERSONAL BEHAVIOUR PERCEPTIONS

The lack of expertise and experience in using the laptop in teaching science certainly led to a lack of teacher self-confidence and stress in the classroom when laptops were being used. The usually overwhelming gusto with which students tackled their work using laptops, the associated logistical problems of simultaneously dealing with numerous individual problems and the other associated problems such as cords everywhere in the classroom, led to a change in teacher behaviour, especially after perceived disasters in the first few lessons with laptops.

For the researcher, this change in behaviour involved taking control of what was to occur in the classroom when the laptops were being used. A lock-step procedure was introduced and this was to be followed by all students simultaneously. Minimum student discussion and movement was insisted upon when any new procedure was explored for the first time. Furthermore, students were discouraged from exploring associated interests because the teacher was only familiar with the work prepared for that particular laptop application. Any variation from the work prepared was unknown and undesirable territory, and it almost always ended in questions and problems the teacher could not address. This behaviour

mellowed each time this particular topic was revisited until 'normal' conditions prevailed again. However, the introduction of a new application of the laptop resulted in the whole scenario repeating itself.
It would be during subsequent lessons, after the introduction of an application of the laptop, that the teacher was able to show more and more interest in students' ideas and related questions, and provide support for students with their problems. However, even then frustration often set in because students would do totally unthinkable things and end up with problems the teacher could not solve. Thus, the situation would quite often arise where the teacher would offer the student support and help several times during the lesson, but finally admonish the student for not following the simple and clearly laid out steps. This admonishing was often the result of the teacher's frustration at not being able to help, rather than the student's creative approach to applying the steps.

It appears students were subjected to the entire range of teacher-student interpersonal behaviour whenever laptop computers were in use. In addition, it is believed that as teacher expertise and experience grew with any particular use of the laptop, teacher-student interpersonal behaviour changed from that of high teacher control and structure to that of a team approach where all were involved and worked together.

7.6 ATTITUDE AND ACHIEVEMENT PERCEPTIONS

There is little doubt in the researcher's mind that students had a better attitude when the laptops were being used in the science classroom. As mentioned several times, students were much more enthusiastic when learning some of the general skills associated with doing science, such as table construction, using a spreadsheet, graph construction, writing laboratory reports and doing projects.

Probably the most striking difference in attitude perceived, other than the enthusiastic approach, was that most students persisted in mastering the skills necessary to do a graph, for example. It appears that students perceived the mastery of computing skills on the laptop as being most relevant to their working futures. Unfortunately, they did not perceive the mastery of science content and process as having the same relevance. It was assumed that student persistence and success in learning to use the laptop to master the skills above would result in a better understanding of the underlying concepts.

This assumption, unfortunately, was generally proven incorrect by student results in the term and semester tests. Again using graphing as the example, many students did not illustrate a better understanding of reading and interpreting graphs, than did their non-laptop counterparts a year earlier. Furthermore, some students appeared to be very confused in 'extrapolation of data type questions', with which they had little trouble when using the laptop. On the laptop they were able to 'plug' in the extra independent value, have a new graph drawn and see the result. It appears they did not understand the concept of extrapolation and only understood what they had to do using the laptop to get a new dependent variable reading.

The above scenario was repeated with many of the science applications of laptops. Probably the only area where there was consistently better work was in the area of laboratory write-ups and projects. Generally presented student work was much more organised and structured, better written, neater and more professional looking. Students took much pride in their efforts in this area, experimented with effective presentation and there developed a sense of friendly competition in the presentation of innovative project work.

No increase in cognitive achievement, by laptop students, was most disappointing, unexpected and initially puzzling. Students appeared to have a better attitude to learning and produced very good work on the laptops, yet their performance on exams did not improve. Being closely involved in the process, it took a long time to step back and hypothesise possible reasons for the lack of improvement in tests. However, once this was done, several rather obvious reasons for this lack of improvement in achievement became apparent.

Firstly, a majority of time spent using the laptops in science, especially the first semester, was spent in the area of learning how to use the computers, using the data collected in classroom experiments. Students were taught how and what could be done with the data using the laptop. Not much was made of what the data really meant or the strengths and advantages of presenting data in tables or graphs. The collected experimental data became a convenient source of 'relevant' data for teaching the laptop skills students had to be taught.

Secondly, there was considerably less class time available to discuss the results of experiments and explore the meaning and significance of the collected data. The amount of work to be covered in the course increased with the addition of laptops, as all previous work was to be covered, plus the new laptop work. The result of this was that by the time the experiment was completed, data collected and entered into the laptop, and all students were able to manipulate the data as required, no time was left for discussing the meaning of the data and the associated information that could be extracted from it. The great pressure to move on, because the class was falling behind, usually only allowed for superficial coverage of both laptop and non-laptop related work.

Thirdly, the laptops were not used to help teach, or further increase the understanding of any science concepts. The laptops were used for data processing and word processing. For example, no software was available or used to teach any content in a creative or more effective manner. No 'probes' such as temperature, light, motion or sound sensors were available for connecting to the laptop to actually collect original data and have the data graphed, for example, as the data were being generated and collected. Students could not witness the creation of a distance-time graph as an object moved, then stopped and then moved in another direction for instance. They were only able to enter the data collected into their laptops and then produce the distance-time graph. By the time this occurred, many could no longer relate the actual motion of the object to the different sections of the graph. This was not really different to the collection and graphing of data in the non-laptop classroom, except it was done on the laptop and there was less time for extensive discussion of the data collected.

It is not surprising that even though laptop students showed more enthusiasm for learning, this did not translate into better achievement in science tests. Students learned computer skills using their laptops, but these skills were never tested on tests; students did not use the laptops to learn science concepts; and students were always rushed because of the large content component of the science course. It is not unreasonable to hypothesise that laptop students learned much about computing, but not more about science, when compared to non-laptop students. If the 'computing component' of the course was included in science tests, it is most likely achievement would have improved, because such tests would reflect what was actually taught in the classroom during laptop science lessons.

The technology aspect that laptops brought with them into the science classroom enthused and appeared to motivate students. They perceived learning how to use the laptops as important to their futures. The challenge appears to be to design science courses that harness the relevance students perceive in this technology, with the scientific concepts most valued in today's society. Science courses, where content is reduced and of secondary importance, and objective relevance is heightened through the use of information and other related technologies appear to be the ideal.

7.7 SUMMARY

This chapter has been a reflection of 'laptops in the science classroom experience' by the researcher. The researcher was at a school when the decision was made to introduce laptops, and was involved in the teaching of the grade 8 science laptop course.

The recounting of the experiences was based on perceptions, some of which were substantiated through discussions with students and staff, others that were simply perceptions or untested hypotheses. The purpose of these data were to provide another perspective to that provided by the analyses of the quantitative and qualitative data collected during this study.

The decision to introduce laptops was generally favourably received, even from the majority of staff who were very apprehensive about their ability to master the laptops, let alone teach classes using them. The experiences of using the laptops during the first few months were to everyone's expectations - students were totally enthusiastic about their use and many staff realised their worst fears, these being not having the expertise, necessary support and experience, to use the laptops effectively in the science classroom.

The science classroom environment changed, as did teacher interpersonal behaviour, when the laptops were being used in the classroom. Generally, students participated more in the teaching/learning process and the amount of teacher personal help students received fluctuated greatly between students. The teacher often exhibited behaviour that was far more authoritarian than 'normal' and often vented the frustration at not being able to help students, on students.

Students' enthusiasm for learning, with respect to using the laptops at least, was increased and their attitude to learning seemed to improve; however, students' achievement on tests did not improve. The main reasons for this appeared to be less time spent on science as relevant computing skills had to be taught. Furthermore, no course content was cut when the teaching of laptop skills was added thus reducing the time spent teaching science, and the laptop was not used to teach or enhance the explanation of science topics. Content-limited, technology-based science courses are favoured as a solution to these observed problems.

The next chapter draws together the findings in the previous three chapters. Firstly, it comments on the appropriateness of using the QTI and SCES in science laptop classroom research. Secondly, it presents the examination of the findings of the study in light of the research questions posed in Chapter 1. Thirdly, it provides a series of suggestions, schools contemplating the introduction of laptops, might find helpful in their deliberations to proceed or not. The last section of the chapter comments on the limitations of this study and identifies areas of possible further research.

CHAPTER 8

CONCLUSION

8.1 INTRODUCTION

This thesis reports on the findings of the research completed in grades 8 and 9 science laptop classrooms in a sample of Australian Independent schools. The research determined students' perceptions of science classroom environment and teacher-student interpersonal behaviour, and associations between these perceptions and attitudinal and cognitive achievement outcomes. Comparisons were also made between the laptop and non-laptop student groups in the areas of science classroom environment perception, teacher-student interpersonal behaviour perception, attitudinal outcomes and cognitive achievement outcomes. The QTI was validated for the first time, using a science laptop student sample. The ICEQ (the main component of the SCES used in this study) was also validated for the first time using a science laptop student sample. As the ICEQ was rewritten in the personal form, in the SCES, this is also the first validation of a personal form of the ICEQ.

This study has been distinctive in its contribution to the fields of teacher-student interpersonal behaviour and science classroom environment research, especially in the understanding of the effects laptop computers have had in these areas. More specifically, this study is unique in the following ways.

First, it makes a significant contribution to the classroom environment and teacher-student interpersonal behaviour fields of research, through the unique use of existing student perception measuring instruments. Students' perceptual data on science laptop classroom environment was gathered using an instrument based on the ICEQ classroom environment instrument whose items were rewritten from the class form to the personal form. The adapted ICEQ was shown to be a valid instrument that differentiated adequately between science laptop classrooms. With one exception, each scale had high reliability. Science laptop students' perceptual data on teacher-student interpersonal behaviour was gathered using the QTI, which has never been used in science laptop classrooms. The QTI proved to be a reliable and valid instrument for use in these classrooms.

Secondly, it is significant in its contribution to the understanding of classroom environment and teacher interpersonal behaviour in science laptop classrooms. This significance is further enhanced as the study examined associations between science laptop students' perceptions of classroom environment and students' attitudinal and cognitive achievement outcomes, and science laptop students' perceptions of teacher-student interpersonal behaviour and students' attitudinal and cognitive achievement outcomes. Comments, based on the student qualitative data collected are also provided, when appropriate, on the various quantitative findings.

Thirdly, it is significant in its contribution to what schools should do to help ensure the successful introduction of laptop computers into their science program. The suggestions should also prove valuable for schools wishing to further enhance their science laptop program. These suggestions are a result of the synthesis of the student quantitative data, the teacher qualitative data and researcher experience.

8.2 MAJOR FINDINGS OF THE STUDY

There were nine research questions posed in this study and each is restated below and addressed in turn.

Are the QTI and SCES valid and reliable instruments for use in science classrooms where laptop computers are in use?

Each QTI scale's internal consistency was shown to be satisfactory, as was each scale's ability to differentiate between classrooms. The circumplex nature of the scale arrangement of the QTI was also verified, with adjacent scales generally being correlated most positively and diametrically opposed scales generally being correlated most negatively.

The SCES (thus the ICEQ) instrument was also shown to have satisfactory scale internal consistency, scale differentiation and scale discriminant validity, with one exception. The Differentiation scale's internal consistency was lower than that desirable in educational research.

The descriptive statistics provided in Chapter 4 show that both the QTI and SCES, display satisfactory levels of reliability and validity for use as educational research instruments in science laptop classrooms. Furthermore, the qualitative data generally confirm the findings of this study, based on the information collected by the QTI and SCES, thus further adding to the sense of confidence with which these two instruments can be used in science laptop classroom research.

What are laptop students' perceptions of teacher-student interpersonal behaviour in science classrooms?

The quantitative data in Table 5.1 indicate that laptop students perceived their teachers as being very organised individuals who preferred structured classroom situations. Teachers were also perceived to be patient, interested in the students and their work, willing to join students in the learning process, show confidence in the students and exhibit considerable friendly behaviour toward students.

Student interview data revealed that teachers often gave students very prescriptive instructions, both written and verbal, when laptops were being used. Students also indicated teacher characteristics such as nervousness, non-confidence, frustration, and occasional short-temperedness in laptop classes. Teachers, when posed with these student perceptions, basically agreed with them and were not surprised students perceived these characteristics. Teachers felt they did not receive sufficient preparation to teach science using laptops and simply had to do it with whatever skills and knowledge they had. It seems logical that highly organised, prescriptive lessons could be a good coping mechanism for the lack of expertise in using laptops to teach science.

Students also felt they were not allowed much responsibility and freedom in science laptop classrooms. Teachers supported this student perception indicating they could not really give students responsibility and freedom because they did not know enough, in most areas of laptop use, to be comfortable in setting open-ended tasks or simply allowing students to experiment with their laptops.

The researcher's feeling of the necessity to adopt directive behaviour in classes when laptops were being used, and the feeling of being uncomfortable to adopt prolonged periods of behaviour that promoted student responsibility and freedom, further supported the students' perceptions of teacher behaviour.

In summary, all the collected data indicate that science laptop students perceived their teachers as exhibiting highly organised, prescriptive, caring, task-oriented and collaborative behaviours. However, there is evidence that some of these behaviours are probably the result of a lack of teacher expertise and experience in teaching science using a laptop computer, than simply because of laptops being used in the classroom.

What are laptop students' perceptions of classroom environment in science classrooms?

The data in Table 5.2 disclose that laptop students perceived their classrooms as being characterised by students having considerable decision-making power and control over their learning and behaviour, an active learning role for students, opportunity for teacher-student interaction and teacher concern for student well-being.

Student interview data indicate that students felt they had to become more independent and active in their learning, especially when laptops were being used as the teachers often did not have the expertise to help. This led to students interacting more with each other and becoming more involved in the teaching/learning process. Students also indicated that teachers generally spent 'hours and hours' with students who were struggling to use their laptops, while other students received little or no help. The teacher interview data support the students' feelings with regard to more student interaction and students having to help themselves more; however, they do not support the students' feelings that teachers spend hours with some students and little or no time with others.

The researcher's experiences supported the student qualitative data, that is, the feelings of students that they had to help themselves more in laptop classes and that there was a change in the amount of teacher individual help provided to different students. The reason for the latter change was because of the tremendous range of laptop computer competency amongst the students in the class.

To summarise, the collected data indicate that science laptop students perceived their classroom environment as allowing them considerable independence, where they can actively be involved in the learning process, and where they often have to depend on getting help from other students, and in turn offer help to others in need.

Are there any differences in students' perceptions of teacher-student interpersonal behaviour between laptop and non-laptop science classrooms?

The answer to this research question was explored in two ways. First to determine whether any statistically significant scale mean score differences existed, between the two groups, for each scale of the QTI, and secondly to determine the effect laptops had on students' perceptions for each scale of the QTI.

The data in Tables 5.3 and 5.4 suggest that, as individuals, laptop students perceived their teachers as exhibiting more indecisive, apologetic and giving student independence type behaviour, than did their non-laptop counterparts. As class groups, laptop science students held these same perceptions, plus they perceived their teachers also exhibiting more criticising and questioning type behaviour, than did their non-laptop counterparts.

In interviews, science laptop students readily talked about such things as their teachers being unable to help with laptop problems and telling them to ask a friend, being frustrated with students being unable to print and thus hand in work, being short-tempered and being intimidated by the presence of laptops in the classroom.

Teachers quite readily agreed with these students' comments and explained why they were exhibiting these behaviours. Reasons ranged from not having the expertise and experience to teach using laptops to the logistics of managing a laptop classroom. The researcher's own experiences of being overwhelmed by the demands of students in a science laptop classroom, and being continually pushed to the limits of his knowledge and experience with laptops, supported the teachers' statements.

To summarise, it appears that students in science laptop classrooms perceived their teachers as being more stressed, unsure of themselves, aggressive and critical, than do students in science non-laptop classrooms. The main reason for this unfavourable teacher-student interpersonal behaviour appears to be the lack of teacher preparation before being placed in a science laptop classroom.

Are there any differences in students' perceptions of classroom environment between laptop and non-laptop science classrooms?

These differences were explored using the same techniques as that used to answer the previous research question.

The data in Tables 5.5 and 5.6 suggest that science laptop students, as individuals, perceived their classroom as being characterised by slightly more selective treatment of students based on factors such as ability or rate of working, than do non-laptop students. This same perception is stronger when class groups of laptop and non-laptop students are compared. Laptop class groups also perceived their science classrooms as being characterised by a greater emphasis on inquiry learning, opportunities to explain or justify newly learned material and more control over personal learning and behaviour.

Comments made by students during interviews indicated that teachers often spent much more time with students struggling to use the laptops while other students received little or no help. Student comments also indicated they often had to find out for themselves, by trial and error or from friends, as the teacher could not help because of a lack of computer expertise or being 'stuck' with several very weak students. Once again, teachers generally agreed with the students' comments, except for the amount of help given individual students ranging from hours to none. Teachers indicated their lack of expertise and experience with laptops in science, and the great range of computer literacy amongst the students, were probably the main factors contributing to the science laptop classroom environment. The researcher's experience indicated agreement with the students' comments that there was a change in the amount of help provided individual students, and that the amount of help given was very unequal.

Most of the data collected provide evidence that science laptop students perceived their classroom as being characterised by greater differentiation, a greater emphasis on skills and problem solving, a greater emphasis on students sharing and explaining ideas to each other and more student decision making, than do science non-laptop students.

What associations exist between laptop students' perceptions of teacher-student interpersonal behaviour in science classrooms, and their attitudinal and cognitive achievement outcomes?

Associations were determined by calculating simple correlations between each QTI scale and each student outcome, and multiple correlation beta weights between each QTI scale and each student outcome.

Laptop students' attitude to science is significantly associated with their perceptions of teacher-student interpersonal behaviour in 10 out of 16 possible associations (see Table 5.7). The most positive associations occurred in science classrooms where laptop students perceived their teachers as being organised, interested, friendly, humorous and leaders. The opposite was true when laptop students perceived their teachers as being angry, irritated, and continually taking students to task.

Eight out of 16 possible associations, between laptop students' cognitive achievement and their perceptions of teacher-student interpersonal behaviour, are significant. The data in Table 5.7 shows that there were no strongly positive associations between cognitive achievement and any particular teacher-student interpersonal behaviours as perceived by students. However, there was one strongly negative association, and this occurred when students perceived indecisive and apologetic teacher-student interpersonal behaviour.

The qualitative data collected indicates no association between attitude and cognitive achievement in science because the student, teacher and researcher data indicated that 'more' or 'better' science was not necessarily taught using the laptops. All agreed that much was taught about computing, and the use of laptops to do science tasks such as making tables, graphing, report writing and doing projects, but little was done to aid students understand the concepts of science. Perhaps the two main reasons for this were because teachers felt they were continually rushed for time and that laptops were simply used as data processing and presentation tools.

To summarise, it appears that students' attitude to science is associated more strongly to their perceptions of teacher-student interpersonal behaviour than is their cognitive achievement in science. However, because laptops were not used to teach science concepts, it is not surprising that this difference in association between the two outcomes and students' perceptions of teacher-interpersonal was found.

What associations exist between laptop students' perceptions of classroom environment in science classrooms, and their attitudinal and cognitive achievement outcomes?

Associations between each SCES scale and each of the student outcomes were determined using the same techniques as in the previous question.

Of the 12 possible associations between laptop students' attitude to science and their perception of science classroom environment, in Table 5.8, eight are significant. The most positive associations occurred in science laptop classrooms students perceived to be characterised by individual student interaction with the teacher, concern for general student welfare and an emphasis on inquiry and problem solving skills. No strongly negative associations were shown to exist.

Table 5.8 indicates that laptop students' cognitive achievement in science is significantly associated with their perceptions of science classroom environment in five out of 12 possible associations. The data also indicate that of the positive associations between cognitive achievement and students' perceptions of classroom environment, none were strong. Only one strongly negative association occurred, this being when laptop students perceived their science classroom characterised by the selective treatment of students based on personal characteristics such as ability or rate of working.

As already stated, the qualitative data indicated no association between attitude and cognitive achievement in science, because science was not necessarily taught using the laptops. The probable reasons for this also were stated earlier.

In summary, science laptop students' attitude to science is associated more strongly to their perceptions of classroom environment than is their cognitive achievement in science.

Are there any differences in attitude to science between laptop science students and non-laptop science students?

The answer to this research question was arrived at by determining if any statistically significant scale mean score differences existed between the laptop and non-laptop groups and the calculation of effect sizes.

The quantitative data in Tables 5.9 and 5.10 indicate that science laptop students, as individuals, perhaps have a slightly better attitude to science than their non-laptop counterparts. When examining class groups, it is evident that science laptop students do have a better attitude to science than do their non-laptop counterpart class groups.

The student interview data supports these finding of an improvement in attitude to science by laptop students. Laptop students indicated aspects of science as being more fun, easier, neat and new when laptops were used. However, others felt there was no change and they passed on the observation that attitude to science depended how well students could use the laptops in science. Those students that were proficient at using laptops also had good attitudes to science, and vice versa.

Teachers' interview data generally supported the students' interview data with observations such as the students being much more enthusiastic, and aspects of science-related tasks 'coming alive' when laptops were used. The researcher's perceptions supported the teachers' data. Overall, it appears the teachers and the researcher felt that the effects of laptops on students' attitude to science, would be greater than the student quantitative and qualitative data indicate.

In summary, laptop science students indicated that laptops made doing some of the mundane data analysis tasks in science easier and more fun, and that laptops allowed them to present professional looking reports and projects. This would account for the better overall attitude. However, it appears that this better overall attitude may be more closely associated with how well students can use the laptop, than the mere presence of the laptop.

Are there any differences in cognitive achievement between laptop science students and non-laptop science students?

The answer to this research question was determined using the same procedure as that for the previous research question.

The data in Tables 5.9 and 5.10 show that there were only negligible differences between the cognitive achievement outcomes of science laptop students and their non-laptop counterparts.

Student qualitative data reveal that laptop students felt that laptops did not help with their knowledge of science nor their understanding of science. Laptop students perceived themselves as being able to construct graphs, charts and tables much more quickly using laptops, but they did not perceive themselves as having greater cognitive ability in these areas because of laptops. Generally students felt that the greatest advantage of laptops in science was that graphs, charts and tables could be completed quickly and neatly.

Teachers offered the observations that students often asked more questions about the computer than science, and that students were often more engrossed in learning a particular computer application than the science being taught. The researcher's perspective added to these teacher observations, the experience of usually rushed lessons and the fact that the laptops were only used as tools for word processing, graphing and other related functions.

To summarise, there appeared to be no differences in cognitive achievement between laptop science students and non-laptop science students. The main reason for this appears to be that laptops were not being used to teach scientific knowledge or understanding, instead they were used simply as tools in science classrooms. Other related reasons appeared to be that students are more interested in learning how to use the computer than the underlying scientific concept being taught and the curriculum being too full of content material.

8.3 IMPLICATIONS OF THIS STUDY

8.3.1 For Teachers in Science Laptop Classrooms

Science teachers using laptop computers now have access to two classroom research instruments, the QTI and SCES, that, for the first time, have been validated and proven reliable when used in science laptop classrooms. Science laptop teachers can use either of these two instruments with confidence, whether simply wishing to know students' perceptions of their efforts, or whether seeking to formally evaluate their science laptop program.

Another implication for science laptop teachers is to perhaps plan their laptop lessons in a manner that allows for more student responsibility and freedom. Students felt they were not given much responsibility and freedom, but appeared to value such opportunities when using laptops. Science laptop teachers must also become aware of the greater tendency for teachers to get caught up in helping students struggling with their laptops, lesson after lesson, to the detriment of other students in the class. Laptop teachers must also not assume that students learn to read and interpret graphs, for example, by simply using the laptop to create graphs.

The third implication for science laptop teachers is that certain teacher-student interpersonal behaviours and certain science classroom characteristics, play an important role in determining students' attitudes to science and, to a lesser extent, their cognitive achievement in science.

The most positive students' attitudes to science are present in science laptops classrooms where students perceive their teacher as being organised, task oriented, caring, interactive, considerate and inspiring; and when they perceive their classroom as having an emphasis on student-teacher interaction, personal welfare of students, skills and processes of inquiry and the application of these in problem solving. Negative attitudes develop when laptop students perceive their teachers as always getting angry, always forbidding students from doing things and always correcting and punishing.

On the other hand, no particular laptop students' perceptions of teacher-student interpersonal behaviours, or science classroom environments, promote student cognitive achievement. However, laptop students' cognitive achievement is suppressed when students perceive their teachers as apologetic, indecisive and insignificant, and when they perceive an emphasis, in the science classroom, on the selective treatment of students based on such factors as ability, interests and learning style.

8.3.2 For Schools Planning to Introduce Laptops In Science Classrooms

Based on the experiences of science teachers at two schools that introduced and use laptop computers in science, the researcher's own experience at a school that introduced and uses laptops in science, and the backdrop of the quantitative and qualitative data collected in this study, the following plan is proposed as an 'ideal minimum plan' schools should follow to effectively introduce laptop computers in science.

First, the decision to introduce laptops should be part of the school's long term strategic plan. The strategic plan must include at what year level, or levels, laptops will first be introduced and how the introduction will progress in subsequent years, with adequate financing, staffing and lead-time being crucial.

Adequate finance is necessary to meet extra staff salaries, the cost of laptops for staff, printers, power leads, redesigning of classrooms, running of optic fibre cables to classrooms, Internet access, servicing and repairing of equipment, software and other costs that may be school specific. A consultant or permanent staff member with expertise and experience in teaching science, using laptops, must be involved when the implementation plan is being formulated and finalised. A lead-time of at least one year is necessary for adequate staff and program development.

Second, an implementation plan must be developed and finalised that, at minimum, addresses the following points.

Firstly, how laptops will be used in the teaching of science. For an effective science laptop program, it is crucial that laptops be used to actually teach, assimilate, interpret and comprehend scientific truths. Laptops must not be used simply as tools for the manipulation and presentation of data, or the production of scientific reports and projects.

Secondly, what equipment and materials will be needed to use the laptops effectively in the science classroom, and what skills teachers and students will need to acquire to effectively use this equipment and materials in conjunction with their laptops.

Thirdly, how students are to be taught the laptop skills necessary to do science. Will individual science teachers be responsible for teaching all skills necessary for science, or will there be a centralised approach were students will be taught most skills by a specialist, or will students learn different skills in different subjects?

Fourthly, an in-service professional development schedule for teachers must be designed to enable them not only to learn the new skills necessary, but to practise them until they are proficient. This training schedule must extend at least throughout one semester, occur weekly and involve some staff release time from normal duties. Teachers will need to gain expertise and experience in all the skills students will learn, even if these skills are taught to students by a specialist or in other subjects.

Fifthly, the assignment of staff, or the hiring of consultants as necessary, to prepare materials, review and purchase appropriate software, and aid and support staff as and when needed.

Other points worthy of consideration and strongly recommended include, first, providing staff with their own laptop computer, at least initially. This services two main purposes, it provides a positive attitude to the innovation, and it motivates staff and makes them feel obligated to make more of an effort as they feel they 'owe' the school. Second, the redesigning of classrooms to accommodate laptops. At minimum, connection facilities to the Internet and school resource centre, and sufficient power points in positions to avoid cords running across desks and isles. And third, providing staff ongoing professional development and in-service in subsequent years, to allow staff to stay abreast of the new laptops, equipment and software that will be introduced into the program.

8.4 LIMITATIONS OF THE STUDY

Perhaps the greatest limitation of this study is that the sample consisted of only volunteer Independent schools, and thus the findings may not be representative of schools in general using laptop computers in science, or even all Independent schools using laptop computers in science. Furthermore, the sample only involved grades 8 and 9 students, which indicates even more caution must be exercised when generalising from the results to all science classrooms where laptops are used.

A second limitation of this study is that most schools in the sample had only used laptops in science for one or two years before the data were collected. As with any educational innovation, the first few years are fraught with problems and difficulties that affect student perceptions, attitudes and achievement. Because of this, the findings may be more of a reflection of the situation of the effects laptops have when they are introduced into science classrooms, than the situation that exist after laptop use has been established. Thus caution must be exercised if generalising the results to schools that have established laptop science programs, or even to the situation that exists today in the schools that participated in this study.

A third limitation is that the cognitive achievement instrument tested purely non-content specific science skills. Student and teacher interviews, and researcher experience, indicate that students learned much about computing, but not much more about science. Students obviously acquired skills and knowledge not tested for by the cognitive achievement instrument, thus caution must also be exercised if generalising that laptop students did not learn more than their non-laptop counterparts, because of there being no significant difference in the cognitive achievement outcomes between the two groups. Such a generalisation can only be applied to the study sample and only to the science concepts that were tested by the cognitive achievement instrument.

The fact that only a very small sample of laptop students were interviewed, 13 out of the quantitative sample of 433, and that their comments have been used to generalise about the total laptop sample, is the fourth limitation of this study. Although the interviewees did provide very valuable insights into what they experienced and how they felt about using laptops in science, their comments must not be generalised, without caution, to the science laptop student population sample in this study, and the science laptop student population in all schools.

8.5 SUGGESTIONS FOR FURTHER RESEARCH

One area of further research that arises out of this study is a study involving only those schools that have used laptop computers in science for a considerable length of time, perhaps five or more years. Such a study would determine more accurately the effectiveness of laptop computers in science classrooms, as the data collected would be less influenced by the introductory experiences of laptops in science classrooms. To further extend the generalisation of the findings, schools from all education sectors should be involved in a future study, and the grade level range should be broadened.

Another interesting area of further research in science laptop classrooms, would be to establish how laptops are used in the teaching of science in the various schools involved in the study. This study has revealed that laptops were used mainly as tools for data manipulation and presentation of work. It would be interesting to determine the effectiveness of laptops in science classrooms, where laptops are used in conjunction with various probes, extensive data bases and excellent software; and where laptops are actually used to teach and enhance student learning of scientific principles, rather than simply as data processing and presentation enhancement tools.

Such an analysis would provide valuable knowledge, with regard to the effectiveness of laptops in relation to how they are used in the teaching of science.

The associations between students' attitude to science and each of teacher-student interpersonal behaviour and science classroom environment were found to be fairly strong in this study. However, this was not the case for students' cognitive achievement. Therefore, a third area of further study would be to complete a study that concentrates on identifying those factors of teacher-student interpersonal behaviour and classroom environment, in science laptop classrooms, that have strong associations with student cognitive achievement. This would prove valuable information for science laptop teachers.

A fourth area of further research that would provide valuable knowledge for science laptop teachers, would be a study to determine the extent to which certain teacher-student interpersonal relationships, or aspects of science classroom environment, actually cause changes in laptop students' attitudinal and cognitive achievement outcomes. This study reported on associations only, which do not allow for causal interpretations.

8.6 FINAL COMMENTS

The findings of this thesis have indicated that, to date, laptop computers in the science classrooms have resulted in slightly more positive student attitudes to science, but that they have not made any impact on students' cognitive achievement in science. Postulated reasons for the lack of impact on cognitive achievement include the purposes for which laptops were used in science classrooms and the lack of teacher expertise and experience in teaching science using laptop computers.

Associations between students' attitudinal and cognitive achievement outcomes with their perceptions of teacher-student interpersonal behaviour, and associations between students' attitudinal and cognitive achievement outcomes with their perceptions of science classroom environment were also identified in this study.

As the results of this thesis are the first reported on the effectiveness of laptop computers in science classrooms, from a teacher-student interpersonal behaviour and science classroom environment perspective, the results have important practical applications for science laptop teachers and schools considering the introduction of laptops in science. The findings of the thesis also add to the general knowledge base of teacher-student interpersonal behaviour and science classroom environment research.

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APPENDICES

Appendix A Questionnaire on Teacher Interaction (QTI)

QUESTIONNAIRE ON TEACHER INTERACTION

- STUDENT PERCEPTIONS -

This questionnaire asks you to describe the behaviour of your teacher. This is NOT a test. Your opinion is what is wanted.

This questionnaire has 48 sentences about the teacher. For each sentence, circle the number corresponding to your response. For example:

	Never				Always
This teacher expresses himself/herself clearly.	0	1	2	3	4

If you think that your teacher always expresses himself/herself clearly, circle the 4. If you think your teacher never expresses himself/herself clearly, circle the 0. You also can choose the numbers 1, 2 and 3 which are in between. If you want to change your answer, cross it out and circle a new number. Thank you for your cooperation.

Please provide the details in the box below and then turn the page and give an answer to every question.

ALL INFORMATION PROVIDED WILL BE TREATED AS STRICTLY CONFIDENTIAL INFORMATION.

a. Do you use laptop computers in this class? (please circle): Yes No

b. Gender (please circle): Male Female

c. School: ____________________ e. Grade/Class: __________

d. Name: ____________________ f. Teacher: ____________

This page is a supplement to a publication entitled *Teacher and Student Relationships in Science and Mathematics Classes* authored by Theo Wubbels and published by the national Key Centre for School Science and Mathematics at Curtin University of Technology.

	Never				Always	Teacher Use
1. This teacher talks enthusiastically about her/his subject.	0	1	2	3	4	Lea
2. This teacher trusts us.	0	1	2	3	4	Und
3. This teacher seems uncertain.	0	1	2	3	4	Unc
4. This teacher gets angry unexpectedly.	0	1	2	3	4	Adm
5. This teacher explains things clearly.	0	1	2	3	4	Lea
6. If we don't agree with this teacher, we can talk about it.	0	1	2	3	4	Und
7. This teacher is hesitant.	0	1	2	3	4	Unc
8. This teacher gets angry quickly.	0	1	2	3	4	Adm
9. This teacher holds our attention.	0	1	2	3	4	Lea
10. This teacher is willing to explain things again.	0	1	2	3	4	Und
11. This teacher acts as if she/he does not know what to do.	0	1	2	3	4	Unc
12. This teacher is too quick to correct us when we break a rule.	0	1	2	3	4	Adm
13. This teacher knows everything that goes on in the classroom.	0	1	2	3	4	Lea
14. If we have something to say, this teacher will listen.	0	1	2	3	4	Und
15. This teacher lets us boss her/him around.	0	1	2	3	4	Unc
16. This teacher is impatient.	0	1	2	3	4	Adm
17. This teacher is a good leader.	0	1	2	3	4	Lea
18. This teacher realises when we don't understand.	0	1	2	3	4	Und
19. This teacher is not sure what to do when we fool around.	0	1	2	3	4	Unc
20. It is easy to pick a fight with this teacher.	0	1	2	3	4	Adm
21. This teacher acts confidently.	0	1	2	3	4	Lea
22. This teacher is patient.	0	1	2	3	4	Und
23. It's easy to make a fool out of this teacher	0	1	2	3	4	Unc
24. This teacher is sarcastic.	0	1	2	3	4	Adm
25. This teacher helps us with our work.	0	1	2	3	4	HFr
26. We can decide some things in this teacher's class.	0	1	2	3	4	SRe
27. This teacher thinks that we cheat.	0	1	2	3	4	Dis
28. This teacher is strict.	0	1	2	3	4	Str
29. This teacher is friendly.	0	1	2	3	4	HFr
30. We can influence this teacher.	0	1	2	3	4	SRe
31. This teacher thinks that we don't know anything.	0	1	2	3	4	Dis
32. We have to be silent in this teacher's class.	0	1	2	3	4	Str
33. This teacher is someone we can depend on.	0	1	2	3	4	HFr
34. This teacher lets us fool around in class.	0	1	2	3	4	SRe
35. This teacher puts us down.	0	1	2	3	4	Dis
36. This teacher's tests are hard.	0	1	2	3	4	Str
37. This teacher has a sense of humour.	0	1	2	3	4	HFr
38. This teacher lets us get away with a lot in class.	0	1	2	3	4	SRe
39. This teacher thinks that we can't do things well.	0	1	2	3	4	Dis
40. This teacher's standards are very high.	0	1	2	3	4	Str
41. This teacher can take a joke.	0	1	2	3	4	HFr
42. This teacher gives us a lot of free time in class.	0	1	2	3	4	SRe
43. This teacher seems dissatisfied.	0	1	2	3	4	Dis
44. This teacher is severe when marking papers.	0	1	2	3	4	Str
45. This teacher's class is pleasant.	0	1	2	3	4	HFr
46. This teacher is lenient.	0	1	2	3	4	SRe
47. This teacher is suspicious.	0	1	2	3	4	Dis
48. We are afraid of this teacher	0	1	2	3	4	Str

For Teacher's Use Only: Lea ____ Und ____ Unc ____ Adm ____ HFr____ SRe ____ Dis ____ Str ____

Appendix B Student Cognitive Achievement Measurement Instrument

STUDENT COGNITIVE ACHIEVEMENT MEASUREMENT INSTRUMENT

FROM: TEST OF ENQUIRY SKILLS TEST BANK

SCIENCE CLASSROOM ENVIRONMENT SURVEY (SCES)

- STUDENT PERCEPTIONS -

DIRECTIONS

1. This questionnaire asks you to describe this classroom which you are in right now. There are no right or wrong answers. This is **NOT** a test. Your opinion is what is wanted.

2. **All answers will be treated as strictly confidential information.**

3. On the next few pages you will find 40 sentences. For each sentence, circle one number corresponding to your answer.

   For example:

	Almost Never	Seldom	Some-times	Often	Very Often
In this class...					
The teacher talks with me.	1	2	3	4	5

   - If you think this teacher **almost never** talks with you, circle the 1.
   - If you think this teacher **very often** talks with you, circle the 5.
   - If you think this teacher is somewhere between the two extremes, then circle the 2, 3 or 4 to indicate the amount you think this teacher talks to you.

4. If you want to change your answer, **cross it out** and circle a new number, e.g.:

   1 2 (3) 4 ~~5~~.

5. Please provide the details in the box below:

   a. Do you use laptop computers in this class? (please circle): Yes No

   b. Gender (please circle): Male Female

   c. School: ____________________ e. Grade/Class: __________

   d. Name: ____________________ f. Teacher: __________

6. Now turn the page and please give an answer for every question.

SCIENCE CLASSROOM ENVIRONMENT SURVEY (SCES)

REMEMBER: You are rating what **actually** happens in this class.

	Almost Never	Seldom	Some-times	Often	Very Often
In this class...					
1 The teacher talks with me.	1	2	3	4	5
2 I give my opinions during discussions.	1	2	3	4	5
3 The teacher decides where I sit.	1	2	3	4	5
4 I find out answers to questions from textbooks rather than from investigations.	1	2	3	4	5
5 I do different work from other students	1	2	3	4	5
6 The teacher pays more attention to boys' questions than to girls'.	1	2	3	4	5
7 I talk with other students about how to solve problems.	1	2	3	4	5
8 I look forward to the learning activities	1	2	3	4	5
In this class...					
9 The teacher takes a personal interest in me.	1	2	3	4	5
10 The teacher lectures without me asking or answering questions.	1	2	3	4	5
11 I choose my partners for group work.	1	2	3	4	5
12 I carry out investigations to test ideas.	1	2	3	4	5
13 I do the same work at the same time as all other students.	1	2	3	4	5
14 Girls get less individual help from the teacher than do boys.	1	2	3	4	5
15 I try to make sense of other students ideas.	1	2	3	4	5
16 The activities are among the most interesting at this school.	1	2	3	4	5
In this class...					
17 The teacher is unfriendly to me.	1	2	3	4	5
18 My ideas and suggestions are used during class discussion.	1	2	3	4	5
19 I am told how to behave in the classroom.	1	2	3	4	5
20 I carry out investigations to answer questions coming from class discussions	1	2	3	4	5
	Almost Never	Seldom	Some-times	Often	Very Often

(Continued on other side)

SCIENCE CLASSROOM ENVIRONMENT SURVEY (SCES)

REMEMBER: You are rating what **actually** happens in this class.

	Almost Never	Seldom	Some-times	Often	Very Often
In this class...					
21 I use different books, equipment and materials than do other students.	1	2	3	4	5
22 Boys have more say than girls.	1	2	3	4	5
23 I ask other students to explain their ideas.	1	2	3	4	5
24 The activities make me interested in science.	1	2	3	4	5
In this class...					
25 The teacher helps me if I am having trouble.	1	2	3	4	5
26 I ask the teacher questions.	1	2	3	4	5
27 The teacher decides which students I should work with.	1	2	3	4	5
28 I explain the meanings of statements diagrams and graphs.	1	2	3	4	5
29 I move on to other topics if I work faster than other students.	1	2	3	4	5
30 Girls and boys are treated the same.	1	2	3	4	5
31 Other students ask me to explain my ideas.	1	2	3	4	5
32 I enjoy the learning activities.	1	2	3	4	5
In this class...					
33 The teacher considers my feelings.	1	2	3	4	5
34 There is classroom discussion.	1	2	3	4	5
35 The teacher decides how much movement and talk there should be in the classroom.	1	2	3	4	5
36 I carry out investigations to answer questions which puzzle me.	1	2	3	4	5
37 The same teaching aid (e.g. black-board or overhead projector) is used for all students in the class.	1	2	3	4	5
38 The teacher expects the same standards of work from boys and girls.	1	2	3	4	5
39 Other students explain their ideas to me.	1	2	3	4	5
40 The learning activities are a waste of time.	1	2	3	4	5
	Almost Never	Seldom	Some-times	Often	Very Often

Professor Barry J Fraser
Director National Key Centre for School Science and Mathematics

University of Technology
Western Australia

GPO Box U 1987
Perth 6845
Western Australia

Kent Street
Bentley 6102
Western Australia

Appendix D Letter Introducing Researcher to Schools

School
Address
Date

Dear Sir/Madam

Mr Ed Stolarchuk is enrolled in the Doctorate of Philosophy Program (Part-time), in the Science and Mathematics Education Centre, Curtin University of Technology, Perth, Western Australia.

Curtin's PhD award is a degree by research and involves the preparation of a thesis which will make a substantial and original contribution the subject area being investigated. His chosen area of research and thesis preparation is entitled 'An Evaluation of the Effectiveness of Laptop Computers in Science Classrooms', which brings me to the purpose of this letter.

I am writing to enlist your support to enable him to carry out his research. To this end, I would be grateful if you (or a member of your staff given your approval) would fill in the attached questionnaire and return it to Ed in the enclosed self-addressed envelope, preferably before August 31, 1994. Should you agree to support his research it will involve the administration, by the classroom teacher, of three questionnaires (one on classroom environment, one on interpersonal behaviour and an achievement test) at approximately this time next year and possibly a classroom observation and interview by Ed (10% of participating schools will be asked to participate in the latter).

Ed's research will involve collecting information from both 'laptop schools' and 'non-laptop schools' so that a valid evaluation can be done, thus he is eager to enlist you support even if your school does not use laptops to teach the science curriculum in this point in time. In return for your support and school's co-operation we will supply you/your school with an executive summary of the findings of the research in late 1997/early 1998 which is the anticipated date of the thesis completion.

Thank you for your consideration.

Yours sincerely

DARRELL FISHER (Dr)
Associate Professor
Science and Mathematics Education Centre

Encl

NATIONAL KEY CENTRE FOR SCHOOL SCIENCE AND MATHEMATICS

Fax +61 8 9266 2503
Tel +61 8 9266 7896
Email:
ismec@info.curtin.edu.au

AN EVALUATION OF THE USE OF LAPTOP COMPUTERS IN SCIENCE EDUCATION

SCHOOL: Name
Address
Postcode

INSTRUCTIONS: Please respond to each statement by placing a tick, in the space provided following each statement.

1. This school uses laptop computers in the science classroom.

   YES ____________ NO ____________

   [If you answered YES to Number 1, proceed to Number 2; if you answered No to Number 1, proceed to Number 3]

2. Laptop computers are used in science classrooms in the followinggrades:

   Eight ____________ Nine ____________
   Ten ____________ Eleven ____________
   Twelve ____________

3. This school is willing to participate in the research on laptop computers in science classrooms.

   YES ____________ NO ____________

4. This school has at least 2 classes in the following grades that could be used in this study.

   Eight ____________ Nine ____________
   Ten ____________ Eleven ____________
   Twelve ____________

5. This school would be willing to participate in a classroom observation/interview situation should it be selected.

   YES ____________ NO ____________

THANK YOU FOR YOUR PRECIOUS TIME USED IN RESPONDING TO THIS QUESTIONNAIRE.

Appendix E QUESTIONNAIRE RE: STUDENTS TO PARTICIPATE IN RESEARCH

SCHOOL: ____________________________

Contact Person: ______________________

1. This School:
   __ (a) has **both** laptop and non-laptop science classes in grade 8
   __ (b) has **both** laptop and non-laptop science classes in grade 9
   __ (c) has **only laptop science classes** in grades 8 and 9
   __ (d) has **only non-laptop science classes** in grades 8 and 9
   __ (e) other - specify: ______________________________________

2. The following classes will take part in the research which involves the filling in of three short questionnaires: Please state entire name/code, for example, 8EST Science, or 8.1 Science etc.

Year 8:	Class: _____	Number in class: ____	Use laptops: Y/N
	Class: _____	Number in class: ____	Use laptops: Y/N
	Class: _____	Number in class: ____	Use laptops: Y/N
	Class: _____	Number in class: ____	Use laptops: Y/N
Year 9:	Class: _____	Number in class: ____	Use laptops: Y/N
	Class: _____	Number in class: ____	Use laptops: Y/N
	Class: _____	Number in class: ____	Use laptops: Y/N
	Class: _____	Number in class: ____	Use laptops: Y/N

3. This School:

   ______ (a) will make its own copies of the "Permission to Participate in Research" forms for each student that will participate in the research.

   ______ (b) will require the researcher to provide the appropriate number of copies of the "Permission to Participate in Research" forms for each student that will participate in the research.

Thank you the time taken to fill in this questionnaire. Expect to receive class sets of the three questionnaires in late June/early July. I would like questionnaires completed, at your convenience, in late July/early August and posted back to me by late August/early September. Please return this questionnaire to me before May 30, 1995. Thanks.

Appendix F PERMISSION TO PARTICIPATE IN RESEARCH

Parents of Grade 8/9 Laptop/Non-laptop Science Classes

My name is Ed Stolarchuk and I am a part-time Doctoral student (Science and Mathematics Education Centre), Curtin University of Technology, Perth, Western Australia. I am currently teaching at an Independent School (in Cairns, Queensland) which has just introduced laptop computers into the secondary school - my area of interest and research is to determine the effectiveness of laptop computers in science classrooms at the grades 8 and 9 levels in Australian Independent schools.

Specifically, I am interested in ascertaining the impact of laptop computers on: the classroom environment, teacher interpersonal relationships in the classroom, student attitudes toward the subject science, and student cognitive achievement in science. Furthermore, I wish to highlight strengths of laptop computers in science (if any) and formulate a plan that schools may find useful when contemplating the introduction of laptop computers into the science classroom.

My research would involve your son or daughter (in either a laptop class or non-laptop class) answering three questionnaires which would take approximately 60 to 70 minutes to complete, and in one or two cases, a personal interview at some later date, at a time convenient to your school and son or daughter. All data collected will be treated as confidential and any published results will NOT reveal student, staff or school names.

If you agree to your son or daughter's participation, please sign the slip below and return it to your son or daughter's classroom teacher by _______________. If you have any questions about any aspect of this research, please do not hesitate to contact me directly [34 Vista Street Bayview Heights, Queensland. 4868; telephone (070) 332 669].

In return for your school's and your co-operation in my research, your school will receive an executive summary of my findings in late 1997/early 1998, the anticipated date of my thesis completion. Thank you in advance for you co-operation.

Yours sincerely,

Ed Stolarchuk

I hereby grant permission for my son/daughter ________________ (name) to answer questionnaires related to the research being conducted by Ed Stolarchuk into the effectiveness of laptop computers in science classrooms. My son/daughter is/is not (strike out which is not applicable) a laptop user.

Parent signature: ______________________________

Date: ____________________