Science and Mathematics Education Centre

The Development and Validation of a Learning Environment Instrument for CSIRO Science Education Centres

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Abstract

Past research into defining and measuring the characteristics of learning environments in Science Education Centres and Science Museums (SECSMs) has been based upon low-inference measures, such as observations and interviews. Many researchers feel that the diversity of informal education settings in SECSMs makes it difficult to develop high-inference measures for informal learning environments. This study used the semi-formal environment of the CSIRO Science Education Centres as a stepping-stone between formal and informal learning environments. A review of learning environment research identified a possible procedure for the development of, and a format for, a suitable instrument. Research in SECSMs was reviewed to identify learning environment factors that defined the CSIROSEC learning environment. A pilot study was conducted to determine the feasibility of developing a learning environment instrument for CSIROSECs. This led to the more formal process of developing a learning environment instrument for CSIROSECs based upon the five scales of Affect, Social Interaction, Novelty, Independence and Involvement. A number of cycles of testing of the instrument, statistical analyses, and subsequent refinements resulted in the Learning Environment Instrument for CSIRO Science Education Centres (LEI for CSIROSECs). The instrument measures distinct, if somewhat overlapping, aspects of the learning environment. The LEI for CSIROSECs displays comparable measures for internal consistency (alpha reliability) and discriminant validity to existing learning environment instruments. The sensitivity of the instrument has been demonstrated for the comparison of different classes, comparison of teacher-student perceptions, comparison of primary and secondary classes, and the comparison of CSIROSEC programs. Suggestions have been made for applications of the LEI for CSIROSECs and its further development, as well as its potential use in research.

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Introduction and Purpose

Introduction

Science Education Centres and Museums (SECSMs) are increasingly characterised by informal learning environments wherein visitors can actively explore scientific principles and phenomena. Much of the knowledge that has been garnered about SECSMs is anecdotal and craft wisdom (Ramey-Gassert, Walberg, & Walberg, 1994). There is great value to science education in more accurately describing and defining the unique characteristics of SECSM learning environments. To do this it may be useful to borrow and adapt techniques from the expanding area of classroom and school learning environment research. There may be great benefit in the coordination of research between the classroom and SECSM learning environments, leading to the acquisition of a better understanding of the learning of science in places like SECSMs.

Rennie (1998) has encouraged researchers in the field of SECSMs to "continue to broaden the research base, by asking a wider range of questions and using a greater variety of research methods and tools to take account of the complexity of the variables involved" (p. 5).

This research enters into the spirit of providing a beginning point for subsequent researchers, by developing a research tool to measure salient aspects of the science learning environment in a SECSM. The research is limited to CSIRO Science Education Centres, with the hope that there is much that other SECSMs can borrow and adapt for their own purposes.

Background

Approaches to SECSM research

The unique nature of SECSMs requires careful thought about approaches to research, starting with new research questions and ways of collecting data (Falk, Koran, & Dierking, 1986). "Much of the literature pertaining to learning in museums is anecdotal and craft wisdom, indicating that more collaborative research efforts are needed in the area of science education in museum settings" (Ramey-Gassert et al., 1994). This view is echoed by Falk and Dierking (1995) who add that "previous attempts to define and measure learning in museums have lacked both a clear focus and a well-formulated theoretical underpinning" (p. 9). McManus (1988) cautions that formal education, with its focus on the individual-as-learner, may not be entirely suitable for studies of informal educational environments such as those found in SECSMs. Griffin and Symington (1998) add that more value may reside in studies on how students are learning than in what they have learned.

In their review of research in science centres, Rennie and McClafferty (1996) conclude "there emerged a picture consistent at only the most general level, which suggests that some cognitive, affective and psychomotor learning occurs most of the time, but there is considerable variation across science centres and also across exhibits within centres" (p. 86). Semper (1990) claims that research on learning in museums is difficult because of the "episodic nature of the interaction, the divergent backgrounds of the visitors, the free-form nature of a museum visit itself and the non-verbal character of the experiences that museums particularly excel in providing" (p. 4). Feher and Diamond (1990), on the other hand, focus upon the positive benefits of using science centres as laboratories for studying how people learn because of their large audiences, free-choice environments, and interactive exhibits. Lucas and McManus (1986) emphasise that data collection wherein the visitor reconstructs the experience immediately after the event is preferable to intervention by a researcher during the session. This is further reinforced by Lucas, McManus, and Thomas (1986) who emphasise the need to preserve the informal context if the results are to be valid.

What is a CSIROSEC?

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is a statutory body of the Commonwealth Government. It is the largest scientific and industrial research body in Australia, with research centres located in every state and territory. As one means of promoting its activities and, at the same time, making a contribution to science education, the CSIRO established a Science Education Centre in Melbourne during the early 1980s as a pilot study. The success of the Melbourne CSIRO Science Education Centre (CSIROSEC) led to the establishment of a larger centre in Adelaide in 1985. This was followed quickly with the establishment of a CSIROSEC in Tasmania and in subsequent years CSIROSECs have been established in every capital city, including the national capital, Canberra, and two centres in Queensland, one in Brisbane and the other in Townsville.

CSIROSECs are hands-on science and technology centres, which cater for school groups in class sizes of approximately 30 students. Some CSIROSECs have diversified their offerings to include shows, which are a thematic series of science demonstrations. Shows are generally performed outside of the CSIROSECs in schools. This study concentrates on the hands-on programs conducted at CSIROSECs.

The researcher and author of this thesis established the CSIRO Science Education Centre in Tasmania and was manager from February 1986 until June of 2000. This research has arisen out of a desire to formalise some of the anecdotal experience that has been accumulated over many years. Accordingly, CSIROSEC Tasmania is the central focus of the current research with data being drawn from other CSIROSECs to increase the generalisability of the resultant instrument. CSIROSEC Tasmania is the subject of Chapter 2, which presents a participant-observer case study to provide the reader with a better understanding of CSIROSECs and the way they operate. This should establish a more meaningful background against which the research can be interpreted.

CSIROSECs offer a wide variety of programs and the age range covered differs between CSIROSECs. CSIROSEC Tasmania has programs covering the full range of classes from grade 1 through to grade 12. Programs in Tasmania, as in other

CSIROSECs, are constantly increasing and changing and include The Little Learner's Lab (1 and 2), Eureka, Eureka Too, Science and Technology (grade 5, 5/6, 6, 7 and 8 programs), Moon Rescue, Balloon Science, Puzzlemania, Illusions, Food Technology and Gene Technology. More information on the programs at CSIROSEC Tasmania, their operation and their development is included in Chapter 2, Appendix 2A and Appendix 2B. Chapter 2 is a participant-observer description of CSIROSEC Tasmania, Appendix 2A provides a brief history of CSIROSEC Tasmania and its programs, while Appendix 2B provides more detailed information on the Moon Rescue program, which is conducted at CSIROSEC Tasmania.

CSIROSECs generally offer such a diversity of programs that the foregoing description is intended only as a general summary. Additionally, each of the CSIROSECs, whilst sharing many commonalities, differ from each other as a result of the need to respond to local circumstances.

Learning Environment Instruments

Lorsbach and Basolo (1998) have described a learning environment in terms of the construction of the individuals in a given social setting, an individual's socially-mediated beliefs about the opportunities that he or she has to learn, and the extent to which the social and physical milieu constrains learning.

According to Lorsbach and Basolo (1998), different individuals interpret the social, physical and psychological factors that constitute an environment in different ways, and in this respect learning environments become personal constructs. Consequently, the interactions that individuals have with their environment will differ from person to person, which in turn may influence the environment as perceived by both the individual and others. In this respect a learning environment is both socially and psychologically dynamic, consisting of an intricate web of interpersonal interactions and interactions with the individual's system of beliefs and personality. These interactions are powerful determinants of the evolutionary direction of the learning environment over time.

Learning environment instruments use high-inference measures to study classroom climates. Participants are asked to make an inference from a series of classroom events using specific constructs, such as satisfaction, cohesiveness, difficulty, teacher control, innovation, involvement, teacher support, etc. (Rosenshine & Furst, 1971). There are general instruments designed especially for classrooms, such as the Learning Environment Inventory (LEI), Classroom Environment Scale (CES) and My Class Inventory (MCI), and instruments for measuring more specific aspects of learning environments, such as the Individualised Classroom Environment Questionnaire (ICEQ), the Science Laboratory Environment Inventory (SLEI) and the Constructivist Learning Environment Survey (CLES). There are many studies that demonstrate students' perceptions of their learning environment can explain an appreciable amount of variance in the students' cognitive and affective outcomes (Fraser, 1986, 1989, 1994; Fraser & Fisher, 1982; Fraser, Walberg, Welch, & Hattie, 1987; Haertel, Walberg, & Haertel, 1981; Walberg, 1976).

Feedback information from learning environment instruments used to assess the learning environment in a classroom can provide the basis for attempts to improve the learning environment. This procedure has been used successfully in studies at the early childhood (Fisher, Fraser & Bassett, 1995), primary (Fraser & Deer, 1983; Fraser, Docker & Fisher, 1988), secondary (Fraser, Seddon & Eagleson, 1982; Thorp, Burden & Fraser, 1994; Woods & Fraser, 1996) and higher education levels (Yarrow & Millwater, 1995; Yarrow, Millwater, & Fraser, 1997). However, to the present time no learning environment instruments have been developed for informal learning environments such as those found in SECSMs, or more semi-formal learning environments such as CSIROSECs.

Research Question

The aim of this research is to develop a valid and reliable instrument to measure students' perceptions of certain aspects of the learning environment in CSIRO Science Education Centres.

Overview of Method

The development of the Learning Environment Instrument for CSIRO Science Education Centres (LEI for CSIROSECs) consisted of a number of well-defined stages.

1. Existing learning environment instruments were reviewed, together with the methodology employed in their development.
2. A literature search was conducted to determine those aspects of the learning environment of SECSMs which define their character.
3. These characteristics were grouped together according to the three basic types of dimensions proposed by Moos (1974) for describing psychosocial environments. Items were written for each scale, based upon findings from the literature search. This stage culminated in a pilot study to field test the instrument.
4. The instrument was revised based upon findings from the pilot study and input from significant others.
5. The scales were field tested and refined.
6. Further testing was conducted, as required.

Statistical analyses of the data collected during field trials included calculations of mean scores and standard deviations, Cronbach alpha internal consistency coefficients, item-scale correlation coefficients, an inter-scale correlation coefficient matrix for all scales, and a principal components analysis.

Data Sources

The pilot study was conducted with secondary classes visiting the Centre in Tasmania (subject to the approval and cooperation of the teachers concerned). The field testing of subsequent revisions of the LEI for SECSMs was conducted with upper primary and secondary classes visiting the CSIROSECs in Tasmania, Victoria, Western Australia and North Queensland. This gave a sufficiently large pool of data for statistical analysis of the instrument and its individual items.

Role of participants

This study involved two separate, but not mutually exclusive, groups of participants. The groups related to two distinct phases of the research, first, the development of the LEI for CSIROSECs involved the use of CSIROSEC managers and other experts in the determination of the construct and face validity of the instrument, and, second, the field testing and validation of the instrument involved four CSIROSECs and their visiting school groups.

Instrument development

This phase of the research involved the initial development of a Draft LEI for CSIROSECs for a pilot study and its subsequent evaluation. The development of the instrument was based upon findings from literature searches into Learning Environment Instrument research and SECSM research matched with the experience gained from establishing and running a CSIROSEC for over 14 years. Input was sought from academic learning environment specialists, CSIROSEC staff, teachers and students. The LEI for SECSMs was developed with a 5-point Likert-type scale consisting of the categories: strongly disagree (scored 5), disagree (4), neither agree nor disagree (3), agree (2) and strongly agree (1). The instrument was completed as a pen-and-paper questionnaire by students and subsequently hand-scored. The data were analysed using SPSS, Statistical Package for the Social Sciences. Revisions of the instrument arose from the statistical analyses, resulting in the development of a number of versions of the instrument until satisfactory discriminant validity and internal consistency reliability figures were achieved.

Instrument field testing

The field testing and validation of the LEI for CSIROSECs involved a statistically appropriate number of student visitors to a number of CSIROSECs (n=864). The instrument was completed by students immediately following their visit, in order to elicit their own personal responses, rather than those developed during conversations with others. It was necessary to obtain permission from, and cooperation of, the class teacher. All participants were assured of the confidentiality and anonymity of their participation.

The determination of scale internal consistency and discriminant validity of the initial instrument led to revisions. This involved further rounds of field testing and statistical analysis of the revised instruments.

Limitations of the Study

This research has been undertaken with a representative sample of CSIROSECs to develop an instrument specifically designed for the CSIROSEC learning environment.

Procedures were taken with the development, testing, modification and retesting of the instrument to ensure its scale internal consistency and establish discriminant validity. Input was sought from experienced practitioners in CSIROSECs during critical phases of the research. These procedures enable CSIROSEC staff to have confidence in its properties. Further, the study drew upon the experiences of the researcher at CSIROSEC Tasmania and carried out at CSIROSEC Tasmania. The generalisability of the findings in this research has been increased by testing the instrument in four CSIROSECs (Tasmania, Victoria, Western Australia and North Queensland), with different presenters, a range of programs (Forensic Frenzy, Science and Technology, Electronics, Moon Rescue, Energy, Food Technology, Gene Technology and Physical World) and across a range of grades (6-12).

Although attempts have been made to establish both internal and external validity, the learning environment instrument resulting from this research is likely to be limited to the semi-formal environment of CSIROSECs. Its use may be possible in places which have a similar purpose and offer similar activities as a CSIROSEC, if such exist, but use of the instrument must be considered carefully in these other places.

Significance of the Study

The coordination of studies within different learning environments may lead to a better understanding of learning in general. Ramey-Gassert et al. (1994) reinforce the need for greater interaction between schools and science centres claiming that "these collaborative efforts provide a promising opportunity for science education researchers to improve science learning" (p. 360). An important step in this direction is developing a means to accurately describe each environment and an attempt to link this to their respective and relative educational outcomes. This study attempts to formalise research into the learning environments in SECSMs using quantitative research methods derived from the area of learning environment research. CSIROSECs, and their semi-formal learning environment, are the targets for this research.

CSIROSECs have existed, and increased in number, in Australia since 1982. It is surprising therefore, that with nine such centres now established, that very little research has been conducted at the Centres. Rennie (1993) claimed "Learning in CSIROSEC is different to learning in the laboratory at school ... but visits to CSIROSEC tend to be more formal than visits to a museum or a science centre ... because it is not open to the public" (Rennie, 1993, p. 29). CSIROSEC managers have made considerable advances and innovations in the areas of informal and semi-formal learning, but very little of this has been communicated to workers or researchers in other SECSM environments. Yet, CSIROSECs, with their semi-formal learning environment may prove to be an ideal venue in which to bridge the gap between the existent and considerable body of knowledge on learning environments in classes and schools and the difficulties associated with research on learning environments in the informal environments of SECSMs. An improved understanding of the nature of the learning environment in one type of SECSM may, in turn, lead to an improved knowledge of how people learn in other informal environments.

This research is significant because it defines a general set of characteristics for the learning environment in a particular type of SECSM, that is CSIROSECs. There are workers in the field, such as Herman (quoted in Falk, Dierking, & Holland, 1995), who have mentioned the idea of doing exploratory factor analyses of outcomes in order to develop a taxonomy of results of museum visits. The general feeling is that it may be too early to go down this path. "Museum professionals are still trying to define reasonable, measurable, generalizable outcomes for which they could conduct a factor analytic study" (et al, p. 29). This study moves closer towards defining outcomes for SECSM visits, by defining aspects of the learning environment, developing a learning environment instrument for CSIROSECs and conducting a factor analytic study of student responses.

The validation of an initial learning environment instrument for use in research studies in SECSMs will broaden the range of tools available for research into student outcomes from SECSM visits and have the potential to improve the learning environments in individual centres. More specifically, the learning environment instrument developed as a result of this research will provide an easy to use tool for managers of CSIROSECs to improve their practice.

Fraser and Fisher (1983a,b) have shown that students achieve better when their classroom environment matches their preferred environment. Studies by Fraser and Deer (1983) and Fraser and Fisher (1986) suggest that there is potential for teachers to employ classroom environment instruments as a means of assessing and guiding change in the classroom environment to one which is closer to a preferred student environment. This study develops an instrument to measure students' perceptions of the actual environment, but the development of a preferred form of the LEI for SECSMs could lead to similar research in SECSMs. In much the same way as teachers can act as researchers within their own classrooms to ascertain and, if necessary, change the learning environment using established instruments, the same should be possible within CSIROSECs, given an appropriate instrument.

Overview of thesis

It has been pointed out that CSIROSECs differ from both the formal learning environments found in science classrooms and laboratories and the informal learning environments found in SECSMs. A participant-observer description of CSIROSEC Tasmania is given in Chapter 2. This provides the reader with an insight into the operation of a CSIROSEC and some of the programs that are offered.

The literature review in Chapter 3 contains three main sections. The first deals with research on learning environments, whilst the second section reviews research on formal and informal learning environments. The final section of the chapter is a synthesis from these reviews of research to produce a number of measurable scales which could be used to develop a learning environment instrument for use in SECSMs.

Chapter 4 reports on a pilot study to determine the feasibility of developing a learning environment instrument for CSIROSECs. This chapter examines the development, administration and analysis of the initial version of the Learning Environment Instrument for CSIRO Science Education Centres, referred to as the Pilot Study Instrument. Recommendations arising out of the analyses lead to the redrafting of the instrument for the major part of this study.

The development, administration and analysis of the Redrafted Instrument is described in Chapter 5. The chapter reports how the development of the Redrafted Instrument was preceded by the formulation of operational definitions and student outcomes and the Redrafted Instrument was tested for face validity by CSIROSEC managers and other experts. Arising from these analyses a number of recommendations were made to refine the Redrafted Instrument.

Chapter 6 reports the field-testing of the refined version of the instrument. The number of items per scale for the Refined Instrument was reduced to six, to produce the Learning Environment Instrument for CSIRO Science Education Centres (LEI for CSIROSECs). Comparisons of the LEI for CSIROSECs with existing learning environment instruments on a number of parameters are described. Comparisons made between the results for different classes, teacher-student perceptions, primary and secondary student perceptions and programs are also described as a way of examining the sensitivity of the instrument.

The final chapter provides a summary of this research, with the conclusions reached and implications of the research. Included are suggestions for the further development of the LEI for CSIROSECs and potential applications of the instrument.

Chapter 2

A Participant-Observer Description of CSIROSEC Tasmania

Overview

This chapter is a description of the CSIROSEC in Tasmania by its creator and manager for over 14 years, together with some generalised perceptions of CSIROSECs. It is included to give the reader a better insight into the nature and functioning of a CSIROSEC. An example of a CSIROSEC session is provided, and issues specific to CSIROSEC Tasmania which have shaped its programs, operation and learning environment are discussed. Considerations in the development of new programs, including staffing, resources and motivation, financial considerations and design considerations are provided. Finally the importance of CSIROSEC programs working to complement school science programs within the context of school laboratory work, curriculum issues and learning environment issues is discussed.

An Example of a CSIROSEC Session

A general overview of the way a session is conducted at CSIROSEC can be gained from the following description of the Science and Technology program for grade 7 students at CSIROSEC Tasmania. Pre-visit information on the organisation of the session, stimulus questions for students and copies of worksheets for each activity are sent to the school prior to the visit. The teacher organises students into groups of three and issues each group with the appropriate worksheets for the activities they will be undertaking. Sessions are usually structured with a class group introduction, a period for smaller groups to work on a number of activities and a concluding whole-class gathering. The introduction includes setting the scene for the session and providing background information on both the theme for the session and individual activities. The focus at this stage is on the activities to be performed by the students, their location, the equipment and how it is used and a brief overview of the way the activity is conducted. The duration and detail of the explanations are decided in conjunction with the teacher prior to the commencement of the session. Some classes are led by teachers who have visited CSIROSEC many times before and have extensively prepared their class for the session. Additionally, many students are familiar with CSIROSEC from visits in previous years. Such groups require the briefest of introductions. Other groups may be visiting CSIROSEC whilst on a school camp. Some of these groups are led by teachers who have never visited CSIROSEC, nor have the students. Furthermore, little, if any, preparation may have been done.

The hands-on portion of the visit is formally structured with students proceeding along a defined path from one activity to another according to a prescribed timeframe. Each group has five activities to complete and groups are given 20 minutes on each activity. It is this degree of structure which is one factor which differentiates CSIROSECs from public SECSMs, yet whilst being more formal than an SECSM environment CSIROSECs are, in many respects, less formal than a school laboratory environment.

The whole-class gathering towards the end of each visit is variously used for drawing general conclusions, conducting demonstrations, promoting other CSIRO Education offerings, such as the CSIRO's Double Helix Science Club, and providing information concerning CSIROSEC's after-school and vacation programs.

CSIROSEC Tasmania offers such a wide variety of programs that the foregoing description can be only a general summary of the operation of sessions.

Tasmanian Population Size Considerations

CSIROSEC Tasmania has a very small population from which to draw its students when compared to most other CSIROSECs in Australia. This brings with it a range of advantages and disadvantages.

During the early days of the establishment of CSIROSEC in Tasmania I visited the Centre in Melbourne and spoke to the manager at that time, Don Hyatt. Amongst the valuable experience and information Don passed on, he made one comment which has stayed with me. It has done so because it tended to highlight one of the crucial differences that would shape an aspect of the individuality of the CSIROSEC in Tasmania. Don's comment went to the effect, "One of our aims is to have each student in Melbourne visit CSIROSEC once during their school career" (Don Hyatt, 1986, personal communication). It was obvious at the time, and became even more obvious over the years, that such an aim would be totally misplaced in CSIROSEC Tasmania.

Two things arose from that single comment. The first was that CSIROSEC Tasmania would need to encourage multiple visits and second, that CSIROSEC would need to institute a travelling program to take its activities to other regions within Tasmania. Initially, multiple visits meant aiming to have students visit once each year during the range within which programs were offered (at that stage the grade 5 to 8 range). As the CSIROSEC grew these aims were regularly reviewed. One of the first changes was to reorganise the primary programs and encourage schools to bring their students for two sessions each year rather than one. This could be two half-day sessions, usually about a week apart, or a full-day session with a break in the middle of the day. Next, alternate programs, such as *Moon Rescue* (see Appendix 2B for more details on the development of the Moon Rescue program), were developed for primary students with the dual aims of encouraging existing visitors to come more often and also encouraging new visitors.

From here the programs at CSIROSEC diverge in a number of directions. The range of offerings was increased to include new visitors. The *Eureka* programs were developed to cater for grade 3 and 4 students and later *The Little Learners' Lab* was developed to cater for Prep to grade 2. To encourage full use of each of these programs it was necessary to develop a second program, enabling programs to be conducted on alternate years. The implication of this new strategy was that a composite grade 3-4 class (composite year groups are currently widespread in many schools in Tasmania) could visit one year and do the *Eureka* program and come again next year, when the grade 3 students had moved into grade 4, and do the *Eureka Too* program.

Other concurrent strategies to encourage increased usage of CSIROSEC Tasmania included

- the development of additional primary programs (eg., *Balloon Science*),
- adapting existing programs from other CSIROSECs (eg., *Cool Chemistry*),
- the development of *Forensic Science* as a new secondary program,
- the use of national travelling programs for senior secondary students (*Gene Technology* and *Food Technology*),
- the development of programs to travel out to local schools on a daily basis (*Puzzlemania*),
- the development of regular after-school sessions (*Curie-ous Kids*, *MicroScientists*, *Silicon Chips*, etc.),
- the development of vacation programs, including one-hour sessions, half-day to full-day sessions and week-long programs (eg., *Forensic Science Certificate*), and
- the development of programs with a dual function, which could be used with school classes, but also would appeal as programs for family groups in more public venues such as regional museums (eg., *Illusions – Science Meets Art*).

Further information on the development of programs is included in Appendix 2A, entitled *A Brief History of CSIROSEC Tasmania*.

Considerations in the Development of New Programs

Staffing

CSIROSECs around Australia are, predominantly, managed by seconded or ex-teachers who generally bring with them education training and considerable experience in classroom teaching. This, however, does not guarantee their success in this new milieu. This very point is noted as a point of caution in the Manual of Curatorship (Wilson, 1992):

> The visitor must not be pandered to by labels in 'Noddy' language, by coloured flashing lights, blonde information officers or any of those caricatures and gimmicks beloved of the educational administrator venturing into the museums field. (p. 85)

There is a body of knowledge and skills that is exclusive to SECSM learning environments and again, more specifically, to the CSIROSEC learning environment. In the past managers have acquired these skills through on-the-job experience and communication, albeit limited, with other managers. Three CSIROSEC managers have pursued additional, specific qualifications in the area of SECSMs, and those who have, have left the CSIROSEC system to pursue this goal. To date, none have returned to share this knowledge with their colleagues. Notwithstanding, many of the CSIROSEC managers have made extraordinary achievements and made considerable contributions in the area of informal learning. Unfortunately, very little of this has been communicated to colleagues in the greater SECSM environment, which is poorer for this disregard.

Resources and Motivation

The scale of CSIROSECs should not be confused with public SECSMs. Whilst they share many of the features that are characteristic of these informal learning environments, CSIROSECs are low budget operations when compared to the publicly funded centres such as Questacon, Scitech, Investigator, Sciencentre, Scienceworks, and public SECSMs in other Australian states. CSIROSECs are required to rely more upon the educational and management expertise of the staff within the Centres than upon external support from CSIRO, Education Departments or sponsors. Revenue generation by Centres through their own activities is crucial to their ongoing survival.

Individual CSIROSECs are not sufficiently funded to have staff dedicated to the development of new programs, the design of activities, construction of equipment etc. Staff members are required to be multi-talented and capable of contributing to a large number of functions important for the maintenance and development of

Centres. The development of new programs is something that proceeds in tandem with the everyday running of the Centre and attending to visiting groups. This has the disadvantage that individuals are not free to concentrate and focus upon developmental tasks. Programs get developed if and when there is time.

This is more than compensated for by many of the advantages that accrue from this approach:

- Staff members develop a strong sense of ownership of programs.
- Programs can be developed which capitalise upon the expertise and interests of staff.
- There is little down-time for training staff in the use of new programs.
- Staff members have to accept the responsibility for the success of programs at the workface. They develop the programs and they conduct them with school groups. Accordingly, they are first to receive any feedback, good or otherwise. This is a great source of motivation for the quality-conscious individual.
- Staff can respond quickly to feedback from groups during the trialing phase and modify programs accordingly.
- Programs can be continuously modified and improved during their operation.
- Staff members have a good feel for what will or won't work from first-hand experience. This is very important when developing activities.
- The educational aspects of activities are not lost in the communication process between the designer, practitioner and constructor because they share in all aspects of the process.

Financial Considerations

Financial considerations in the development of new programs are capital costs, running costs (including salary) and potential income. With respect to the present economic situation, programs must be able to recoup capital costs within the financial year and, at least, run on a cost recovery basis. An explanation of the way programs such as *The Little Learner's Lab*, *Eureka* and *Eureka Too* are conducted in order not to incur running costs for presenters is included in Appendix 2A. However, other infrastructure costs for these programs do need to be considered. Nevertheless, the proportionally higher profit margin for these programs is essential to the budget of CSIROSEC.

The capital development costs of programs (neglecting salary) are in the order of hundreds of dollars or thousands of dollars, not the tens of thousands or hundreds of thousands of dollars, and beyond, for the larger public science centres. The ability to create quality programs on minimal funding is a valued commodity within CSIROSECs, as are the abilities to recycle, reuse, beg, borrow, construct, etc. The approach is closer to that of the bricoleur than the engineer.

The costs associated with running a program must also be considered during the development phase. The cost-effectiveness of programs can be improved by minimising or eliminating consumables and expendables. Chemistry programs are generally more expensive to conduct, in this respect, than many other types of programs. This is not an advocation for the deletion of programs that use large amounts of consumables, rather, the overall context of a Centre's programs (and budgeting) must be balanced. The more cost-effective programs, such *as The Little Learner's Lab* etc., must support the less cost-effective programs, such as *Cool Chemistry*. Salary costs are a large component of any session and it is important to produce programs that minimise these costs. One way of doing this has been discussed for the *Little Learner's Lab* and *Eureka* programs (see Appendix 2A). An assumption is made that the base salary cost of any session will be the time during which the students are present and this will be a function of the length of the session. The other salary costs for a program include the amount of time required for preparation and setting up, and the packing up time. As a generalisation, a Chemistry program requires more time than a Physics program. In this respect, the most cost-efficient programs are those which include activities (and experiments) requiring no preparation and no cleaning up. This needs to be considered during the design phase of individual activities.

Design Considerations

An example of the development process of activities is an activity called *Heat Conduction*, which is included in the grade 7 Science and Technology program. The aim was to produce a piece of equipment that would allow students to measure the conduction of heat along four strips of different metals. This had to be completed safely during a 20 minute time slot and the equipment had to be immediately ready for use by the next group. The core of the equipment included thermistors, displays, a heating element and a timing system. It was considered too expensive to reproduce this equipment so that a fresh piece of equipment was available for each group. A replaceable unit for the four strips of metal was considered, but concerns were expressed over the potential wear and tear associated with the continual removal and replacement of these units. A cooling system was devised to return the metal strips to room temperature during the time-frame of the activity. This raised the issue of students remembering to activate the cooling unit in time for the next group, particularly as it was not essential for the results of their own activity. The solution to this problem was to make the cooling process an integral part of the activity. That is, students had to collect data for heating curves for each of the metal strips, had to activate the cooling unit and continue to collect data, but this time for the cooling curves of each of the metal strips. This was manageable during the 20 minute time-frame and resulted in an activity which was immediately repeatable. This approach has proven to be highly successful and is an important consideration in the design of all new programs, activities and equipment. A copy of the *Heat Conduction* worksheet, showing the equipment, is appended (see Appendix 2C).

Conclusion

The 'big picture' contains elements above and beyond cost effectiveness, such as the provision of a balanced science program. Economic survival is a reality, but it must not be allowed to completely overwhelm the educational nature of the enterprise. Whilst inadequate funding can make it more difficult to achieve an ideal outcome, it can create an environment which is more conducive to lateral thinking and innovative problem solving. But in the long run, CSIROSECs must be primarily driven by educational rather than management imperatives.

Complementing School Science Programs

In order to decide how CSIROSECs contribute to existing school programs it is relevant to know what researchers are saying about laboratory science in schools.

School Laboratory Work

When we consider school laboratory work we need to be sure of what it is we are considering. Hofstein and Lunetta (1982) state that some laboratory activities are organised deductively to allow students to gather data in order to further understand laws or relationships that have been outlined earlier in class, whilst other activities are used to introduce a topic to students by involving them in the collection of data, the inferring of relationships and the making of generalisations. Some school laboratory activities are quite prescriptive with students proceeding in a structured, stepwise fashion, whilst other activities are more open with students involved in the planning process.

Bates (1978), Bredderman (1985), and Tobin and Gallagher (1987) all report non-significant differences with respect to the effectiveness of learning science concepts in laboratories compared to learning concepts from conventional teaching methods. Some researchers have questioned the value of laboratory work (Bates, 1978; Saunders & Dickinson, 1979). For example, Bates (1978) throws down the challenge to teachers when he says:

> Teachers who believe that the laboratory accomplishes something special for their students would do well to consider carefully what those outcomes might be, and then to find ways to measure them. ... What does the laboratory accomplish that could not be accomplished as well by less expensive and less time consuming alternatives? (p. 75)

But Hofstein and Lunetta (1982) in their analysis of research conclude that (1) appropriate laboratory activities can be effective in promoting logical development and the development of some inquiry and problem-solving skills, (2) they can assist in the development of manipulative and observational skills, (3) they can assist in the understanding of scientific concepts, (4) they can promote positive attitudes, (5) they provide opportunities for success, and (6) they foster the development of skills in cooperation and communication.

Schulz and McRobbie (1994) studied the application of a constructivist approach to laboratory activities and concluded, "where school science laboratory activities were designed from a constructivist perspective for conceptual change there was an educationally and statistically significant increase in learning when compared to an instructional program based on the more traditional laboratory activities" (p. 301).

It is perhaps worthwhile, as an academic exercise, to look towards the use of resources external to the school environment for laboratory experiences for students. Many schools use public swimming pools for aquatic education, community athletics tracks for carnivals, and zoos and botanical gardens as educational resources, because they can afford neither the capital investment nor the cost of maintenance of such facilities. Is it conceivable that somewhere in the future science laboratory facilities may be centralised for use in a similar way? I hope not. Whilst I am a firm advocate of SECSMs, I also see practical laboratory work and the development of the accompanying attitudes and physical and mental skills as central to science. If this were to be diminished in any way it would eliminate that which defines science as a discipline. The role of SECSMs and CSIROSECs is to complement the work that is already happening in schools. Within the present context it is appropriate to suggest that schools need to consider which goals are best achieved in their own school laboratory, which are best achieved in an SECSM or CSIROSEC and which are best achieved by utilising a combination of learning environments.

Curriculum Content Issues

When the CSIRO Science Education Centre opened in Hobart in 1987, teachers were looking for something different to do with their science classes, things they could not do in their own classroom. In many instances, enrichment of the science curriculum by providing a *different* experience was sufficient.

In the intervening years changes in the science curriculum have placed teachers under increasing pressure to 'complete the course.' The opportunity for experiences peripheral to the curriculum has been lost to time constraints. In this respect, even science centres are susceptible to that great law of nature, which says 'adapt or die.' The nature of the offerings from CSIROSEC Tasmania had to change to reflect the changing circumstances in schools. Programs had to become relevant to the curriculum and able to be readily integrated with the existing curriculum. To achieve this a number of changes were required.

CSIROSEC Tasmania has, since its inception, always provided teachers with pre-visit and post-visit materials and activities. These have changed to reflect both a greater demand and a new relevance with the advent of the National Curriculum.

Many new programs have been introduced over the years. The style of programs has been broadened to provide a greater degree of flexibility for teachers when choosing programs. Thematic and scenario-based programs have been developed along with cross-curricular programs.

Learning Environment Issues

Programs consist of more than curriculum content and it was also important during the establishment phase of CSIROSEC Tasmania to address the crucial issue of the nature of the learning environment which was to be created. Schools will not visit an SECSM to do the same things in the same way that they could do them at school. Over the years the learning environment at CSIROSEC Tasmania has been continually reshaped by findings from current research in SECSMs, learning environments and other issues in education. Other important contributing factors have been accumulated experience, conferences, and visits to other CSIROSECs and SECSMs, both in Australia and overseas.

CSIROSECs are considered as hands-on science education centres which are less formal than a classroom or laboratory learning environment but more formal than the informal learning environments of public science centres. This semi-formal environment is created by the structure of sessions and contributes to CSIROSEC learning environments being 'minds-on' as well as hands-on. This implies active participation and involvement by students at both the mental and physical level. Active learning is important and students are encouraged to be involved in making their own independent interpretations and reaching their own conclusions from activities. From a constructivist perspective this means students should be allowed to develop their own models and activities should contribute to the incremental growth of students' existing concepts. It is, therefore, essential that activities are presented in such a way as to allow the construction of meaningful concepts and they should avoid opportunities for students to reinforce naïve concepts. This relies, to a large extent, upon the experience of the professionals developing new activities and programs, but ultimately such factors can only be accurately ascertained by adequate trialing and feedback from students.

Activities and programs are developed so that the involvement of students requires the use of a large number of skills. It is firmly believed that the use of multi-sensory skills enhances the opportunities for learning from each experience. But students must also be motivated to both participate and learn, and curiosity is held to be a great motivator. Activities and programs must be sufficiently novel and innovative to encourage a curiosity to discover, enhance motivation and encourage involvement.

The opportunity to work together in groups is an important aspect of the CSIROSEC visit. Experience has shown that the most effective social interaction occurs in a group with three students. Effective, in this context, refers to that compromise which exists between students enjoying the social interaction and it contributing to the achievement of common goals. Students at CSIROSECs are encouraged to work cooperatively as teams in a mutually helpful way.

CSIROSEC visits aim to be primarily learning experiences within an enjoyable, interactive context. This could be contrasted with the two other contexts, that is, the informal public SECSM and the formal school classroom or laboratory. It could be argued that the public SECSMs are more intent upon ensuring that their visitors have an enjoyable experience within a more or less educational context. Classrooms are places where learning is expected to occur. This environment is more enjoyable for some students than others, and is more or less enjoyable depending upon the nature of the task being undertaken at the time. The types of affective outcomes that are aimed for from the CSIROSEC experience are that students should think CSIROSEC is fun, the activities are interesting, they would like to repeat the experience and the visit has enhanced their attitude to science.

Conclusion

This insight into the formation and conduct of CSIROSEC Tasmania has established a background for interpreting the current research. CSIROSECs need to be seen as different from public science centres and museums, and, whilst sharing many commonalities, each CSIROSEC has its own idiosyncrasies arising from its need to respond to factors, such as the nature and needs of the local population, which shape its individual environment.

CSIROSECs can be seen as part of a national network of such Centres, but also as being largely self-dependent in ensuring their own on-going survival. CSIROSECs share ideas and programs, but need to develop or adapt programs to meet the individual needs of their own environment. In this respect, each CSIROSEC is enormously dependent upon the experience and expertise of the staff to respond to local needs. An ability to create and conduct quality educational programs on a limited budget is imperative to the success of each Centre.

CSIRO Education provides management at the national level, but very little in the way of educational guidance, and if CSIROSECs are to continue to be successful they must be driven by educational rather than management imperatives. The educational factors established as important in CSIROSECs include cooperative learning and social interaction, active participation and involvement of students, innovative programs with novel activities, the opportunity for students to explore, activities that encourage the use of multi-sensory skills, activities that utilise multiple modes of learning, the reinforcement of classroom learning and the enhancement of a positive attitude towards science. It is hoped that this current research will provide a means of evaluating such aspects of the learning environments in CSIROSECs and thus establish a starting point for increased educational guidance therein.

Chapter 3

Research on Learning Environments and Learning in Science Education Centres and Museums

Introduction

This chapter consists of three sections – a review of the literature on learning environments and learning environment instruments, a review of research on learning in formal and informal environments and a synthesis from these reviews of a number of measurable scales which could be used for the production of a learning environment instrument for use in science education centres and science museums.

The first section of the chapter begins with a brief historical introduction to approaches to studying educational environments and the development of learning environment instruments. Summaries of a number of examples of learning environment instruments are given and relevant outcomes from research on the use of learning environment instruments are discussed.

The second and largest portion of the chapter presents a review of learning in formal and informal environments, particularly with reference to science education centres and museums. Much of the available literature on learning in science education centres and museums is based upon anecdotal evidence, accumulated experience and observational research techniques. The question is raised as to what students learn in SECSMs. Some specific aspects of SECSMs are discussed, including interactive exhibits, the role of previsit preparation, constructivism in SECSMs, the multisensory approach to learning, social interaction, the novelty factor and the use of worksheets. This leads to a discussion of what constitutes an effective SECSM visit. CSIRO Science Education Centres are discussed together with their intermediate positioning between the extremes of formal and informal learning environments and their relationship to Wellington's (1990) features of formal and informal science learning.

The third section of this chapter derives from the reviewed literature a number of scales that have potential for use to characterise aspects of the learning environments in science education centres and museums. These scales are related to the scheme developed by Moos (1974) for classifying human environments, which includes the relationship dimension, the personal development dimension and the system maintenance and change dimension.

Learning Environments

A Brief Historical Perspective on Learning Environments

The history of learning environment research is marked by two main, overlapping periods. The earlier period is characterised by low inference measures and the later period by high inference measures. Low inference measures are defined by Rosenshine and Furst (1971) as specific, denotable, relatively objective classroom behaviour recorded as frequency counts by an observer. High-inference measures are more concerned with the perceptions of the participants about the meaning of classroom factors.

The early period of educational environment research was strongly influenced by Lewin's (1936) work on field theory, which identified the interaction of the environment with the personal characteristics of the individual as a major determinant of behaviour. This is expressed in the Lewinian formula $B = f(P, E)$, where behaviour (B) is a function of both the person (P) and the environment (E). Murray (1938) followed the lead of Lewin and proposed a needs-press model which permits the analogous representation, in common terms, of person and environment. "Personal needs refer to motivational personality characteristics representing tendencies to move in the direction of certain goals, while environmental press provides an external situational counterpart which supports or frustrates the expression of internalised personality needs" (Fraser, 1998a, p. 529).

Murray (1938) defined the alpha and beta press as different perspectives for describing the environment. The alpha press is the environment as described by a detached observer, whilst the beta press is the environment as perceived by its participants (milieu inhabitants). Stern, Stein, and Bloom (1956) have extended the concept of beta press to include the private beta press (the individual's idiosyncratic view of their environment) and the consensual beta press (the shared view that members of a group hold about their environment). It is important to define the methodology of data collection and the unit of analysis since the alpha press may differ from the beta press and the private beta press may differ from the consensual beta press.

Low inference measures. An example of an educational environment instrument using low inference measures is OScAR (Observation Schedule and Record), developed by Medley and Mitzel (1958). The OScAR has 14 scoring keys that result in three scales – emotional climate, verbal emphasis and social organisation. The 14 scoring keys are (a) time spent on reading, (b) problem-structuring teacher statements, (c) autonomous administrative groupings, (d) pupil leadership activities, (e) freedom of movement, (f) manifest teacher hostility, (g) supportive teacher behavior, (h) time spent on social studies, (i) disorderly pupil behaviour, (j) verbal activities, (k) traditional pupil activities, (l) teacher's verbal output, (m) audiovisual materials, and (n) autonomous social groupings. OScAR was designed to decrease the difficulty of judgements required in previous instruments, increase observer behavior and reduce the amount of training required for its use. However, it still relied upon the judgments of observers, or Murray's (1938) alpha press, in determining the educational environment within the classroom.

High inference measures. Walberg and Moos, working independently, built upon the earlier work of Lewin and others, to construct instruments which relied upon high inference measures. As a part of Harvard Project Physics (Walberg & Anderson, 1968), Walberg assisted with the development of the Learning Environment Inventory (LEI). Out of his research programs in perceptual measures in a diversity of environments, including psychiatric hospitals, prisons and university residences, Moos developed the Classroom Environment Scale (CES). Both of these instruments relied upon the students' perceptions of their learning environment, moving measurement from the alpha to the beta press.

Walberg's construction of the Learning Environment Inventory (LEI) was guided by Getzels' and Thelen's (1960) theory of the class as a social system, which implied that personality needs and role expectations interacted to form a climate in which group behaviour, including learning, could be predicted. The LEI is intended to measure the social climate of learning in the classroom as perceived by the students. The 15 climate dimensions are (a) cohesiveness, (b) diversity, (c) formality, (d) speed, (e) environment, (f) friction, (g) goal direction, (h) favouritism, (i) cliqueness, (j) satisfaction, (k) disorganisation, (l) difficulty, (m) apathy, (n) democraticness, and (o) competitiveness. The LEI contains 7 statements per scale and students express their agreement or disagreement on a four-point scale (strongly disagree, disagree, agree or strongly agree). Typical items in the Learning Environment Instrument are "All students know each other very well" (Cohesiveness scale) and "The pace of the class is rushed" (Speed scale).

The Classroom Environment Scale (CES), developed by Trickett and Moos (1970), is a high inference measure based upon the Needs-Press Model of Murray (1938). The CES has 9 scales – (a) involvement, (b) affiliation, (c) support, (d) task orientation, (e) competition, (f) order and organisation, (g) rule clarity, (h) teacher control, and (i) innovation. Each scale contains 10 items which are responded to in a True-False format. The CES can be used to measure the actual environment and the preferred environment, and to measure teachers' perceptions as well as students' perceptions. Typical items in the Classroom Environment Survey are "The teacher takes a personal interest in the students" (Teacher Support scale) and "There is a clear set of rules for students to follow" (Rule Clarity scale).

Learning Environment Instruments and Moos's Scheme

The term "press" developed by Murray (1938), fell into disuse and learning environment instruments are now generally related to Moos's (1974) scheme for classifying human environments This scheme has three types of dimensions – the relationship dimensions, the personal development dimensions, and the system maintenance and system change dimensions. Relationship dimensions identify the nature and intensity of personal relationships within the environment and evaluate the extent to which people are involved and support and help each other. Personal development dimensions evaluate basic directions along which personal growth and self-enhancement tend to occur. System maintenance and system change dimensions assess the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change.

Table 3.1 shows the relationship between the scales of eight classroom environment instruments and Moos's (1974) scale for classifying human environments. The instruments shown are the Learning Environment Inventory (LEI), the Classroom Environment Scale (CES), the Individualised Classroom Environment Questionnaire (ICEQ), My Class Inventory (MCI), the College and University Classroom Environment Inventory (CUCEI), the Science Laboratory Inventory (SLEI), the Constructivist Learning Environment Survey (CLES) and What Is Happening In This Classroom? (WIHIC).

Advantages of High Inference Measures

Fraser and Walberg (1981) outline some advantages of the high-inference, student perceptual measures over low-inference, observational techniques:

1. Paper-and-pencil perceptual measures are more economical than the use of trained observers.
2. Perceptual measures are based on students' experiences over many lessons, whereas observations may be limited to a few lessons.
3. Perceptual measures involve the pooled judgements of all students in a class, whereas observation techniques typically involve a single observer.
4. Students' perceptions, because they are determinants of student behaviour more than real situations, can be more important than observed behaviours.
5. Perceptual measures of classroom environment typically have been found to account for considerably more variance in student learning outcomes than directly observed variables.

Table 3.1. Summary of Scales from Eight Classroom Environment Instruments.

Instrument	Scales Classified According to Moos's Scheme: Relationship Dimensions	Personal Development Dimensions	System Maintenance and Change Dimensions
Learning Environment Inventory (LEI) (Fraser, Anderson, & Walberg, 1982)	Cohesiveness Friction Favoritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material environment Goal direction Disorganisation Democracy
Classroom Environment Scale (CES) (Moos & Trickett, 1987)	Involvement Affiliation Teacher support	Task orientation Competition	Order & organisation Rule clarity Teacher control Innovation
Individualised Classroom Environment Questionnaire (ICEQ) (Fraser, 1990)	Personalisation Participation	Independence Investigation	Differentiation
My Class Inventory (MCI) (Fraser, Anderson, & Walberg, 1982)	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
College & University Classroom Environment (CUCEI) (Fraser, Treagust, & Dennis, 1986)	Personalisation Involvement Student cohesiveness Satisfaction	Task orientation	Innovation Individualisation
Science Laboratory Environment Inventory (SLEI) (Fraser, Giddings, & McRobbie, 1991)	Student cohesiveness	Open-endedness Integration	Rule clarity Material environment
Constructivist Learning Environment Survey (CLES) (Taylor & Fraser, 1991)	Personal relevance Uncertainty	Critical voice Shared control	Student negotiation
What Is Happening In This Classroom? (WIHIC) Aldridge, Fraser, and Huang, 1999)	Student cohesiveness Teacher support Involvement	Investigation Task orientation Cooperation	Equity

(Adapted from Fraser, 1998b)

In addition, and with particular relevance to the development of a learning environment instrument for CSIROSECs, high-inference measures can be less intrusive on the students' participation during their visit. That is to say, the instrument can be completed at the conclusion of the visit and not interfere in any way with the session itself. The matter of economy of data collection assumes an increased importance in the CSIROSEC environment because of the limited timeframe for each group visit to CSIROSEC. The discrete nature of the visit means that an observer cannot return to that particular class in that same environment to confirm earlier observations or to make additional observations.

Forms of Learning Environment Instruments

Actual and preferred instruments. Most instruments have not only a form to measure perceptions of the actual classroom environment, but a form to measure perceptions of the preferred classroom environment. The preferred form of the instrument measures perceptions of the ideal classroom environment or the type of classroom students, and teachers, would most like to work in. The actual and preferred forms of an instrument are very similar. The wording of the instructions for completing the instrument is varied to ensure that the person completing the survey is aware of which type of environment they are considering. For example, part of the instructions for the actual form of the Science Laboratory Environment Inventory (SLEI) (Table 3.1) reads, "This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked **how often** each practice **actually takes place**." In the preferred form the same section of the instructions reads, "This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked **how often** you would **prefer** each practice to take place." Items may also be reworded. For example, an item from the actual form of the Science Laboratory Environment Inventory (SLEI) reads "I am able to depend on other students for help during laboratory classes", whilst the preferred form of the item reads "I would be able to depend on other students for help during laboratory classes."

Long form and short form instruments. The early learning environment instruments, such as the LEI and the CES, are now referred to as long forms of the instrument. These instruments, after trials and analyses of the items, were reduced to 105 and 90 statements, respectively. Instruments of this size took quite some time to administer and score and both teachers and researchers stated a desire for a more economical form of learning environment instrument. Short forms of the Individualised Classroom Environment Questionnaire (ICEQ), My Class Inventory (MCI) and Classroom Environment Scale (CES) were developed (Fraser, 1982; Fraser & Fisher, 1983c) with a number of important properties. The number of items was reduced to approximately 25, which made for more economical administration and scoring, the latter able to be done by hand. Fraser (1994) asserts the short form of each instrument has adequate reliability for uses which involve the class mean as the unit of analysis, but if the individual is the unit of analysis the long form of the instrument should be used. Fraser (1994) outlines a number of reasons for defining the unit of analysis:

1. Measures having the same operational definition can have different substantive interpretations with different levels of aggregation.
2. Relationships obtained using one unit of analysis could differ in magnitude and even in sign from relationships obtained using another unit.
3. The use of certain units of analysis violates the requirement of independence of observations and calls into question the results of statistical significance tests because an unjustifiably small sample estimate of the sampling error is used.
4. The use of different units of analysis involves the testing of conceptually different hypotheses.

(Fraser, 1994, p. 496).

Validation of Learning Environment Instrument Scales

In order to be useful for the designated purpose learning environment instruments must satisfy certain statistical criteria. Table 3.2 reports statistical data for the Classroom Environment Scale (CES), the College and University Classroom Environment Inventory (CUCEI) and the Science Laboratory Environment Inventory (SLEI). The data reported are for the student actual form of each instrument and the individual student has been used as the unit of analysis.

Table 3.2 provides information about the internal consistency reliability (Cronbach Alpha coefficient), the discriminant validity (mean correlation of a scale with the other scales) and the ability of the scale to differentiate between the perceptions of students in different classrooms (significance level and *eta*^{2} statistic from ANOVAs). Fraser (1994) suggests that, generally, each scale for each of the instruments shown has adequate internal consistency reliability, discriminant validity and the ability to differentiate between classrooms. Each instrument does, however, appear to measure overlapping aspects, as shown by the interscale correlations.

Table 3.2. Statistical Data for Three Learning Environment Instruments.

Scale	Alpha Reliability	Mean Correlation with Other Scales	ANOVA Results *Eta*^{2}
Classroom Environment Scale (CES) (N=1083 students)			
Involvement	.70	.40	.29*
Affiliation	.60	.24	.21*
Teacher support	.72	.29	.21*
Task orientation	.58	.23	.25*
Competition	.51	.09	.18*
Order & organisation	.75	.29	.43*
Rule clarity	.63	.29	.21*
Teacher control	.60	.16	.27*
Innovation	.52	.19	.26*
Personalisation	.79	.28	.31*
Participation	.70	.27	.21*
Independence	.68	.07	.30*
Investigation	.71	.21	.20*
Differentiation	.76	.10	.43*
College & University Classroom Environment Inventory (CUCEI) (N=372 students)			
Personalization	.75	.46	.35*
Involvement	.70	.47	.40*
Student cohesiveness	.90	.45	.47*
Satisfaction	.88	.45	.32*
Task orientation	.75	.38	.43*
Innovation	.81	.46	.41*
Individualisation	.78	.34	.46*
Science Laboratory Environment Inventory (SLEI) (N=3727 students)			
Student cohesiveness	.77	.34	.21*
Open-endedness	.70	.07	.19*
Integration	.83	.37	.23*
Rule clarity	.75	.33	.21*
Material environment	.75	.37	.21*

* $p < .01$.

Note: Results for CES, CUCEI and SLEI taken from Fraser (1994, Table 17.2, p. 500).

Research Involving Classroom Environment Instruments

Research using classroom environment instruments is varied and proliferating. Past research is summarised into 12 types by Fraser (1998b) in the first edition of the journal *Learning Environments Research.* The 12 types of past research include (1) associations between student outcomes and environment, (2) evaluation of educational innovations, (3) differences between students' and teachers' perceptions of the same classroom, (4) whether students achieve better when in their preferred environments, (5) teachers' practical attempts to improve their classroom climates, (6) combining qualitative and quantitative methods, (7) school psychology, (8) links between educational environments, (9) cross-national studies, (10) transition from primary to secondary education, (11) teacher education, and (12) teacher assessment.

What is immediately noticeable within the context of this research is the absence of research involving the use of learning environment instruments in informal learning environments. A classroom environment instrument is a measure that has become associated with more formal educational environments. It is one aim of this research to produce a learning environment instrument to move learning environment research one step closer to informal learning environments.

Teachers' Attempts to Improve Classroom and School Environments

> Teaching ... affects the environment and is in turn affected by it.
>
> (Fraser, 1994, p. 493).

This section looks first at the influence of the teacher's epistemology on the classroom learning environment and then at one example of a practical application of learning environments instruments as a tool to assess and guide change in the classroom learning environment.

The teacher's epistemology

> The manner in which a teacher sets up a classroom and engages students is probably dependent on what the teacher intends students to learn and how he/she believes students learn. (Tobin & Gallagher, 1987, p. 550)

An educational theory consists of two major components, a theory of knowledge and a theory of learning (Jackson & Hann, 1994; Russell, 1994). Epistemology can be seen as a continuum with realism at one extreme and construction of meaning at the other. We can believe that knowledge is an absolute and exists independently of the learner or that knowledge consists only of ideas and concepts constructed in the mind of the learner. Likewise, how one learns can be represented on a continuum. At one extreme is the behaviourist position that learning is the incremental accumulation of facts, knowledge and ideas that result in knowledge. This theory has been referred to as the *tabula rasa* or the 'jug-to-mug' theory on the assumption that one starts with an empty mind and gradually fills it with knowledge. At the other extreme is the view that learning is the construction of meaning and concepts that result from the unique experiences of each individual and his/her equally unique and flexible interpretations.

In reality, many classrooms will fall somewhere along this continuum with the pedagogical approaches being dictated mainly by the teacher's beliefs and preferences. Other factors such as resources, the abilities and interests of the students, the nature of the material to be learned and other imperatives such as time constraints and coverage of the curriculum need also to be considered. A flexible approach to teaching would see constant movement along this continuum in response to the needs of the students and the perception of the teacher as to the "best" way to meet the current needs.

Using learning environment instruments to guide change. A significant function of teaching is the creation of a suitable learning environment. "discrepancies between actual and preferred environments can provide a practical basis for planning environmental changes which align the actual environment with students' or teachers' preferred environment" (Fraser, 1981, p. 131). Numerous research programs have shown that student perceptions account for appreciable amounts of variance in learning outcomes, often beyond that attributable to background student characteristics. Teachers can act as researchers within their own classrooms to ascertain and, if necessary, change the learning environment.

This type of research is an example of person-environment fit research (Hunt, 1975). It involves an assessment of the students' actual and preferred perceptions of the classroom environment, identification of differences and the implementation of strategies to reduce discrepancies. This method has been used in studies at elementary (Fraser & Deer, 1983), secondary (Fraser, Seddon, & Eagleson, 1982), and higher education levels (De Young, 1977) with success. Research has shown students achieve better when their classroom matches their preferred environment (Fraser & Fisher, 1983a; Fraser & Fisher, 1983b). An implication for the classroom teacher is that certain aspects of class achievement could be improved by aligning the actual classroom environment more closely with that preferred by the class as a whole (Fraser, 1989).

According to Fraser (1989) the procedure has five steps. The first step is assessment of the actual and preferred learning environments using a suitable learning environment instrument; Fraser and Deer (1983) used the MCI and Fraser and Fisher (1986) used the CES. Assessment is followed by the steps of feedback, reflection and discussion, intervention and reassessment. This procedure can be implemented in a cyclical fashion to implement incremental changes over a period of time. Fraser and Deer (1983) reported improvements in all five dimensions of the MCI. Significant differences were only recorded, however, on the two dimensions promoted by the teacher for change, Competitiveness and Cohesiveness. Fraser and Fisher (1986), in their study, reported statistically significant improvements in Teacher Support, Task Orientation and Order and Organisation. Two of these dimensions were those that the teacher had promoted during the intervention.

In both studies there appeared to be side-effects from the interventions. In the Fraser and Deer (1983) study, the intervention could have resulted in the classroom becoming less difficult and less challenging than the students would have preferred. In the Fraser and Fisher (1986) study, the intervention could have resulted in the classroom becoming more task oriented than the students would have preferred. These studies suggest that there is a potential for teachers to employ classroom environment instruments as a means of assessing and guiding change in the classroom environment to one that is closer to a preferred student environment.

However, "the teacher and students do not necessarily agree always about the direction of desired change and this, in turn, presents a dilemma for those attempting to plan changes in their classroom environment" (Fraser, 1981, p. 142).

Conclusion

Lewin's (1936) statement of behaviour as a function of the interaction between personal characteristics and the environment established a base upon which learning environment research could be built. Early learning environment analyses were based upon low inference measures until the independent work of Walberg and Moos in developing separate learning environment instruments based upon high inference measures. Walberg developed the Learning Environment Inventory (LEI) and Moos and Trickett developed the Classroom Environment Survey (CES). Moos's (1974) scheme for classifying human environments has been adopted by learning environment researchers as a means of classifying scales within learning environment instruments (Table 3.1). Moos's three basic dimensions are the relationship dimension, the personal development dimension and the system maintenance and system change dimension.

Learning environment instruments have diversified from the original long form which measured students' perceptions of the actual environment. There are now instruments for measuring perceptions of the preferred environment, and short forms of instruments that use the class as the unit of analysis. Instruments currently in use have been trialled, analysed and validated (see examples in Table 3.2). There is a growing body of research based upon the use of learning environment instruments, and instruments are currently employed for such practical applications as their use by teachers to analyse and improve their own classroom learning environment.

A learning environment instrument has not yet been developed for use in informal learning environments such as SECSMs and CSIROSECs. Yet many of the scales used in existing instruments may be applicable to more informal learning situations. Some of the scales identified in Table 3.1 might provide a useful starting point; scales such as involvement (derived from CES, CUCEI, WIHIC), participation (ICEQ), innovation (CES, CUCEI), independence (ICEQ), investigation

(ICEQ,WIHIC), task orientation (CUCEI, WIHIC, CES), cooperation (WIHIC), cohesiveness (LEI, SLEI, WIHIC, MCI), teacher support (CES, WIHIC), and material environment (LEI, SLEI). A review of the literature on learning in informal environments may identify additional scales that may be used to characterise the learning environments in SECSMs in general and, more specifically, in CSIROSECs.

Learning in Formal and Informal Environments

> The notion of distinguishing between informal and formal **learning** is unproductive, after all, learning is learning. However, it is often useful to consider the nature of the setting or context in which the learning takes place. (Rennie, 1998, p. 2, original emphasis)

It is useful to work from the simple to the more complex in describing the nature of formal and informal learning environments. Hein (1998) summarises the distinction between formal and informal learning environments in quite succinct terms when he says "'formal' and 'informal' [refer to] a description of settings and the presence or absence of a formal curriculum" (p. 7). This highlights a major difference between formal and informal learning environments, but it could also lead to oversimplification and misunderstanding.

As McManus (1992) points out,

> In formal educational situations, where you will learn, who you will learn with, whether you are qualified to learn, who you will learn from, what you will learn, how long you will be given to learn it, and agreement on what you have learned and your level of understanding are matters largely out of control of the individual learner. ...In contrast, informal education in museums is entirely free choice in every respect. (pp. 165-166)

The informal learning environment of SECSM settings is characterised as open-ended, nonlinear, voluntary, hands-on and entertaining, with no prerequisites, no evaluation, no grades and social interaction is often an integral component of the experience.

Wellington (1990) outlines a number of features of informal and formal learning environments (Table 3.3). This dichotomy will be useful later in the chapter for placing the semi-formal CSIRO Science Education Centre learning environment within the context of informal and formal learning environments.

Table 3.3. Features of Formal and Informal Science Learning.

Informal learning	Formal learning
Voluntary	Compulsory
Unstructured	Structured
Unsequenced	Sequenced
Nonassessed	Assessed
Unevaluated	Evaluated
Open-ended	Close-ended
Learner-led	Teacher-led
Learner-centered	Teacher-centered
Out-of-school context	Classroom context
Non-curriculum-based	Curriculum-based
Many unintended outcomes	Fewer unintended outcomes
Less directly measurable outcomes	Empirically measured outcomes
Social intercourse	Solitary work
Nondirected or learner directed	Teacher directed

Note: Modified from Wellington (1990, p. 248).

Learning environments include schools, classrooms, museums, zoos, science education centres, field centres and homes, in fact, almost anywhere can provide learning opportunities. Dierking (1991) claims that any of these settings can be seen as formal or informal depending upon the structure of the learning opportunity and the perception of the individual. In-depth interviews conducted by Birney (1988) in her study into some aspects of museums and zoos as learning environments allowed students to define their own optimal learning experience. "What they described strongly resembles researchers' definition of the informal-learning rather than the formal-learning process" (p. 313). This research will focus on developing a learning environment instrument as a means of determining the perceptions of students visiting CSIRO Science Education Centres. The remainder of this literature review will, therefore, concentrate upon past research relating to the learning environments in Science Education Centres and Museums in order to identify a number of measurable variables which describe the CSIROSEC learning environment.

Research in Science Education Centres and Museums

"Much of the literature pertaining to learning in museums is anecdotal and craft wisdom, indicating that more collaborative research efforts are needed in the area of science education in museum settings" (Ramey-Gassert, Walberg, & Walberg, 1994). This view is echoed by Falk and Dierking (1995) who add that "previous attempts to define and measure learning in museums have lacked both a clear focus and a well-formulated theoretical underpinning" (p. 9).

Feher and Rice (1985) contend that science centres have a dual role to fulfill in public enlightenment and scholarly research. Feher and Diamond (1990) support the use of science centres in education research claiming they are excellent laboratories for studying how people learn. Lucas and McManus (1986) concur, also highlighting the importance of coordinating studies from diverse areas when they say,

> Despite the difficulties inherent in the study of learning from informal settings such as museums, we believe that there is promise in investigating such activities; this is particularly true if studies of other sources of learning such as television and the press, and the interactions between knowledge gained in these ways with that gained in school or other formal instructional settings, is conducted in conjunction. In this way, we can gain evidence of how people come to hold some of the beliefs that recent studies have revealed. Without such evidence, these studies rest on conjecture, and the suggestion for action made as a result of them may be misguided, since they focus on the symptoms, not the etiology of the problematic interpretations.
>
> (Lucas & McManus, 1986, p. 351)

Much of the past research has referred to science education centres and museums (SECSMs) collectively. There are basic distinctions, however, which separate the different types of centres in a functional sense. From the works of Danilov (1982) and McManus (1992) describing the historical development of science centres and interactive science-technology centres, a distinction emerges between museums, with their collections of objects, and interactive science and technology centres (ITSCs) which are based upon the presentation of ideas and concepts using interactive exhibits.

Rennie and McClafferty (1996) have described the characteristics of the science centre. The characteristics of all contemporary interactive science-technology centres are summarised in McClafferty's unpublished article of 1999. (1) The culture between museums and science-technology centres is different, as previously pointed out by Danilov (1982) and McManus (1992). (2) The exhibit's concept or phenomena is removed from the social and cultural context where it is commonly experienced by visitors. (3) The exhibits are purpose built and require visitors to engage physically by manipulating and exploring, with the exhibit responding and visitors learn as they attempt to make sense of the responses. (4) All science centres have attendants who explain and assist visitors to understand the exhibit's message and act as docents. (5) All of the centres have a mission statement squarely based on the popularisation of science through learning, play and exploration, and some science centres want their visitors to have fun and enjoy the experience.

The unique nature of SECSMs requires a rethink on approaches to research about learning, starting with new research questions and ways of collecting data (Falk et al., 1986). One answer may lie in the use of both qualitative and quantitative research methods.

SECSMs are fun, but what do students learn?

It is important to define what is meant by learning in informal contexts such as science education centres and museums. Falk and Dierking (1992) say that visitors learn from a museum visit when they "assimilate events and observations in mental categories of personal significance and character determined by events in their lives before and after the museum visit" (p. 123). In addition, "there is an increased probability that self-directed learning and generalisation beyond the specific content presented will occur, since museums tend to facilitate the learner's ability to relate content to personal experiences and backgrounds" (Falk, Koran, & Dierking, 1986, p. 505).

Semper (1990) suggests that there are at least four themes in education theory that especially relate to the learning activities found in museums. They are multiple modes of learning, curiosity or intrinsically motivated learning, the presence of self-developed models in the process of learning science, and play and exploration in the learning processes.

In their review of the literature, Falk and Dierking (1995) conceptualised learning in SECSMs as involving seven major factors: "prior knowledge and experience; subsequent, reinforcing experiences; motivation and attitude; culture and background; social mediation; design and presentation; and the physical setting" (p. 11).

Science education centres and science museums have been criticised for being playgrounds (Dolan, 1988) where visitors are entertained rather than educated (Shortland, 1987; Wymer, 1991; Shields, 1993; Young, 1993). But education and enjoyment can be linked (Bitgood, Serrell, & Thompson, 1994), and Duckworth, Easley, Hawkins and Henriques (1990) consider learning itself to be a playful process, wherein one toys with ideas as a means of reducing complexity and producing generalisations. Bruner, Jolly and Sylva (1976) claim play creates an attitude of mind that facilitates problem-solving. The Sciencecentre in Brisbane, Queensland, has an interactive early childhood exhibition, entitled ScienceSpot, that emphasises the notion of play as being fundamental to learning for young children (Henderson, 1998). Moyles (1989) points out that many eminent educationalists believe that the most valuable learning comes through play.

Play provides a motivation to participate in activities and participation, at least at the mental level, is a prelude to learning. Not all science can be presented as play, but this does not preclude the presentation of science in an enjoyable way that affords fun to those participating. Eratuuli and Sneider (1990) state that the designers of the Wizard's Lab at the Lawrence Hall of Science were primarily concerned that visitors enjoy themselves. It was assumed that if the visitors enjoyed interacting with the exhibits they would learn about scientific principles and processes and develop a positive attitude towards science (Eratuuli & Sneider, 1990). The fun aspect of learning in SECSMs is reinforced by Holligan (quoted in Mardell, 1995) who says that science centres make the link between science and fun. He goes on to add that visitors learn relatively little, but visits provide an inspiration.

Borun, Flexer, Casey and Baum (1983) found that the real value in a museum visit resides in its capacity for generating enthusiasm for and interest in science learning, rather than the ability of a visit to convey large amounts of information. Borun (cited in Hicks, 1986) added, in relation to children's learning on field trips:

> The actual amount of science learned was small, but their feelings about the subject were significant and the motivational impact of the visit was profound. So for me, that says that the museum is complementing other learning media and that its strong suit is not in transmitting nuggets of information, but in motivating, stimulating and exciting people.
>
> (Borun, 1977, cited in Hicks, 1986, p. 33).

Falk and Dierking (1992) criticised the definition of learning that has been applied in much of the research on learning in museums, arguing that it derived from "the misguided notion that learning is primarily the acquisition of new ideas, facts or information, rather than the consolidation and slow incremental growth of existing ideas and information" (p. 98). Many constructivists would embrace these sentiments wholeheartedly. And as Griffin and Symington (1998) point out, ultimately there may be more value in investigating the processes of student learning in SECSMs than investigating what they have learned.

In his review, Prather (1989) found that there were many benefits for science learning inherent in field trips. These included broadening student experiences, discovery learning, reinforcement of classroom exercises, social interaction, attitude improvement toward science, and activity learning. Dierking and Falk (1994) found that when more naturalistic methodologies were used to enable an investigation of the family museum experience within its own social and physical context, there was good evidence that learning did occur. SECSM visits have been found to lead to improved attitudes towards science and technology (Finson & Enochs, 1987; Tuckey, 1992a; Wellington, 1990). The emphasis with hands-on activities in SECSMs can also assist with the development of psychomotor skills including dexterity, hand-eye coordination and other manipulative skills (Wellington, 1990).

In relation to the structure of museum visits and learning, Stronck (1983) found that students had significantly greater cognitive learning when they participated in a more structured tour, but they had significantly more positive attitudes when they participated in a less structured tour (p. 283). Other researchers have reported gains in cognitive learning and/or more positive attitudes to science resulting from SECSM visits (Balling & Falk, 1980; Dymond, Goodrum, & Kerr, 1990; Eratuuli & Sneider, 1990; Gottfried, 1980; Javlekar, 1989; Lam-Kan, 1985; Schibeci, 1992; Wright, 1980).

Museum exhibits can encourage active participation (Wolf, 1986) leading to a heightened acquisition and retention of information (Madden, 1985) and exhibits can focus attention (Csikszentmihalyi, 1987). Koran, Koran and Longino (1984) quote proponents of SECSMs as asserting that exhibits visitors can physically interact with lead to increased perceptual opportunities and contribute to enhanced curiosity, interest, motivation, and the growth of exploratory skills. Feher and Rice (1988) state, quite succinctly, "immersion in such a phenomenon-rich environment is undoubtedly a necessary, even if not sufficient condition for learning to occur" (p. 649). Carlson (1993) claims that when people are actively learning, information is more likely to be retained over a long period of time. Tuckey (1992a) concludes that "pupils' recall of exhibits showed that pupils tend to remember the exhibits that have made the greatest demands on their attention and require most active participation" (p. 37). Smith and Nagel (1972), likewise, contend that multisensory experiences, particularly for concrete operational, elementary school students appear to be the ones they are least likely to forget.

In his research on the pedagogical framework of an interactive exhibit, McClafferty (1998) found, incidentally, that the framework was similar to the Yale Communication Program (Hovland, Janis, & Kelley, 1953). The program McClafferty worked with, *Let's Get Physical*, was an exhibit made up from six activities designed to assess participants' physical fitness. Its purpose was to encourage participants to be active every day. In relation to his research with *Let's Get Physical*, McClafferty concludes "the exhibit exposed visitors to the message of engaging in regular physical fitness, and by visitors' knowledge of their fitness rating, visitors' attitude to physical activities was enhanced and they were persuaded to be active every day" (p. 100). An important aspect of McClafferty's model is the time-frame for attending, comprehending, accepting and initiating, suggesting that the outcomes from exposure to exhibits are not immediate. This may be, for some, a useful model for exploring the effects of exhibits and SECSM visits on influencing attitudes and changing behaviour of visitors over a period of time.

Interactive Exhibits

> Much of the criticism directed towards science centres concerns exhibits seen to be "hands-on" at the expense of "minds-on."
>
> (Rennie & McClafferty, 1996, p. 87)

In the past, terminology regarding the interactivity of exhibits has been used indefinitely. The terms hands-on and interactive have often been used interchangeably, but they are not the same (Rennie & McClafferty, 1996). Hands-on implies the touching, handling, feeling or manipulation of an exhibit. This may merely involve the pressing of a button and "exhibits which contain buttons which simply light up a graph or turn a motor are not interactive systems" (Screven, 1974, p. 17). Interactivity requires some degree of reciprocity, with exhibit and visitor acting upon each other (Miles, Alt, Gosling, Lewis, & Tout, 1988) or as Screven puts it, there should be an interdependency between the exhibit and the visitor. An interactive exhibit should offer feedback to the visitor that encourages further interaction (Rennie & McClafferty, 1996).

The term hands-on is also inaccurate because it implies some degree of physical contact, and this is not always necessary in order to interact with an exhibit. An optical illusions program is a good example of this and there are many good examples of this type of exhibit in the *Exploratorium Cookbook* (Bruman, 1975). Here the sense being used is predominantly sight, and there may be little requirement to physically manipulate many of the exhibits. For example, the *Pulfrich's Universe Illusion* (Bruman, 1975, Recipe No. 52) is one that requires interaction, but no physical contact. When observed with both eyes the illusion does not exist, however, when observed with both eyes, but with the image delayed to one eye by looking through a piece of tinted plastic, the illusion becomes apparent. Similarly, the *Rotating (or Trapezoidal) Window Illusion* (Bruman, 1975, Recipe No. 61) appears normal through both eyes, however, closing one eye eventually reveals the illusion. This illusion is a particularly good example of interaction, because stereo vision is not immediately lost when one eye is closed, and it takes a short period of time before the brain processes the new visual input and the illusion becomes apparent. *Ambiguous Figures* is another group of illusions that requires extensive visual contact and mental processing. What appears to be one image, can, by careful observation, resolve itself into a second image (or more). All of these examples require the use of visual sensory input rather than actual contact (hands-on) and furthermore, require mental processing of the image to occur before the illusion becomes apparent. Figures 3.1 and 3.2 provide examples of ambiguous figures.

Active participants in the development of interactive science and technology centres, including Oppenheimer (1968a), Gregory (1989), Feher (1990) and Gore (1984), were strong proponents of the belief that visitors learn by interacting with exhibits. Oppenheimer saw passive exhibits as irrelevant and proposed that science should be presented in a way which allowed the public to interact with the occurring phenomena, to experiment, ask questions and to discover answers for themselves (Oppenheimer, 1968a). He believed that exhibits should possess an inherent capacity to attract, engage and motivate people to manipulate, interact and explore. "They require apparatus which people can see and handle, and which display phenomena which people can turn on and off at will" (Oppenheimer, 1968b, p. 206).

These early notions are supported by the research of Tuckey (1992a), who found that in relation to impact on children's memory, interactivity of exhibits was more important than visual attractiveness. This is supported by Farrell's research (1998) into adult participation at the Gulf Coast World of Science and the Orlando Science Centre. She found that those exhibits which were less "polished" were reported as having a greater ease of use and concludes that the user needs to be considered and exhibits should provide an inviting, easy-to-use presentation.

Semper (1990) outlines a number of guidelines in exhibit design which are now followed by designers at the Exploratorium:

1. The user of an exhibit, not the designer, should be in control of the learning activity.
2. Everyday objects and experiences offer good starting points for many exhibits.
3. The development of the exhibit aesthetic is critical.
4. Artists, as well as scientists and educators, can provide ideas for exciting exhibits.
5. The functional design of an exhibit is important for learning.
6. Exhibits have an individual scale and a group identity.
7. The entire museum environment is important.

(summarised from Semper, 1990, pp. 7-8).

Perry (1989, 1992) concluded from her research into exhibit-visitor interaction that there were six factors that were important for an exhibit to be successful – curiosity, confidence, challenge, control, play, and communication.

Figure 3.1
Ambiguous figures in black and white.

This picture can be interpreted as that of an old woman or a young woman or both.

Figure 3.2
Ambiguous figures in greyscale.

This is a different version of Figure 3.1. Some people find it easier to identify the people in this version.

Feher (1990) distinguished four levels of interaction with exhibits – experiencing, exploration, explaining, and expanding. Experiencing is driven by curiosity and is related to the attracting power of an exhibit. Once attracted, the user explores the exhibit by physically interacting with it. The user then brings prior knowledge to bear in an effort to explain the results of the exploration. The culmination is expansion, wherein the student formulates generalisations from interactions with related exhibits. An important aspect of this process is the relationship between the conceptual content of the exhibit and the pre-conceptual understandings that the student brings to the experience. It is always possible that students may reinforce naïve concepts, or, as Tuckey (1992b) points out, where multiple explanations are possible the student may construct unorthodox models to explain phenomena. The possibility of the construction of unorthodox models or the reinforcement of naïve concepts needs to be taken into consideration in the design of exhibits and eliminated or, at the least, minimised.

Sealie (1998) states that it is important during the construction of a new exhibit not just to establish the consensus model underlying the exhibit and ensure that this is communicated, but to identify all possible misunderstandings and alternative conceptions that visitors may construct from their interaction with the exhibit. This is best achieved by extensive trials of the exhibit with its target audience, elucidating prior knowledge and concepts and the identification of resultant visitors' conceptions. Issues that emerge from such an analysis can then drive the construction and display of the final form of the exhibit.

SECSMs have been in a growth phase for quite some time and many of the same exhibit ideas are repeated in many centres. A challenge exists to ensure that exhibitions and exhibits continue to be contemporary and are presented in currently effective ways to each centre's own public. The same exhibit idea may be expressed in a number of diverse ways "in the form of a toy to be enjoyed at home, in an exhibition devised by a cultural bricoleur, in the hard-sell surroundings of a trade fair, or as a public-art piece in Kensington Gardens" (Quin, 1989, p. 35). The use of varying designs and materials will result in different experiences for the user and often the learning outcomes will also be quite different. However, the agenda and motive of the individual or group will still be major determinants of the nature and extent of the learning experience. Gregory (1989) also points toward the importance of developing more and more effective ways of explaining phenomena and principles so that interactive science centres "become viable mutations in the future they will help to create" (p. 8).

Previsit Preparation

> People learn best those things that they already know about and interest them, and people are interested in those things they learn best.
>
> (Falk & Dierking, 1992, p. 100)

People who attend SECSMs with more prerequisite science knowledge tend to learn more than those with less prerequisite knowledge (Shettel, Butcher, Cotton, Northrup & Slough, 1968; Beiers & McRobbie, 1992). Since learning is most effective when the conceptual level of the student is matched to the conceptual level of the exhibit, the benefit of an SECSM visit can be enhanced by integrating it with current classroom science teaching (Tuckey, 1992b; also Rennie & McClafferty, 1995, 1996). This is most effective when a visit is used to reinforce science concepts that have recently been outlined for students (Flexer & Borun, 1984). The majority of students who have been prepared for the visit by their teacher tend to concentrate better and learn more from the experience (Delaney, 1967; Koran & Baker, 1978; Gennaro, 1981; MacKenzie, 1986). Delaney found that pre-visit preparation was beneficial for improving the learning of average and below average students, whilst Gennaro found that students at all levels benefited from pre-visit instructional materials. It has been found that both cognitive and affective learning can be increased when teachers use pre-instructional activities to structure their class's visits (Finson & Enochs, 1987; Koran, Lehman, Schafer, & Koran, 1983). The same may be said of in-visit and post-visit activities, which have also been found to contribute significantly to higher class means and posttest scores (Finson & Enochs, 1987). However, Gottfried (1979, 1980) reported that the majority of the teachers in his studies did not plan either preparatory or follow-up activities. Likewise, whilst teachers see pre-visit and post-visit activities as important they are rarely prepared and used in conjunction with an excursion (Rennie & McClafferty, 1995). This is supported by similar findings relating to pre-visit preparation from Cox and McComas (1997), Griffin (1994b) and Tulip and Christensen (1994).

Balling, Falk and Aronson (1995) investigated three aspects of pre-visit preparation of students visiting the National Zoo, Washington – (a) cognitive, (b) process skills, and (c) the student-centred agenda. Each group received one type of pre-visit preparation. Cognitive issues dealt with what would be discussed on the field trip, process skills covered the techniques of observing animals and the student-centred agenda dealt with the usual (but important) concerns and anxieties of students relating to travel, eating, the zoo shop and what they would see and do. The pre-visit preparation that achieved the greatest learning was that which dealt with the student-centred agenda. This emphasises the importance of dealing with the hidden agenda issues of students prior to an excursion, thus freeing them up to concentrate without the distraction of other anxieties and concerns.

SECSMs as Constructivist Learning Environments

Hein (1995) has represented his version of the relationships of the theories of knowledge and learning and their impact on the style of a museum. Hein's diagram is reproduced in Figure 3.3. Graphic models, such as Figure 3.3, allow us to free ourselves from an exclusive linguistic interpretation of the relationships between theories and bring a visual interpretation to bear. Two questions need to be answered in order to establish the position of a particular museum on Hein's model: First, what is the theory of knowledge applied to the content of the exhibition? Second, how do we believe that people learn?

It should be immediately obvious to the experienced SECSM practitioner that a particular centre need not occupy a single position on the model, unless it is completely homogeneous with respect to its programs. Many centres have programs differing one from the other in both knowledge content and style of learning. Many Systematic and Orderly Museums have discovery areas, whilst Constructivist Museums, with a high proportion of hands-on and minds-on activities, may still have a proportion of text-based displays. Hein's model can be used to define the predominant theories of knowledge and learning in an SECSM, but it can also be used to determine which programs contribute to the overall philosophy of the SECSM.

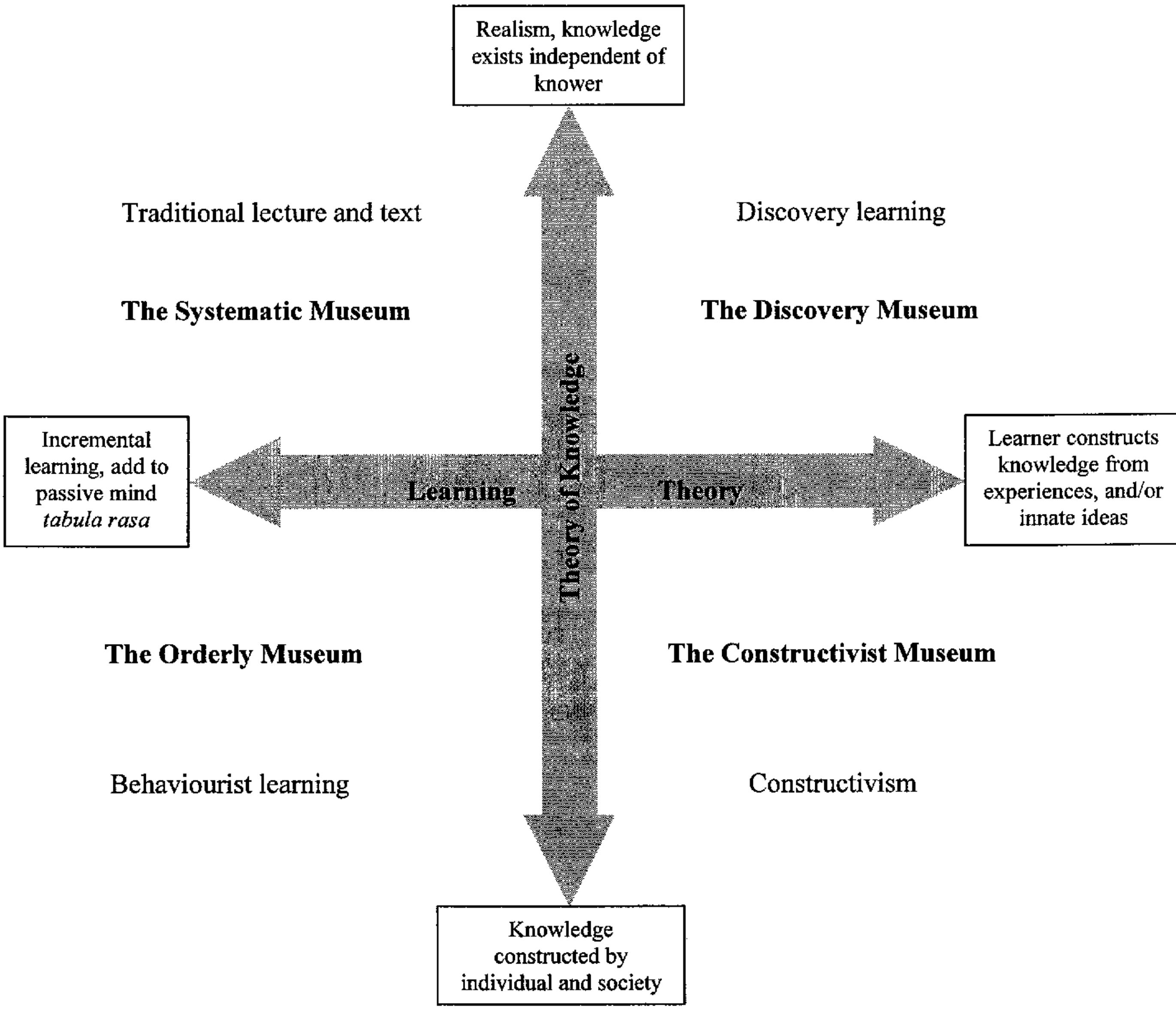

Figure 3.3. Model of Theories of Knowledge of Learning in Museums (After Hein, 1995).

An understanding of theories of knowledge and learning and their contribution to learning in SECSMs is an important precursor to defining the learning environment within a particular centre. CSIROSECs are hands-on, minds-on centres based upon the belief that knowledge is constructed by individuals and society and in which students construct knowledge from their own experiences. It is essential that CSIROSECs are established as constructivist centres, since it is from this platform that we can begin to understand and define the predominant characteristics of their learning environment.

A constructivist environment is necessary in SECSMs, since different participants will bring different backgrounds, levels of education, experience, ability and skill with them. This will, in turn, determine the meanings ascribed to particular activities by each individual and the ability to interact with meaning. An important variable for a learner in a learning situation is prior knowledge of the area, and students' prior knowledge is important in how they interact with and what they learn from exhibits (Beiers & McRobbie, 1992; Falk & Dierking, 1992; Falk, Koran, & Dierking, 1986; Gelman, Massey, & McManus, 1991; Gottfried, 1979; Lucas, McManus, & Thomas, 1986; Sneider, Eason, & Friedman, 1979; Tulley & Lucas, 1991). There is a considerable body of research asserting that the most effective interaction between students and exhibits occurs when the thought processes of the student are matched with those needed to understand the exhibit (Boram & Marek, 1991; Feher & Rice, 1985; Javlekar, 1989; Semper, 1990; Tuckey, 1992b). Wellington (1990) found that hands-on science centres could relate science and technology to things that most people see and use.

Feher (1990) raises the issue of prior misconceptions and "naïve notions" (p. 46) and the tendency of children to cling onto such concepts. Her response is to present each concept in a variety of contexts via multiple exhibits, invoking repetition and reinforcement. Tuckey (1992b) approaches the issue from a standpoint of prior preparation, since learning is most effective when the concepts of the child are matched to those of the exhibit. He entreats teachers to integrate a visit to an interactive science centre into their science teaching and so maximise potential benefit.

With more complex phenomena it is increasingly important that visitors have a sufficient degree of pre-understanding so as to construct meaning and reduce ambiguity (Anderson, 1994). The findings of Beiers and McRobbie (1992) are consistent with the view that while exhibits can enhance understanding, they are less likely to teach unfamiliar concepts (Tuckey, 1992b).

Despite all the foregoing arguments concerning learning outcomes from SECSM visits, Carr (1989) claims that the most important learning may occur after the excursion in subsequent reflection, observations, discussion, and other activities. "It seems clear that for perceptual experience to be meaningful it has to be *interpreted*" (Gregory, 1989, p. 5). This lends support to the provision of follow-up activities for SECSM visits that promote interpretation. This is arguably one of the greatest values in SECSM excursions, that the knowledge, skills and attitudes gained can form the building blocks for subsequent concept construction. Falk and Dierking (1992) point this out when they say, "reinforcement, consolidation and reshaping of knowledge are critical aspects of the learning process" (p. 120). Gilbert, Stocklmayer, and Garnett (1998) found from their study at Questacon that cognitive outcomes continued to develop after a visit, as relationships were made with prior knowledge, interests and everyday experiences. In view of the evidence on learning subsequent to SECSM visits one might expect that constructivist teachers would be eager to maximise learning from the new experiences students have been subjected to by providing appropriate post-visit activities (Anderson, Lucas, Ginns, & Dierking, 1998). Yet the effects of post-visit activities on learning from SECSM visits have been described sparsely in the literature.

A Multisensory Approach

Evidence exists that individuals differ in the learning styles that they display (Gilbert, 1995). Combinations of preferring to learn by touch (concrete experience), by watching what is going on (reflective observation), by thinking about what is in the environment (conceptualization), and by trying things out (experimentation) have been observed as personal characteristics of learning style (McCarthy, 1986; Gilbert, 1995).

Gardner's (1993) theory of multiple intelligences provides another relevant model which should be considered by designers of exhibitions and exhibits for SECSMs.

Gardner suggested that there are seven different types of intelligences that need to be addressed during the formative phase of educational programs. They are: Linguistic Intelligence, Logical-Mathematical Intelligence, Spatial Intelligence, Musical Intelligence, Body-Kinesthetic Intelligence, Interpersonal Intelligence and Intra-Personal Intelligence. One implication of Gardner's model is that individuals will approach an exhibit with a unique combination of intelligences and consequently their own preferred style of learning. Whilst designers need to be warned of attempting to be all things to all people, it is important to make provision for the diversity of approaches that visitors may exhibit.

Developmentalists propose that young children want and need a large amount of tactual interaction with their environment (Pulaski, 1971; Rowland & McGuire, 1980). Feher and Rice (1985) support this notion with respect to exhibit design when they say "to foster the enhanced understanding that will yield more sophisticated explanations of an effect, it is desirable to expand the kinesthetic experience of the visitor" (p. 45). But not all learning in SECSMs is directly related to exhibits. Falk and his colleagues (Falk, 1983; Falk & Balling, 1982; Falk, Martin & Balling, 1978; Martin, Falk, & Balling, 1981) have shown in several studies of the environmental effects on learning, that children can demonstrate considerable non-exhibit related learning after visits to SECSMs.

The stimulation of curiosity in SECSMs is a function of the attracting power of an exhibit. Once attracted, this curiosity then becomes a "stimulus in its own right to influence expanded perception when objects can be manipulated" (Koran, Morrison, Lehman, Koran, & Gandera, 1984, p. 362). In other words, the opportunity to interact with exhibits in a multisensory fashion allows visitors to satisfy their curiosity. Curiosity researchers point out that as the novelty and complexity of the stimulus increase, attention, length of fixation, number of questions, and interest in manipulation increase accordingly (Koran & Longino, 1983; Koran et al., 1984). Bresler (1991) claims that informal learning is essential for the development of curiosity. Children often lose curiosity, insightfulness, and natural ability to learn from exploration by the third grade because of the emphasis on rote learning in formal education (Harte, 1989; Semper, 1990). SECSMs are informal learning environments and Semper (1990) and Madden (1985) emphasise the importance and the integral role of curiosity in this learning environment.

Social Interaction

It is now known that a great deal of what is learnt anywhere is a result of discussion between the members of a group (Priest & Gilbert, 1994). Diamond (1986) found that learning in science museums was not just a function of the interaction of visitors with the exhibits, but that social interactions between visitors were also important in learning from exhibits. Gilbert (1995) found that the quality of interactions between members of a group and the exhibits greatly influenced learning in museums. Children feel that social interaction with peers is characterised by an equal exchange of information, greater freedom to explore, humor, and shared values. (Birney, 1988, p. 314). Social interactions can be improved by SECSM experiences (Diamond, 1980, 1986; Kremer & Mullins, 1992; Semper, 1990; Tuckey, 1992a). Tuckey (1992a) found that interactions between pupils enhance interactions between pupils and exhibits, especially through peer teaching. "Generally, ... students working in small groups were more able to ask questions and receive answers, did more 'hands-on' work and became more involved in their learning" (Price & Hein, 1991, pp. 511-512). Crook (1995) outlines three ways that peer interaction promotes learning: (1) collaboration may motivate participants to articulate their thoughts openly, (2) conflict may lead co-workers to negotiate consensus, and (3) new knowledge may be jointly constructed as individuals converge on a shared hypothesis or framework of understanding.

McManus (1987) reported that the most enjoyable feature of a visit to a science centre, for students, was working in groups. This indicates that social interaction is an important and integral part of the affective experience students encounter at science centres. The degree and quality of social interaction can, however, be affected by the composition of a group. This, in turn, may influence the extent and the effectiveness with which members of a group communicate their ideas about an exhibit to each other (McManus, 1988). Appleton (1996) has established that three is the optimum number of pupils for a laboratory lesson.

The division of the class unit into smaller sub-units has implications for social interaction. For arguments sake, let us consider a class unit of 30 students and implement class management strategies that will maximise the efficiency of student-teacher interaction. By dividing the class into 10 smaller groups of 3 students each, the teacher has effectively reduced the number of potential questions arising at any one time from 30 down to 10. This number may be further reduced by interaction between students within a group. This can arise from the sharing of prior knowledge and experience, shared problem-solving, peer teaching and, in some but not all cases, working towards a common or shared goal.

Focusing on the individual-as-learner may not provide a complete understanding on learning in informal learning environments such as those in SECSMs (McManus, 1988). The differences between learning in informal and formal settings mean that models of learning in formal education environments may not be entirely relevant in informal settings. This is supported by Serrell (1990) who claims that classroom research does not easily translate to the museum setting and that assumptions made about learners in extrinsically motivated situations are different from those in museums. Clearly other methods of evaluation of learning in informal environments are required (Kimche, 1978; Price & Hein, 1991) which may rely upon the use of naturalistic methods (Dierking & Falk, 1994) and multiple methods (Serrell, 1990). One step towards a better understanding of learning in informal environments is to more accurately describe and assess the characteristics of the learning environments in SECSMs.

The Novelty Factor

A component of the environment of the SECSM is the presence of novelty, which may direct students' behaviour away from learning (eg., Martin et al., 1981; Falk et al., 1978; Kubota & Olstad, 1991). Researchers have shown that as novelty and complexity increase, attention, length of fixation, number of observer questions, and manipulation increase (Cantor & Cantor, 1964, 1966; Mendel, 1965; Faw & Nunnally, 1968; Greenberger, Woldman, & Yourshaw, 1968; Ross, 1974; Rabinowitz, Moely, Finkel, & McClinton, 1975; Henderson & Moore, 1979). Falk et al. found that when subjected to a novel environment rich in stimuli, subjects are first and foremost concerned with adjusting to the environment rather than with learning. (Falk, Martin, & Balling, 1978).

Balling and Falk (1980) have graphically attempted to define the relationship between variations in setting novelty, learning and non-task behaviour as shown in Figure 3.4. Balling and Falk (1980) and Falk (1983) found that as novelty wears off, students learn more. This is one of the advantages inherent in multiple visits (Balling & Falk, 1980; Falk & Balling, 1982; Price & Hein, 1991). Bitgood (1991) provides guidelines for reducing novelty behaviour during excursions and increasing the emphasis on learning behaviour. Lehman and Lehman (1984) advocate the use of pre, post, or both types of attention-directing and cueing experiences to focus students' activities and enhance field trip experiences. Gennaro (1981) showed students who received advanced instruction on what they would be seeing at the museum learned more than those who didn't. "The key to facilitating cognitive learning in a novel museum setting may be to reduce the novelty of the setting enough to allow children to bypass the preliminary diversive exploratory phase" (Kubota & Olstad, 1991, p. 226). Anderson (1994) found that pre-visit orientation to the physical features and layout at the Sciencentre in Brisbane was successful in reducing setting novelty and enhancing students' learning. Other researchers have recommended orientation to the physical layout of the site to be visited (Anderson & Lucas, 1997; Gennaro, 1981; Kubota & Olstad, 1991; Orion & Hofstein, 1994).

Rennie and McClafferty (1996) conclude that explainers, amongst other factors, can play an important role in assisting visitors to SECSMs to focus on exhibits. Martin, Brown, and Russell (1991) have produced evidence that the presence of explainers increases the time spent at an exhibit. The author and his colleagues, at CSIROSEC Tasmania, have consistently observed that parents with visiting school groups can achieve a similar function in focusing students' attention and assisting them to remain on task. Brown (1995) found that the type and extent of parent involvement may be a major influence on what children gain from their visit to a centre, and that parent involvement is not sufficiently harnessed through exhibit design. It is essential that parent helpers (and explainers) be encouraged to act as guides along the learning pathway, leading students to discover for themselves rather than providing answers.

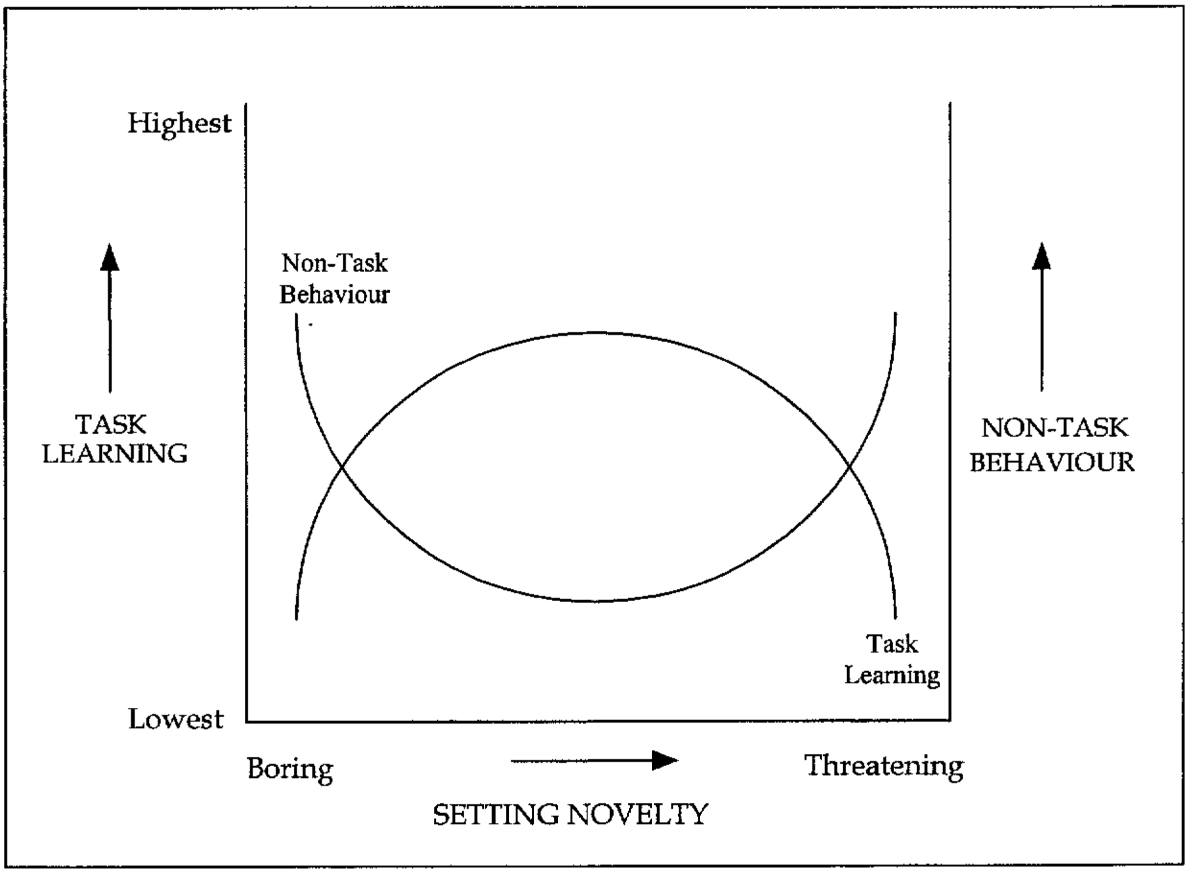

Figure 3.4. Relationship between Variations in Setting Novelty, Learning, and Non-Task Behaviour. (Balling & Falk, 1980, p. 238, Figure 1)

Martin, Falk, and Balling (1981) emphasise that the novel environment of the SECSM may make important contributions to learning, but it may not be the best environment for conceptual teaching. They suggest that more complex thinking and conceptual learning may best be achieved in the familiar and less stimulating environment of the classroom. The most important museum learning may occur outside the institution in subsequent reflection, observations, discussion, and other activities (Carr, 1989). Ramey-Gassert et al. (1994) conclude that "ideally students need both aspects for meaningful learning to occur – active, novel, interest-promoting experiences as well as environments more conducive to constructing personal understanding of the conceptual knowledge" (p. 348).

Worksheets

Worksheets can play a powerful role in managing the visit to an SECSM (McManus, 1985; Lucas & McManus, 1986). Rennie and McClafferty (1995) suggest from their research that worksheets can enhance learning by focusing the student's attention on a particular exhibit. Price and Hein (1991) differ from these opinions by claiming that "worksheets too often actually impede student learning by inhibiting true observation, preventing students from formulating their own questions, and causing students to focus on the narrowly described task to the exclusion of broader questions" (p. 515). It may well be that the degree of efficacy of worksheets is more closely related to the specific nature of the science centre environment and the tasks to be undertaken, than it is to SECSMs in general. It is important to recognise the difference between public science centres (such as Investigator, Scitech, Questacon and Exploratorium) and CSIROSECs in this respect. In accordance with the findings of McManus (1985), worksheets at CSIROSEC Tasmania are linked to group work with a central recorder for each activity allowing the whole group to participate. But, it is important to ensure that worksheets enhance the visit and not just get in the way (Falk, Koran, Dierking, & Dreblow, 1985).

An Effective SECSM Visit

Bitgood (1991) identified nine activities contributing to the effectiveness of the broad area of field trips, of which SECSMs are a subset:

1. integrating the museum experience with the school curriculum in complementary ways,
2. evaluating students' interests, ability, and experience before the trip,
3. previewing the trip with an agenda explaining the field setting,
4. using classroom pre-visit exercises to introduce students to the subject matter,
5. using the museum trip as a means for students to gather experiences rather than facts,
6. designing on-site activities that best utilise the setting,
7. evaluating the reactions of the students for future improvements,

8. reinforcing field trip experiences with post-visit classroom activities, and
9. controlling behaviour problems by thoughtful planning.

(quoted in Ramey-Gassert et al., 1994).

SECSMs may be more effective in reaching some students than classroom environments. Hein (1985) reported the greater involvement of non-academic and non-English-speaking students, with increased excitement about learning and experiences of success. Gottfried's (1980) study provided anecdotal evidence of 'turned-off kids' or 'poorly motivated' students becoming successful leaders of groups. Discussions with managers of CSIROSECs would indicate that this is a sufficiently common phenomenon as to require further research.

CSIRO Science Education Centres

CSIROSECs have been increasing in number in Australia since 1982. It is surprising therefore, that with nine such centres now established, that very little research has been conducted at the centres. The most studied CSIROSEC is in Perth, Western Australia, where a number of studies have been conducted by Rennie and her colleague (Rennie, 1993, 1994; Rennie & Elliott, 1991). The first study was a general overview of what students do at CSIROSEC, the second measuring cognitive outcomes and the third measuring affective outcomes. A qualitative evaluation of the Brisbane CSIROSEC has been undertaken by Tulip and Christensen (1994). Another study has been conducted by Harington (1994) into the use of previsit activities at CSIROSEC in Tasmania. Whilst Tulip and Christensen found very few teachers did any previsit preparation with groups visiting the Brisbane CSIROSEC, Harington found the opposite was true at the Tasmanian CSIROSEC, with the majority of teachers engaging in some organised previsit preparation with their students.

Semper (1990) argued that the formal education system tends to reduce the natural curiosity of students, and Bresler (1991) claimed informal education was vital to develop curiosity – the foundation for science learning. CSIRO Science Education

Centres fall in between the formal and informal learning environments and, as such, are poised to take advantage of the benefits of both environments.

CSIRO Science Education Centres are unique in that they are positioned somewhere between a school science laboratory and the more traditional and widespread science education centres and museums. As such, they tend to incorporate a number of aspects from informal learning environments within a more structured context. In this respect it is important that researchers have an understanding of current research into SECSMs, classroom teaching environments, but also, laboratory learning environments.

Rennie (1993) claimed "learning in CSIROSEC is different to learning in the laboratory at school ... but visits to CSIROSEC tend to be more formal than visits to a museum or a science centre like Scitech because it is not open to the public" (p. 29). Tulip and Christensen (1994) found in their study of the Brisbane CSIROSEC that the structure of the programs provided opportunities for learning in both formal and informal environments. They found that most students accepted the formal structure of the visit, whilst some students stated that they preferred it to the unstructured nature of a Sciencentre visit.

Science centres must be about how science is conducted, and the lack of this has been the substance of considerable criticism of many science centres (Champagne, 1975; Dolan, 1988; Wellington, 1989). Csikszentmihalyi and Hermanson (1995) promote the development of science exhibits that allow visitors to experiment and test phenomena and to become involved in the real stuff of science – testing ideas. This should be the real strength of CSIROSECs. McLean (1993) proposes a more stringent description of interactive exhibits than those presented in a previous section of this review. He says interactive exhibits are "those in which visitors can conduct activities, gather evidence, select options, form conclusions, test skills, provide input, and actually alter a situation based on input" (p. 93). This degree of interactivity can be very difficult to achieve in a safe and manageable way in a public science centre, but not so difficult in the more controlled environments of CSIROSECs.

CSIROSECs are interactive science centres where students get to *be* scientists and conduct experiments. They are about the 'how' of science, with an emphasis on the skills and methodology of science, such as working scientifically and data collection and treatment. Students are able to experiment and test their own theories within the security of an organised framework. Tulip and Christensen (1994) found that students at the Brisbane CSIROSEC were motivated by the chance to do some different experiments, to learn, to have fun, to see how science works and to work out things for themselves. The aim of CSIROSECs is total immersion of students in discovery activities in a truly interactive science context, resulting in consequent, but subsequent, concept formation.

The structure of the CSIROSEC experience extends beyond the visit itself with the provision of follow-up activities. These are designed to encourage reflection on the experiences back at school. As Russell (1990) has stated in relation to SECSMs "the classroom is the place for explanation; this is the place for exploration" (p. 262). This sentiment was supported by Pizzey's (1991) comment that "the formal learning comes later at school, at home or in the library" (p. 10). Gregory (1997) argued that this was a weakness of many interactive science and technology centres. They catered for the hands-on component of the experience but they needed to improve upon commonsense explanations (hand-waving) and research investigations (handle-turning), or as he puts it, "for perceptual experience to be meaningful it has to be **interpreted**" (Gregory 1989, p. 5, original emphasis).

In line with previously quoted studies (Balling & Falk, 1980; Falk & Balling, 1982; Price, & Hein, 1991) CSIROSEC Tasmania is in a unique position to maximise children's learning through repeated visits. Whilst a former manager of CSIROSEC Melbourne stated that one of his aims was to have each child visit CSIROSEC once during his/her school-life, the aim in Tasmania is to encourage schools to bring each grade each year. To this end, CSIROSEC Tasmania has a range of programs catering for students from Prep through to Grade 12. Multiple visits occur in other CSIROSECs, generally as a function of factors such as population and location.

In order for school groups to obtain the maximum benefit from their visit to an SECSM it is important for the teacher to have a good understanding of the learning environment and the nature of the experience being offered. Griffin and Symington (1997) concluded that most teachers do not have a good understanding of how to use museums as an informal learning resource. Lucas (1999) reported in his study of a class visit to the Sciencentre, "it is possible that [the teacher] had not conceptualised the Sciencentre as a different learning environment than the normal classroom, one that required him to adopt a different teaching approach, and the students a different approach to learning" (p. 14). A more accurate means of describing the informal learning environment of the CSIROSEC may lead to a better understanding of this setting by teachers with a consequence that more effective use is made of the experience.

The distinction between formal and informal learning environments proposed by Wellington (1990) could be modified to show the CSIROSEC environment as falling in between the formal and informal extremes, as shown in Table 3.4. It is necessary, however, to suggest a flexible interpretation of the CSIROSEC learning environment as it may vary from one CSIROSEC to another, and within CSIROSECs, depending upon the particular program which is under consideration.

CSIROSEC sessions tend to be similar to informal learning environments in that they are more learner-led and learner-centred than the teacher-centred and teacher-led learning in the more formal classroom environment. Also in common with informal learning environments, CSIROSEC sessions are non-assessed, unevaluated, and outcomes are not measured at CSIROSEC, sessions occur in an out-of-school context, there are unintended outcomes from visits and the work is completed by students in small social groups.

CSIROSEC sessions tend to fall somewhere in between informal and formal learning in that they are semi-compulsory, semi-structured, semi-sequenced, semi-directed, may have aspects of both open-ended and close-ended learning and may be curriculum-based, but not necessarily. The extent to which each of these factors represents formal or informal learning may vary according to the program being undertaken. In essence, CSIROSECs could be described as structured, informal learning environments.

Table 3.4. Wellington's Dichotomy of Informal and Formal Learning Environments Expanded to Include the CSIROSEC Learning Environment.

Informal learning	CSIROSECs	Formal learning
Voluntary	Semi-compulsory	Compulsory
Unstructured	Semi-structured	Structured
Unsequenced	Semi-sequenced	Sequenced
Non-assessed	Non-assessed	Assessed
Unevaluated	Unevaluated	Evaluated
Open-ended	Aspects of both	Close-ended
Learner-led	Learner-led	Teacher-led
Learner-centered	Learner-centered	Teacher-centered
Out-of-school context	Out-of-school context	Classroom context
Non-curriculum-based	Either	Curriculum-based
Many unintended outcomes	Unintended outcomes	Fewer unintended outcomes
Less measurable outcomes	Not measured	Empirically measured outcomes
Social intercourse	Social group work	Solitary work
Nondirected or learner directed	Semi-directed	Teacher directed

Modified from Wellington (1990, p. 248).

The unique nature of CSIROSECs may suit them well to utilising and/or adapting the types of research methodologies employed to investigate both classroom learning environments and SECSM learning environments. CSIROSECs are able to utilise aspects of research from both of these environments. CSIROSEC research could be used as a means of bridging the existing gaps in research between informal and formal learning environments.

Learning Environment Scales for SECSMs

At the end of the section on learning environment instruments earlier in this chapter, a number of factors were identified that might have potential applications in the development of an instrument for informal learning environments. The factors identified were involvement, participation, innovation, independence, investigation, task orientation, cooperation, cohesiveness, teacher support, and material environment.

From the second section of this chapter, particularly the research relating to informal learning in SECSMs, additional factors that could be used to develop scales for a learning environment instrument for SECSMs have been derived. These are shown in Table 3.5 together with their source.

Table 3.5. Learning Environment Factors Identified from Informal Learning Research and Their Source.

Factor	Source
Cooperative learning	Dierking & Falk, 1994
Social interaction	Appleton, 1996; Birney, 1988; Crook, 1995; Diamond, 1980, 1986; Gilbert, 1995; Kremer & Mullins, 1992; McManus, 1987, 1988; Prather, 1989; Priest & Gilbert, 1994; Price & Hein, 1991; Semper, 1990; Tuckey, 1992a
Support	Brown, 1995; Martin, Brown, & Russell, 1991; Rennie & McClafferty, 1996
Curiosity	Bresler, 1991; Feher, 1990; Koran et al., 1984a; Koran & Longino, 1983; Madden, 1985; Perry, 1989, 1992; Semper, 1990
Novelty	Anderson, 1994; Balling & Falk, 1980; Bitgood, 1991; Cantor & Cantor, 1964, 1966; Falk, 1983; Falk et al., 1978; Greenberger, Woldman, & Yourshaw, 1968; Henderson & Moore, 1979; Kubota & Olstad, 1991; Martin et al., 1981; Rabinowitz, Moely, Finkel, & McClinton, 1975; Ramey-Gassert et al., 1994; Ross, 1974
Exploration and play	Bruner, Jolly, & Sylva, 1976; Csikszentmihalyi & Hermanson, 1995; Duckworth et al., 1990; Henderson, 1998; McClafferty, 1999; Moyles, 1989; Perry, 1989, 1992; Semper, 1990; Sneider & Gould, 1987; Tulip & Christensen, 1994
Self-developed models	Anderson, 1994; Anderson et al., 1998; Gelman, Massey, & McManus, 1991; Gilbert, Stocklmayer, & Garnett, 1998; Falk & Dierking, 1992; Falk, Koran, & Dierking, 1986; Feher, 1990; Sealie, 1998; Semper, 1990; Stent, 1982
Multi-sensory skills	Feher, 1990; Feher & Rice, 1985; Gilbert, 1995; Koran, Koran, & Longino, 1984b; McCarthy, 1986; Pulaski, 1971; Rowland & McGuire, 1980; Smith & Nagel, 1972; Wellington, 1990
Attitude	Bitgood, Serrell, & Thompson, 1994; Borun, Flexor, Casey, & Baum, 1983; Mardell, 1995; Finson & Enochs, 1987; McClafferty, 1999; Prather, 1989; Stronck, 1983; Tuckey, 1992a; Wellington, 1990
Multiple modes of learning	Semper, 1990
Active learning	Carlson, 1993; Feher, 1990; Gore, 1984; Gregory, 1989; Madden, 1985; McClafferty, 1999; Miles et al., 1988; Oppenheimer, 1968a; Prather, 1989; Tuckey, 1992a; Tulip & Christensen, 1994; Wolf, 1986
Reinforcement of prior learning	Biers & McRobbie, 1992; Borum & Marek, 1991; Falk & Dierking, 1992; Falk, Koran, & Dierking, 1986; Feher, 1990; Feher & Rice, 1985; Flexer & Borun, 1984; Gottfried, 1979; Javlekar, 1989; Lucas, McManus, & Thomas, 1986; Prather, 1989; Rennie & McClafferty, 1995, 1996; Sealie, 1998; Semper, 1990; Shettel et al., 1968; Sneider, Eason, & Friedman, 1979; Tuckey, 1992b, Tulley & Lucas, 1991; Wellington, 1990

Factors from existing learning environment instruments have been coordinated with factors identified from SECSMs research. These are summarised in Table 3.6, where the factors have been classified according to Moos's classification of human environments. Descriptions are provided for each factor together with sample items. This provides a summary of factors that could eventually be used for the development of scales for a learning environment instrument for SECSMs.

For example, innovation is a scale from two of the learning environment instruments shown in Table 3.1 (CES and CUCEI). Innovation could be linked to novelty, which has been identified as an important aspect of the learning environments in SECSMs. A potential scale for a learning environment instrument for SECSMs could include innovation or novelty. The scale could be described as the extent to which exhibits are perceived to be novel. A possible item for such a scale could be "The activities are different to the things we do in class". The innovation/novelty scale belongs to the system maintenance and system change dimension of Moos's classification of human environments. This dimension measures the extent to which the environment is orderly and clear in its expectations, maintains control, and is responsive to change.

The objective of this research is to produce an economical learning environment instrument that represents the CSIROSEC learning environment. Accordingly, the factors representing the learning environment in CSIROSECs need to be reduced to a manageable number. It is important that any instrument that is produced should be able to be conveniently and quickly administered to classes at the conclusion of a session. The administration of the instrument should not interfere with the session nor should it be too time consuming. Six factors are considered to be a reasonable number for the instrument since this could give a representative coverage of the CSIROSEC learning environment and, with, say five items for each factor, the instrument could fit onto a single A4 sheet. In this form the instrument would be easy to produce, copy, administer and hand-score. An instrument of 30 items could also be administered at the conclusion of a session without being too great an imposition upon visiting groups.

Table 3.6. Factors Derived from Literature Search and Related to Moos's Classification to Guide the Development of Scales for a Learning Environment Instrument for CSIRO Science Education Centres.

Factor	*LEI for SECSMs Description of Factor*	*Sample Item*	*Basic type of dimension*	*Moos's classification of human environments Description of basic type of dimension*
Cooperative learning, Social Interaction	Students work together towards a common goal of learning.	Other students in my group contribute important ideas.	Relationship	The nature and intensity of personal relationships within the environment. The extent to which individuals are involved in the environment and the extent to which they support and help each other.
Cohesiveness	The extent to which students are friendly, helpful and supportive of each other.	I can work well with the students in my group.		
Support	Extent to which students feel they can gain support from the education officer, teachers and parents.	I am able to quickly get help when I have a problem.		
Participation, Involvement	The extent to which students actively participate and contribute.	Other students do all the work. (-ve).		
Curiosity	Students are intrinsically motivated by curiosity.	I am curious to find out what is happening with the activities.	Personal development or goal orientation	The potential or opportunity for personal growth and the development of self-esteem. Goal-orientation variables relate to specific functions of the environment.
Exploration, Play, Investigation	Students are allowed or encouraged to explore things that interest them.	I am able to look at those things that interest me most.		
Self-developed models, Independence	Students are encouraged to make their own sense of each experience and to develop their own models.	I am able to decide for myself what is happening in each activity.		
Multi-sensory skills, Interactivity	The extent to which students are able to bring a range of senses to bear on each of the activities.	I have to touch and handle things to make them work.		
Attitude, Enjoyment	The extent to which a more positive attitude to science is generated.	I think this kind of science is fun.		
Material environment	The extent to which the materials and equipment are adequate.	The equipment makes it easier to complete each activity.	System maintenance and system change	Extent to which the environment is orderly and clear in its expectations, maintains control, and is responsive to change.
Task orientation	The extent to which activities are clear and well organised.	Instructions are easy to follow.		
Multiple modes of learning	The extent to which different modes of learning are used.	There is no one way to do all of the activities.		
Active learning	The extent to which students are required to be actively involved in the learning process.	I have to do something to make things happen in each activity.		
Novelty, Innovation	The extent to which exhibits are perceived to be novel.	The activities are different to the things we do in class.		
Reinforcement of prior learning	The extent to which activities reinforce knowledge and skills learned in the classroom.	Many activities are different ways of looking at things we do in class.		

The selection of which factors to include and which factors to exclude is something about which a judgement must be made. There are conflicting arguments for and against the selection of many of the factors, but ultimately the number needs to be reduced in order for the instrument to have a practical use. In this study the researcher has drawn upon his own experience with CSIROSECs to select from the factors which have been identified from the review of learning environment instruments and SECSM research to produce a Pilot Study Instrument. This seemed the most sensible approach to take so that development could begin.

Table 3.7. Learning Environment Factors Selected for the Pilot Study Instrument.

Pilot Study Instrument Factors	Factors from the Literature Review
Curiosity	Curiosity
Self-Developed Models	Self-Developed Models Independence
Innovation	Innovation Material Environment Novelty
Multi-Sensory Skills	Multi-Sensory Skills Interactivity
Attitude	Attitude Enjoyment
Active Learning	Active Learning Multiple Modes of Learning

Those factors selected for the Pilot Study Instrument include curiosity, self-developed models and independence, innovation and novelty, multi-sensory skills and interactivity, attitude and enjoyment, and active learning. The pilot study factors and their relationships to the factors identified from the literature review are shown in Table 3.7. The term "Independence" is used in a constructivist sense to mean independence of thought or independent interpretation of the experiences students have during a session. Aspects of social interaction during a CSIROSEC session have not been incorporated as a factor for the development of the Pilot Study Instrument, despite the importance of social interaction during SECSM visits highlighted in the literature review. This has arisen partly due to the necessity of reducing the number of factors in order to produce an economical instrument. It was considered that social interaction may be a factor which is more easily observable during a session, and that the learning environment instrument should concentrate more upon less observable perceptions of students.

Conclusion

> ... the exact nature and extent of the learning activity in science centres are not fully understood.
>
> (Semper, 1990, p. 3).

Wellington (1991) considers it "surprising that children's informal science learning in science, with its acknowledged influence on pupils and its potential for classroom enrichment, remains a relatively under-valued and under-researched area" (p. 364). Rennie and McClafferty (1996) claim that "to fulfil their mission more effectively, science centres must become more involved in their own research" (p. 86). More specifically, Griffin (1994a) says that "more emphasis should be placed on working with teachers to develop integrated learning packages involving school and museum learning through student-centred approaches and involving insights from informal museum learning patterns." (p. 6). There is much, of mutual benefit, to be gained from the cross-fertilisation of ideas from both formal and informal learning environments – the ultimate goal being a better understanding of science education and a more global concept of learning in diverse science education environments.

Many of the studies conducted into SECSMs have been evaluative studies, often formative in nature, lending themselves to specific outcomes, but limited generalisability. One must always be careful in deriving generalisations from these findings and applying them to new situations. This is particularly so in the rich diversity of environments found in SECSMs. Can research into SECSMs become more definitive on the one hand, whilst at the same time produce results which are more generalisable within this type of learning environment? Can research within

SECSMs utilise the growing number of learning environment instruments that concentrate on perceptual measures? For this type of research, it is important that researchers have a good knowledge of learning environment research instruments that are applicable in other situations. It is only by being familiar with the use of these instruments that researchers will be able to determine the applicability of such instruments to their own research into other aspects of SECSM learning environments.

The development of a generic learning environment instrument for SECSMs may be realistically unachievable at this time, because of the great diversity in these informal learning environments. It may be possible to approach the problem from another direction. This research attempts to provide the first stepping stone to bridge the gap between existing learning environment instruments for formal learning environments and the informal learning environments of SECSMs. CSIROSECs provide a convenient stepping stone because of their semi-formal learning environment, which places them between existing formal learning environments such as classrooms and the informal learning environments in SECSMs.

The learning environment factors shown in Table 3.6 have been used to identify potential scales that may contribute to the development of a pilot study learning environment instrument for use in CSIRO Science Education Centres (see Table 3.7). The factors for the Pilot Study Instrument are curiosity, self-developed models, innovation, multi-sensory skills, attitude and active learning. The development of scales for the Pilot Study Instrument is described in the next chapter.

Chapter 4

The Pilot Study

Introduction

This chapter examines the development, administration and analysis of the initial version of the Learning Environment Instrument for CSIRO Science Education Centres, referred to as the Pilot Study Instrument. The Pilot Study Instrument is administered to classes visiting the CSIROSEC in Tasmania. The data are analysed using SPSS yielding item statistics, correlations and principal components analyses. The chapter concludes with recommendations arising out of the analyses leading to the redrafting of the instrument for the major part of this study.

Development of the Pilot Study Instrument

A Generic Procedure for Developing a Learning Environment Instrument

The development of a learning environment instrument characteristically involves a number of well-defined stages, which have been synthesised from the literature review on learning environment research in Chapter 3. First, factors are chosen which characterise the learning environment. The factors can be arrived at by combining information from a number of sources. The experience of the constructor is important as is the recent literature. Existing learning environment instruments are a valuable source of information. Other experts in the areas of learning environment instruments in general or practitioners familiar with the specific learning environment can be used. Second, a format for the instrument is chosen to meet the requirements for its use. Answers are considered to questions such as, should it be a long-form instrument enabling the use of the individual student as the unit of analysis or is a short form instrument using the class as the unit of analysis adequate? How is the instrument to be scored, by hand or machine? How much time is available for administration of the instrument? Third, items need to be written for each factor to develop scales. The writer should be familiar with both learning environment instruments and the learning environment for which the instrument is being written. Existing instruments can again be used as a good guide and also a valuable source of items. The face validity of items should be established by referring the list of items to practitioners in the specific learning environment and also learning environment instrument specialists. Fourth, the instrument is administered to its target population and scored. Fifth, the data are analysed to obtain item analyses, measures of discriminant validity and internal consistency. Sixth, if necessary, the instrument is revised and retested. This procedure is followed during the remainder of this chapter showing the development, administration, analysis and evaluation of the Pilot Study Instrument.

Procedure for Developing the Pilot Study Instrument

The literature review on learning environment and of SECSM research identified the learning environment factors that are relevant to learning in SECSMs (see Table 3.6). The number of factors was reduced to a manageable number for the purposes of this study and to produce an economical instrument (see Table 3.7). It was essential that the instrument should be easily administered during a short time period at the conclusion of each visit to CSIROSEC, as school excursions are usually run according to a tight time-frame and it was important that neither the length nor the quality of the visit be diminished in order to collect data. Ideally, the instrument should fit on a single sheet of paper. This reduces cost and time spent on collating and stapling. More importantly, if both the items and space for the students to record their responses are on this single sheet, this will avoid errors arising from transferring responses to a separate answer sheet.

These six factors were selected as those considered most indicative of the CSIROSEC learning environment: Curiosity (C), Self-Developed Models (S), Innovation (I), Multi-

Sensory Skills (M), Attitude (A), and Active Learning (L). These factors are described in Table 4.1.

Table 4.1. Description of Factors for the Pilot Study Instrument.

Factor	Description of Factor
Curiosity	The extent to which students are intrinsically motivated by curiosity
Self-Developed Models	The extent to which students are encouraged to make their own sense of each experience and to develop their own explanatory models
Innovation	The extent to which students see the activities as unusual and different from classroom activities
Multi-Sensory Skills	The extent to which students are able to bring a range of senses to bear on each of the activities
Attitude	The extent to which a positive attitude to science is generated
Active Learning	The extent to which students are actively involved in the learning process

Five items were developed to prepare a scale for each factor and these are listed in Table 4.2. The items were based upon the researcher's experience in a CSIROSEC, items from existing learning environment instruments and obtaining feedback from other experts during discussions. The items were organised into a learning environment instrument according to a cyclic format so that all the items from a particular scale were found in the same position in each block of six items. The first item in each block assessed *Curiosity* (C); the second item assessed *Self-Developed Models* (S); the third item assessed *Innovation* (I); the fourth item assessed *Multi-Sensory Skills* (M); the fifth item assessed *Attitude* (A); and the final item assessed *Active Learning* (L).

Table 4.2. List of Items Used in Pilot Study Instrument, Grouped According to Scale.

C	Curiosity
S	Self-Developed Models
I	Innovation
M	Multi-Sensory Skills
A	Attitude
L	Active Learning

C1	I am curious to find out what is happening with the activities
C2	**Most of the activities are boring**
C3	Most of the activities are interesting
C4	I was really keen to do many of the activities
C5	I was interested to find out what happened in each activity
S1	**I need help to understand what is happening in each activity**
S2	I can reach my own conclusions from most activities
S3	I am able to decide for myself what is happening in each activity
S4	Once you do an activity it is easy to work out what it means
S5	You can make up your own mind what each activity means
I1	Many of the activities are different to the things we do in class
I2	Many of these activities are things I have not done in class
I3	**I have done many of these things in class**
I4	I have been able to try new things here
I5	This type of science is different to the science we do in class
M1	I have to touch and handle things to make them work
M2	I have to do things different ways in different activities
M3	I get to practise different science skills
M4	**Many of the activities are done in much the same way**
M5	I have to use many science skills to do all of the activities
A1	I think this kind of science is fun
A2	I would like to do science like this more often
A3	Science is more fun than I thought
A4	Our class should come here more often
A5	**I don't like this kind of science**
L1	I have to do something to make things happen in each activity
L2	I have to investigate to find out what will happen in each activity
L3	I make measurements in many of the activities
L4	**I don't have to do much in many of the activities**
L5	I found out how things happened by doing things

Note: Items shown in bold are reverse scored.

As for most learning environment instruments, a five point Likert scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree) was adopted as the response format for the items. Responses were scored 1 = strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, and 5 = strongly disagree. One negatively worded item is included for each scale, and was reverse scored. A copy of the student form of the instrument is included as Appendix 4A. A list of the items, together with the appropriate identification code, is in Table 4.2. The items shown in bold are negatively worded items.

Administration of the Pilot Study Instrument

The Pilot Study Instrument was administered to nine classes at CSIROSEC Tasmania with a total of 189 students. Four classes were grade 7 students from a co-educational government high school studying the *Moon Rescue* program. Four classes were grade 8 students from a boys' Catholic college studying the *Science and Technology* program for grade 8 students. The remaining class was grade 9 students from a girls' Catholic college studying an *Energy* program.

Table 4.3. Composition of Pilot Study Sample.

Type of School	No. of Classes	Year	Boys	Girls	Total
Government	4	7	40	42	82
Catholic Boys	4	8	89	0	89
Catholic Girls	1	9	0	18	18
Total	9	-	129	60	189

Permission was sought from the teacher of each of the classes involved in the pilot study. All participants were assured that responses would only be seen by the researcher, and once coded for class, student and grade, their responses would become anonymous.

Instructions for completing the instrument were printed on its reverse side (see Appendix 4A), but the instructions were also given verbally by the researcher to each of the participating classes. The instrument was administered to classes at the conclusion of the session, taking about 10 minutes to complete.

Prior to data entry a code was assigned to each student's completed instrument to indicate the class (eg. 01 for the first class), student (eg. 06 for the sixth student) and grade (eg. 07 for grade 7). The final code was of the form 01 06 07, which allowed for ease of entry of data into SPSS for analysis and as a means of checking back to the source data in cases of inaccurate data entry. Responses were manually entered into a Word document for loading into SPSS. Negatively worded items were entered as reverse scored items.

Results

The students' responses were analysed using SPSS to obtain percentage responses, means and standard deviations. Correlations were calculated among items, among items and the proposed scales, and between the proposed scales. A principal components analysis was conducted, with varimax rotation to obtain information on the separation of items into separate components and to compare this with the hypothesised structure of the scales.

Item Analysis

The results of the item analysis are shown in Table 4.4. This shows that the frequency distributions for most items tend to be skewed towards the "agree" end of the scale. This is reflected in the mean values reported in Table 4.4 (remembering that items in the pilot study are scored as 1 for strongly agree through to 5 for strongly disagree, therefore lower means indicate a greater degree of agreement). It is likely that the degree of skewness may be a result of the majority of students perceiving the learning environment at CSIROSEC very favourably. It is noteworthy that all but one of the choices (strongly disagree for item I2) attracted responses. Standard deviations range between 0.77 and 1.19 and represent a good spread of responses.

Table 4.4. Percentage Responses, Means and Standard Deviations of Student Responses in the Pilot Study Instrument.

Item	% Responses 1 Strongly Agree	 2 Agree	 3 Neither	 4 Disagree	 5 Strongly Disagree	Mean	SD
C1	12.8	66.3	10.7	6.4	3.7	2.22	0.89
C2[a]	29.8	44.1	16.0	6.4	3.7	2.10	1.02
C3	27.7	54.8	9.0	5.9	2.7	2.01	0.92
C4	33.5	43.1	12.8	7.4	3.2	2.04	1.03
C5	33.3	48.7	7.9	6.9	3.2	1.98	0.99
S1[a]	12.2	45.7	12.8	22.9	6.4	2.65	1.15
S2	18.1	58.0	13.8	6.4	3.7	2.20	0.94
S3	22.5	57.2	10.2	7.0	3.2	2.11	0.94
S4	19.0	56.6	10.1	11.6	2.6	2.22	0.97
S5	16.1	53.2	13.4	14.0	3.2	2.35	1.01
I1	46.6	45.5	4.2	2.6	1.1	1.66	0.77
I2	44.6	43.5	4.9	7.1	0.0	1.74	0.85
I3[a]	34.6	48.4	8.0	8.0	1.1	1.93	0.92
I4	43.1	43.6	6.4	4.3	2.7	1.80	0.93
I5	37.3	47.0	7.6	4.9	3.2	1.90	0.96
M1	29.4	39.0	16.6	13.4	1.6	2.19	1.05
M2	30.3	50.8	9.2	9.2	0.5	1.99	0.90
M3	24.3	55.0	10.1	7.4	3.2	2.10	0.96
M4[a]	11.1	44.4	20.6	19.6	4.2	2.61	1.05
M5	14.5	39.2	16.1	23.7	6.5	2.68	1.17
A1	44.1	37.6	12.9	3.2	2.2	1.82	0.93
A2	44.1	29.0	14.0	7.0	5.9	2.02	1.18
A3	27.3	43.3	10.7	13.4	5.3	2.26	1.16
A4	42.0	30.3	11.7	11.2	4.8	2.06	1.19
A5[a]	50.0	31.4	9.0	4.3	5.3	1.84	1.10
L1	38.8	41.0	9.6	7.4	3.2	1.95	1.04
L2	20.3	55.6	9.6	11.2	3.2	2.21	1.00
L3	10.2	48.9	21.0	15.6	4.3	2.55	1.01
L4[a]	16.0	45.5	14.4	20.9	3.2	2.50	1.09
L5	25.0	59.6	8.0	3.7	3.7	2.02	0.90

[a] indicates negatively worded items which were reverse scored.

Correlations Among Items

The inter-item correlation matrix is presented as Table 4.5. Correlations between individual items and the proposed scales have been calculated (see Table 4.6) and correlations between the mean item scores for the proposed scales are shown (see Table 4.7). These are discussed scale by scale.

Curiosity

Table 4.5 shows that there are high correlations between all of the Curiosity items with other Curiosity items, varying from .39 between C1 (I am curious to find out what is happening with the activities) and the negatively worded C2 (Most of the activities are boring) and .53, C4 (I was really keen to do many of the activities) and C5 (I was interested to find out what happened in each activity). The Curiosity scale also correlates strongly with Attitude scale, .72 (see Table 4.7). When correlations for individual items with scale totals are examined (see Table 4.6), Curiosity items correlate most strongly with the Curiosity scale, although high correlations of between .48 and .61 exist with the Attitude scale.

The highest correlation between items on the Curiosity and Attitude scales, .57, was between C5 (I was interested to find out what happened in each activity) and A3 (Science is more fun than I thought). Other moderate to high correlations between items on the Curiosity scale and items on other scales were mostly with C5 (I was interested to find out what was happening in each activity). For example, between C5 and I4 (I have been able to try new things here) was .47; C5 and M3 (I get to practise different science skills) was .39; C5 and L2 (I have to investigate to find out what will happen in each activity) was .35; and C5 and L5 (I found out how things happened by doing things) was .43.

Table 4.5. Inter-Item Correlations for the Pilot Study Instrument.

	Curiosity					Self-Developed Models					Innovation					Multi-Sensory Skills					Attitude					Active Learning				
	C1	C2	C3	C4	C5	S1	S2	S3	S4	S5	I1	I2	I3	I4	I5	M1	M2	M3	M4	M5	A1	A2	A3	A4	A5	L1	L2	L3	L4	L5
C1	1.00																													
C2	.39	1.00																												
C3	.47	.48	1.00																											
C4	.44	.43	.42	1.00																										
C5	.49	.47	.44	.53	1.00																									
S1	-.09	.11	-.05	.03	.01	1.00																								
S2	.12	.14	.05	.14	.14	.25	1.00																							
S3	.18	.15	.05	.18	.17	.28	.44	1.00																						
S4	.15	.14	.20	.15	.24	.12	.21	.25	1.00																					
S5	.17	.04	-.03	.14	.16	.14	.31	.45	.30	1.00																				
I1	.24	.15	.13	.18	.14	-.16	.05	.06	.17	.10	1.00																			
I2	.16	.11	.09	.11	.09	.04	.18	.03	.11	.08	.29	1.00																		
I3	.00	.16	.03	-.02	.05	.03	-.10	.05	.14	.02	.09	.36	1.00																	
I4	.15	.26	.28	.26	.47	.01	.11	.18	.26	.20	.17	.22	.17	1.00																
I5	.11	.24	.03	.13	.14	-.02	.13	.06	.23	.15	.33	.30	.29	.32	1.00															
M1	.17	-.07	-.04	.04	.11	-.09	.14	-.03	.10	.03	.21	.12	-.07	.11	.12	1.00														
M2	.11	.08	.15	.23	.19	-.05	.15	.22	.10	.11	.17	.11	.07	.23	.15	.21	1.00													
M3	.31	.37	.30	.34	.39	.03	.12	.27	.18	.10	.08	.01	.07	.30	.10	.04	.16	1.00												
M4	.02	.24	.16	.17	.11	-.02	-.16	-.14	-.15	-.14	.01	-.07	.02	.26	.13	.03	.16	.13	1.00											
M5	.23	.01	.05	.20	.27	-.14	.13	.15	.18	.18	.20	.07	-.08	.15	.05	.23	.06	.15	.03	1.00										
A1	.38	.49	.53	.56	.39	-.02	.07	.19	.15	.06	.16	.08	.04	.31	.01	.01	.24	.27	.15	.03	1.00									
A2	.42	.39	.44	.44	.34	.07	.09	.08	.24	.07	.14	.23	.08	.22	.11	.01	.01	.19	.11	-.01	.59	1.00								
A3	.39	.47	.53	.51	.57	.07	.08	.19	.21	.17	.11	.11	.08	.46	.12	.01	.24	.41	.19	.11	.54	.55	1.00							
A4	.29	.24	.15	.37	.29	.27	.18	.26	.22	.17	.15	.09	.01	.15	.11	.06	.00	.23	.10	.03	.35	.54	.34	1.00						
A5	.42	.49	.51	.53	.48	.06	.11	.17	.28	.13	.21	.15	.11	.37	.09	-.05	.14	.29	.23	.09	.56	.65	.62	.42	1.00					
L1	.19	.10	.24	.15	.21	-.00	.20	.19	.30	.18	.18	.13	.05	.36	.21	.33	.44	.14	.05	.19	.27	.23	.20	.05	.16	1.00				
L2	.28	.15	.18	.26	.35	-.06	.08	.23	.15	.16	.03	.02	-.07	.20	.10	.15	.40	.26	.08	.32	.13	.08	.25	.23	.05	.33	1.00			
L3	.14	.11	.12	.14	.19	.09	.21	.17	.34	.13	.05	.08	.06	.22	.03	.05	.17	.23	.01	.19	.22	.21	.25	.06	.22	.32	.07	1.00		
L4	.05	.05	.05	.07	.11	.15	-.01	.12	.08	.01	-.04	.04	.27	.27	.22	-.10	.04	.21	.18	.02	.03	.09	.17	.20	.14	.07	.07	.10	1.00	
L5	.25	.26	.23	.29	.43	.10	.05	.09	.18	.12	.08	-.01	-.05	.45	.04	.10	.32	.36	.19	.22	.31	.19	.41	.15	.36	.29	.29	.28	.18	1.00

Table 4.6. Correlations of Items with the Sum of All Items on the Scale for the Pilot Study Instrument.

Item	Curiosity	Self-Developed Models	Innovation	Multi-Sensory Skills	Attitude	Active Learning
C1	.73	.15	.21	.31	.48	.30
C2[a]	.75	.18	.29	.21	.53	.22
C3	.74	.06	.18	.21	.54	.27
C4	.76	.19	.21	.35	.61	.29
C5	.78	.21	.29	.39	.53	.42
S1[a]	.01	.61	-.03	-.11	.12	.10
S2	.16	.66	.12	.13	.14	.18
S3	.20	.73	.12	.16	.23	.27
S4	.23	.56	.29	.15	.28	.35
S5	.12	.67	.18	.10	.16	.20
I1	.22	.05	.57	.25	.20	.10
I2	.15	.13	.67	.09	.17	.09
I3[a]	.06	.05	.61	-.01	.08	.10
I4	.38	.22	.61	.37	.38	.50
I5	.17	.16	.71	.20	.12	.21
M1	.05	.03	.15	.58	.01	.18
M2	.20	.15	.23	.54	.15	.45
M3	.45	.20	.18	.50	.36	.39
M4[a]	.19	-.18	.12	.49	.20	.17
M5	.20	.13	.12	.60	.06	.31
A1	.63	.13	.19	.24	.75	.31
A2	.54	.16	.25	.10	.86	.27
A3	.66	.22	.29	.34	.78	.42
A4	.36	.34	.16	.15	.69	.23
A5[a]	.65	.23	.30	.24	.83	.30
L1	.23	.25	.30	.42	.23	.67
L2	.32	.16	.09	.44	.19	.58
L3	.18	.28	.14	.23	.24	.60
L4[a]	.09	.12	.25	.11	.17	.50
L5	.39	.17	.17	.42	.36	.64

[a] indicates negatively worded items which were reverse scored.

Table 4.7. Correlations Between Scales for the Pilot Study Instrument.

Scale	C	S	I	M	A	L
Curiosity (C)	1.00					
Self-Developed Models (S)	.21	1.00				
Innovation (I)	.31	.20	1.00			
Multi-Sensory Skills (M)	.39	.12	.29	1.00		
Attitude (A)	.72	.28	.30	.27	1.00	
Active Learning (L)	.40	.33	.33	.53	.39	1.00

Self-Developed Models

The correlation of items for Self-Developed Models with other items for Self-Developed Models vary between .12 and .45 (see Table 4.5). The highest correlations between items in the Self-Developed Models scale are S2 (I can reach my own conclusions from most activities) with S3 (I am able to decide for myself what is happening in each activity), .44, and S3 (I am able to decide for myself what is happening in each activity) with S5 (You can make up your own mind what each activity means), .45. The highest correlation of an item on the Self-Developed Models scale with an item on any other scale is S4 (Once you do an activity it is easy to work out what it means) and L3 (I make measurements in many of the activities), .34 (see Table 4.5).

Table 4.6 shows that Self-Developed Models items correlate more strongly with the Self-Developed Models scale than with any other scale and that items from other scales do not correlate as strongly with the Self-Developed Models scale as do Self-Developed Models items.

The correlations between scales for the Self-Developed Models scale with other scales ranges from .12, with Multi-Sensory Skills, to .33, with Active Learning (see Table 4.7).

Innovation

The correlations of Innovation items with other Innovation items varies from .09 to .36 (see Table 4.5). From Table 4.5 it can be seen that moderate to high correlations between items on different scales are all with I4 (I have been able to try new things here), I4 with C5 (I was interested to find out what happened in each activity), .47; I4 with A1 (I think this kind of science is fun), .31; I4 with A3 (Science is more fun than I thought), .46; I4 with the negatively worded A5 (I don't like this kind of science) .37; I4 with L1 (I have to do something to make things happen in each activity) .36; and I4 with L5 (I found out how things happened by doing things), .45.

Table 4.6 reveals that item I4 (I have been able to try new things here) has moderate correlations with a number of scales. Its correlation with other items on the Innovation scale is .61, whilst its correlations with other scales is Curiosity (.38), Attitude (.38), Multi-Sensory Skills (.37) and Active Learning (.50). When compared with the other scales in Table 4.7, the correlations with the Innovation scale range from .20 (Self-Developed Models) to .33 (Active Learning).

Multi-Sensory Skills

The items for Multi-Sensory Skills have low correlations with other Multi-Sensory Skills items ranging between .03 and .23 (see Table 4.5). Table 4.5 shows that the correlations among M3 and individual Curiosity items vary between .30 and .39. Other notably high correlations are M3 with A3 (Science is more fun than I thought), .41, M2 (I have to do things different ways in different activities) with L1 (I have to do something to make things happen in each activity), .44, and M2 with L2 (I have to investigate to find out what will happen in each activity), .40.

Reference to Table 4.6 shows that with the exception of M1 (I have to touch and handle things to make them work) all items have moderate to high correlations with other items on other scales. M3 (I get to practise different science skills) has a correlation with the Curiosity scale of .45 and with Attitude it is .36.

High correlations of the Multi-Sensory Skills scale with other scales include Curiosity, .39 and Active Learning, .53 (see Table 4.7).

Attitude

The items for Attitude have correlations with other Attitude items varying from .34 to .65 (see Table 4.5). A number of items have high correlations with Curiosity items – A1 (I think this kind of science is fun) has a correlation of .56 with C4 (I was really keen to do many of the activities); A3 (Science is more fun than I thought) has a correlation of .51 with C4; the negatively worded item A5 (I don't like this kind of science) has a correlation of .53 with C4; C3 (Most of the activities are interesting) has a correlation of .53 with A1 (I think this kind of science is fun), C3 has a correlation of .53 with A3 and C3 has a correlation of .50 with A5; A3 has a correlation of .57 with C5 (I was interested to find out what happened in each activity).

Table 4.6 reveals that the correlations of individual Attitude items with the Curiosity scale vary between .36 and .66. The correlation of the Attitude scale with the Curiosity scale is very high at .72 (see Table 4.7).

Active Learning

The items for Active Learning have rather low correlations with other Active Learning items varying from .07 to .33 (see Table 4.5).

Reference to Table 4.6 shows that the correlations of Active Learning items with different scales need to be taken into consideration. Item L2 (I have to investigate to find out what will happen in each activity) has a correlation with Multi-Sensory Skills of .44 and with Curiosity of .32. Item L5 (I found out how things happened by doing things) has correlations with Multi-Sensory Skills of .42, with Curiosity items it is .39 and with Attitude it is .36.

The correlation of the Active Learning scale with the Multi-Sensory Skills scale is .53 and its correlation with the Curiosity scale is .40 (see Table 4.7).

Principal Component Analysis

A principal component analysis was conducted, the rotation method was varimax with Kaiser normalisation. Because the hypothesised structure was six scales, six components were extracted and the total variance accounted for by the first eight components is shown in Table 4.8. Loadings less than 0.3 are not shown for the rotated component analysis in order to simplify visual presentation and interpretation (see Table 4.9). The full matrix for the rotated six-component solution is shown in Appendix 4B.

Table 4.8. Eigenvalues and Variance Explained for Pilot Study Instrument with Six Components Extracted.

Component	Eigenvalues	% of Variance	Cumulative % of Variance
1	6.90	23.01	23.01
2	2.45	8.16	31.16
3	1.98	6.60	37.76
4	1.87	6.22	43.98
5	1.65	5.50	49.49
6	1.25	4.17	53.65
7	1.16	3.88	57.53
8	1.10	3.65	61.18

Table 4.8 shows eight components with Eigenvalues greater than 1.0. If 6 factors are extracted to account for the six proposed scales then 53.65% of the variance is explained.

Table 4.9. Varimax Rotated Component Loadings for the Pilot Study Instrument with Six Components Extracted.

	Component					
Item	1	2	3	4	5	6
C1	.62		.39			
C2[a]	.67					
C3	.71					
C4	.70					
C5	.61		.38			
S1[a]		.54	-.35			
S2		.65				
S3		.74				
S4		.43		.39		
S5		.64				
I1			.31		.57	
I2					.70	
I3[a]					.60	.32
I4				.42		.47
I5					.69	
M1			.46			
M2			.33	.56		
M3	.39					.40
M4[a]		-.39				.49
M5			.64			
A1	.77					
A2	.77					
A3	.72					
A4	.51	.40				
A5[a]	.80					
L1				.73		
L2			.64			
L3				.63		
L4[a]						.69
L5	.33			.44		.38

[a] indicates negatively worded items which have been rescored.
Note. Loadings > .3 are shown.

The extraction of six components does not provide a satisfactory solution. The rotated component loadings reported in Table 4.9 shows that items from some of the scales are clustered together onto particular components. The items for Curiosity (C) and Attitude (A) are clustered together onto component 1, indicating that they may be measuring similar things. The loadings for Curiosity vary between .61 and .71, whilst the loadings for Attitude vary between .51 and .80. The items for Self-Developed Models (S) are clustered onto component 2, with loadings between .43 and .74. Four of the five items for Innovation (I) are clustered onto component 5, with loadings between .57 and .70. The items for both Multi-Sensory Skills (M) and Active Learning (L) are spread over a number of components, with loadings greater than .4 on components 3, 4 and 6.

A number of other extractions were tried with the four component rotation working best. The rotated component analysis for four components extracted is shown in Table 4.10, and the full matrix for the four-component solution is shown in Appendix 4B. Table 4.10 reveals the separation of scale items onto components as follows. The items for Self-Developed Models (S) and Innovation (I) are clustered together as separate components. Items for Self-Developed Models are loaded onto component 3 with loadings between .46 and .73. Items for Innovation are loaded onto component 4 with loadings between .40 and .71. The items for Curiosity (C) and Attitude (A) are again clustered together onto component 1, indicating that they may be measuring similar factors. The items for Multi-Sensory Skills (M) and Active Learning (L) are not clustered coherently and those which show some clustering are on the same component, component 2. In order to determine the best next step in developing an improved version of the instrument, the items and their content were examined for each of the four components reported in Table 4.10.

Component 1

Items for the Curiosity scale (C) are loaded onto component 1 with values between .57 and .71 (Table 4.10). This reflects the high correlations among items on the Curiosity scale, reported in Tables 4.5 and 4.6. Item C5 (I was interested to find out what happened in each activity) has a loading of .34 on the second component which contains a number of items from the Multi-Sensory Skills scale (M1, M2 and M5) and the Active Learning scale (L1, L2 & L5).

Table 4.10. Varimax Rotated Component Loadings for the Pilot Study Instrument with Four Components Extracted.

Item	Component 1	2	3	4
C1	.57			
C2[a]	.68			
C3	.70			
C4	.71			
C5	.65	.34		
S1[a]		-.31	.55	
S2			.66	
S3			.73	
S4			.46	
S5			.63	
I1		.31		.43
I2				.64
I3[a]				.71
I4	.39	.36		.40
I5				.71
M1		.56		
M2		.59		
M3	.48			
M4[a]	.30		-.40	
M5		.57		
A1	.76			
A2	.72			
A3	.77			
A4	.51		.36	
A5[a]	.80			
L1		.62		
L2		.59		
L3			.31	
L4[a]				.37
L5	.45	.43		

[a] indicates negatively worded items which have been rescored.
Note. Loadings > .3 are shown.

All of the Attitude (A) items are loaded onto component 1. Items A1, A2, A3 and A5 have loadings between .72 and .80. Reference to Table 4.6 shows that these high loadings are not entirely due to the correlations of Attitude items with the Attitude scale, but also because of the strong correlations these particular Attitude items have with the Curiosity scale (.54 to .66).

Item A4 (Our class should come here more often) has a loading on component 1 of .51, but also loads on component 3 at .36 with all of the Self-Developed Models items. Reference to Table 4.6 shows that A4 correlated much lower (.36) with the Curiosity scale than did the other Attitude items, but moderately with the Self-Developed Models scale (.34).

Component 2

Three items from each of the scales Multi-Sensory Skills and Active Learning are loaded onto the rotated component 2. This reflects the high correlations among a number of items on each of these scales (see Table 4.5), and the moderate to high correlations between individual items and the other scale (see Table 4.6).

The items for the Multi-Sensory Skills scale (M) are spread across a number of components with three items loaded onto component 2 – M1 (I have to touch and handle things to make them work), M2 (I have to do things different ways in different activities), and M3 (I get to practise different science skills). The items for the Active Learning scale (L) are also spread across a number of scales with three items loading onto component 2 – L1 (I have to do something to make things happen in each activity), L2 (I have to investigate to find out what will happen in each activity), and L5 (I found out how things happened by doing things). Of these items L5 also has a loading of .45 on component 1 which contains all of the Curiosity and Attitude items. Table 4.6 shows moderate correlations between item L5 and a number of scales – Multi-Sensory Skills (.42), Curiosity (.39) and Attitude (.36).

Item M3 (I get to practise different science skills) has its highest loading on component 1. Table 4.5 shows that M3 has correlations of between .30 and .39 with all five of the Curiosity items and a correlation of .41 with Attitude item A3 (Science is more fun than I thought). The correlation between item M3 and the Curiosity scale is .45 (see Table 4.6). The negatively worded item M4 (Many of the activities are done in much the same way) has very low correlations with other items on the Multi-Sensory Skills scale (.03 to .16) and its low to moderate correlations among items on the other scales have been sufficient to draw it onto component 1 (.30) and component 3 (-.40).

Item L3 (I make measurements in many of the activities) is loaded weakly onto component 3 (.31) together with the items from the Self-Developed Models scale. The negatively worded item L4 (I don't have to do much in many of the activities) is loaded weakly onto component 4 (.37) together with the items from the Innovation scale.

Component 3

Items for the Self-Developed Models scale (S) are all loaded onto component 3 with values between .46 and .73 (see Table 4.10). The negatively worded item S1 (I need help to understand what is happening in each activity) also loads on the second component with a value of -.31. Item S4 has the lowest loading on component 3 at .46. Given the fairly low inter-item correlations for the Self-Developed Models items reported in Table 4.5, it is perhaps surprising that the items cluster so well together. However Table 4.5 also shows that, in general, these items do not correlate more highly with those of other scales. However, three other items also have modest loadings on component 3, so the component has attracted some other items.

Component 4

Items for the Innovation scale (I) are all loaded onto component 4 at values between .40 and .71 (see Table 4.10). Item I1 (Many of the activities are different to the things we do in class) is loaded weakly at .43 and also loaded (at a value >.3) onto the second component. Item I4 (I have been able to try new things here) has the lowest loading of the Innovation items on component 4 at .40. I4 is also loaded at .39 on component 1, containing Curiosity and Attitude items, and .36 on component 2, containing Multi-Sensory Skills and Active Learning items. This reflects the number of moderate to high correlations between item I4 and a large number of items on other scales (see Table 4.5).

Outcomes of the Pilot Study and Proposed Actions

Improvements to Scales and Items

Curiosity and Attitude. The items representing the proposed Curiosity and Attitude scales are highly inter-correlated and are loading on the same component in the rotated matrix. Clearly, the overlap between the meaning of items on the two scales is considerable. Thus, the items for these two scales will be used to form a new scale, to be called Affect (A), to represent the affective dimension of a CSIROSEC visit. The items with the highest loadings on component 1 will be retained. The one exception is item A4 (Our class should come here more often), which has a lower loading than some other items. This item has a loading of .51 on the same component as Curiosity and Attitude but also has a loading of .36 on component 3 with Self-Developed Models items. It is considered, however, that this item is representative of the affective dimension of a CSIROSEC visit and should be a good measure of affect if the item is reworded to be more specific.

Recommendation 1. The best performing items from the two scales Curiosity and Attitude will be combined into one new scale to be called Affect (A).

Self-Developed Models. The items representing the Self-Developed Models (S) scale are cohering as an independent scale, but could be improved with the rewording/replacement of the negatively worded item S1 (I need help to understand what is happening in each activity) and item S4 (Once you do an activity it is easy to work out what it means). Item S1 has a loading of .55 on the same component as the remainder of the Self-Developed Models items, but also has a loading of -.31 on component 2, with a number of Multi-Sensory Skills and Active Learning items. Item S4 has the lowest rotated component loading (.46) of the Self-Developed Models items. Table 4.5 shows that S4 also has moderate correlations with a number of items on other scales (I4, .26; A5, .28; L1, .30; L3, .34) and from Table 4.6 it can be seen that S4 has a moderate correlation with the Active Learning scale (.35). S4 could be reworded to make it more central to the scale meaning.

"Self-Developed Models" is a terminology borrowed from the field of constructivism and may not be representative of what is actually occurring during the CSIROSEC session. Previously cited research indicates that much of the contribution of an SECSM visit to concept development occurs later in the more reflective environment of the classroom. During a CSIROSEC visit students are more actively engaged in interpreting what they are doing, reaching conclusions and finding meaning at a more superficial level. For example, "The heat output from a mini-fluorescent lamp is much lower than from an incandescent globe for the same light output" derives some immediate meaning from an activity without delving into the concepts of energy, power, wattage, quality of light etc., which can be followed up in class at a later stage. Independent interpretation is a more appropriate and representative terminology for this scale.

Recommendation 2. The Self-Developed Models scale will be renamed Independent Interpretation (Ind) to cover the independent interpretation of activities by the students during a visit. Items will be reworded to more accurately reflect the scale meaning.

Innovation. The items representing the Innovation (I) scale are cohering as an independent scale. This scale may be further improved with the rewording of item I4 (I have been able to try new things here). Item I4 is loading at .40 on the same component as the other Innovation items, but is also loading on component 1 (.39) with Curiosity and Attitude items and component 2 (.36) with a number of Multi-Sensory Skills and Active Learning items. The wording of the item is very general and could be improved by making it more specific. This is a general comment, which could be made of many of the items.

The term "Innovation" does not really capture the meaning of this scale. "Innovation" is a terminology borrowed from the College and University Classroom Environment Inventory (CUCEI). It may be more relevant to adhere to the terminology used in SECSM literature and refer to this scale as Novelty.

Recommendation 3. The Innovation scale will be renamed Novelty (N) and, where necessary, items will be reworded.

Multi-Sensory Skills and Active Learning. There is a high correlation (.53) between the two scales Multi-Sensory Skills and Active Learning. Three of the items representing the scales Multi-Sensory Skills (M) and Active Learning (L) are loading on the same component, component 2. These six items will be combined to form a new scale called Involvement and the other items deleted. The items on the Involvement scale will reflect a philosophy of "hands-on and minds-on science".

Recommendation 4. The six items from the Multi-Sensory Skills and Active Learning scales which define component 2 will be combined into a new scale to measure Involvement (Inv).

There were six scales for the Pilot Study Instrument and, based upon the analysis, this has now been reduced to only four. Earlier in the chapter, decisions were made about which scales would be included or excluded from the Pilot Study Instrument. It is now worthwhile to review which scales may be included in a redrafted instrument. This may ensure a more comprehensive coverage of aspects of the learning environment in CSIROSECs.

A New Scale – Social Interaction. The importance of social aspects of a CSIROSEC visit needs to be recognised and to be included as a scale in the revised learning environment instrument. This covers the relationship dimension of Moos's Classification (see Table 3.6). During the construction of the Pilot Study Instrument a decision was made to limit the size of the instrument and accordingly the number of scales. Social interactions among students did not make the final list of scales despite its importance to the outcomes of SECSM visits as outlined in the literature (see Chapter 3) and its perceived importance during a CSIROSEC visit. It was thought at the time that social interaction was one of the more easily observable characteristics of a visit. On reflection, the decision not to include social interaction as a scale in the Pilot Study Instrument was regrettable, but it was thought more important to collect data on other, perhaps less observable, aspects of the learning environment in CSIROSECs. The combining of the Curiosity and Attitude scales and the Multi-Sensory Skills and Active Learning scales has provided the opportunity to redress this omission.

Recommendation 5. A new scale, called Social Interaction (S), will be included to measure social aspects of the CSIROSEC experience including cooperative learning, cohesiveness and participation in group work.

General Improvements for a Redrafted Instrument

The Pilot Study Instrument is unsatisfactory in its present form, because it is not discriminating sufficiently between the hypothesised scales. This is evidenced by the loading of items from different scales on the same component and the split loadings of items from one scale on other components. The first step in the development of an improved instrument, to be called the Redrafted Instrument, is to define more precisely the scales and what they are seeking to measure. Then further refinement of the items within each scale will be necessary to produce an instrument with improved discriminant validity. A general comment applying to many of the items is that their wording is insufficiently specific as to capture the essence of the scale they represent.

Recommendation 6. Operational definitions and expected student outcomes will be defined for each scale of the Redrafted Instrument.

Recommendation 7. Items will be more specifically worded, or reworded, so as to be more representative of the meaning of their respective scales.

Five items are too few in each scale and allows no flexibility if items are unsatisfactory and need to be deleted. It is necessary to have sufficient items to allow some redundancy so that items can be identified whose removal will improve scale internal consistency and discriminant validity between scales. "While scale internal consistency (is) enhanced by removing any item with a low correlation with the total for its scale, scale discriminant validity (is) enhanced by removing any item whose correlation with its *a priori* assigned scale (is) smaller than its correlation with any of the other ... scales." (Rentoul & Fraser, 1979, p. 241). After the removal of items, alpha reliability coefficients are calculated as indices of internal consistency and scale intercorrelations as indices of discriminant validity. After refinement of the instrument it will be necessary to field test again to cross-validate and detect any unwanted effects arising from the removal of items.

Recommendation 8. Seven items will be defined for each scale. This will allow for the deletion of the least effective item after data collection and analysis. The aim is to produce a final instrument with five scales and six items per scale which will present an instrument of reasonable size to complete in the time available.

Additional face validity will be sought for the redeveloped instrument prior to data collection. Managers of CSIROSECs and other experts will be sent a copy of the operational definitions and the expected student outcomes for the Redrafted Instrument. They will also receive a list of the items in random order. The items will not be assigned to their scales nor identified in any other way as being associated with a particular scale. Participants will be asked to place the items onto what they consider to be the appropriate scale, using the operational definitions and the expected student outcomes as a guide. This should help to identify potentially weak items.

Recommendation 9. Face validity will be sought from CSIROSEC Managers and other experts for the Redrafted Instrument.

Summary

On the basis of the results obtained from the pilot study, recommendations are proposed for the development of a redrafted version of the Learning Environment Instrument for CSIRO Science Education Centres. The new instrument will consist of five scales – Affect, Novelty, Social Interaction, Independent Interpretation and Involvement. There will be seven items per scale, allowing for a reduction to six items after analysis.

Chapter 5

Field Testing the Redrafted Instrument

Introduction

This chapter reports the redrafting of the Learning Environment Instrument for CSIRO Science Education Centres based on the findings of the Pilot Study. It begins by describing how construct and face validities for the Redrafted Instrument were established with the assistance of managers of CSIROSECs and experts in appropriate fields. The administration of the Redrafted Instrument to groups from the Tasmanian, Melbourne, Perth and Townsville CSIROSECs is described. Statistical analyses are conducted yielding item statistics, correlations and principal components analyses. A number of recommendations are made to refine the Redrafted Instrument.

Development of the Redrafted Instrument

The Pilot Study has shown that the original scales selected for the instrument need to be more precisely defined. This was achieved by constructing operational definitions for each of the new scales recommended from the Pilot Study. Measurable student outcomes form an important component of the definition of each of the new scales. These provide an immediate starting point for the rewriting of items to more specifically reflect the meaning of each scale. The number of scales for the Redrafted Instrument is reduced to five – Affect, Novelty, Involvement, Independent Interpretation and Social Interaction. The number of items per scale has been increased to seven items to allow for the subsequent deletion of one item per scale.

Development of Scales for the Redrafted Instrument

The scales for the Redrafted Instrument have been developed from the findings of the Pilot Study. Greater coverage of the factors identified from the literature review has also been achieved. This provides an instrument with a broader coverage of the students' perceptions of the CSIROSEC learning environment. The sources of the new scales for the Redrafted Instrument are summarised in Table 5.1. This shows the relationship between similarly named scales which have arisen from the literature review (Table 3.5) and the scales used for the Pilot Study Instrument (Table 4.1).

Table 5.1. Relationship of the Redrafted Instrument Scales to Scales Derived from the Literature Review and Scales Used for the Pilot Study Instrument.

Redrafted Instrument Scale	Pilot Study Instrument Scale(s)	Scale(s) from the Literature Review
Affect	Attitude Curiosity	Attitude Curiosity Enjoyment
Novelty	Innovation	Innovation Material Environment Novelty
Involvement	Multi-Sensory Skills Active Learning	Multi-Sensory Skills Active Learning Multiple Modes of Learning Interactivity
Independent Interpretation	Self-Developed Models	Self-Developed Models Independence
Social Interaction	Not included	Cooperative Learning Participation Cohesiveness

Operational Definitions of Scales

The operational definitions of the new scales for the Redrafted Instrument are shown below, together with measurable student outcomes. These were used to guide the writing of new items and the rewriting of items from the Pilot Study Instrument. The aim was to ensure that the items related more specifically to their prescribed scale and correlated less with other scales.

Affect is the attitude students have towards CSIROSEC and doing science activities at CSIROSEC.

A student who has a positive attitude to science at CSIROSEC

1. will think science at CSIROSEC is fun,
2. will find CSIROSEC activities interesting,
3. will be keen to do CSIROSEC-type activities,
4. would like their class to visit CSIROSEC more often, and
5. will have an enhanced attitude to science following a visit to CSIROSEC.

Novelty is the extent to which students perceive the science activities and equipment at CSIROSEC to be different from those in their school.

Students who perceive a high level of novelty at CSIROSEC will think the learning environment is different from that in their own classroom in terms of

1. the type of science they do at CSIROSEC,
2. the way science is done at CSIROSEC,
3. the type of science activities at CSIROSEC, and
4. the different equipment which they use at CSIROSEC.

Involvement is the extent to which students need to participate physically and mentally in activities at CSIROSEC.

Students who are involved in the CSIROSEC experience will

1. be involved in activities to make things happen,
2. be involved both mentally and physically, and
3. use their own skills in every activity.

<u>Independent Interpretation</u> is the extent to which groups are able to perform activities independently and students are able to make their own interpretation of activities and their outcomes.

Groups of students who are working independently at CSIROSEC will

1. collect their own data,
2. decide what they need to do in each activity, and
3. proceed without help from the teacher.

At the individual level, students who are working independently at CSIROSEC will

4. make their own interpretation of what is happening in each activity, and
5. reach their own conclusions from each activity.

<u>Social Interaction</u> is the extent to which students collaborate/cooperate in groups to perform activities.

Students who demonstrate a high level of social interaction during their CSIROSEC visit will

1. work well with the members of their group,
2. realise the importance of teamwork and cooperation in completing each activity, and
3. work in a mutually helpful way.

The Redrafted Instrument

The Redrafted Instrument is shown in Figure 5.1. The items have been grouped according to their scale for easier interpretation. The codes in the first column identify the scale and the item number. The items shown in bold and with the identifying code underlined are negatively worded items. As with the Pilot Study Instrument these items will be reverse scored prior to statistical analysis of the students' responses. The student version of the Redrafted Instrument and written student instructions for its completion are included as Appendix 5A.

	A = Affect N = Novelty Inv = Involvement Ind = Independent Interpretation S = Social Interaction	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
A1	I think science at CSIROSEC is fun					
A2	I would like to do science like this more often					
A3	Science is more fun than I thought					
A4	I would like our science class to visit CSIROSEC more often					
A5	**I don't like science at CSIROSEC**					
A6	The activities are interesting to me					
A7	I was really keen to do the activities					
N1	The activities are different to the things we do in class					
N2	I use different equipment at CSIROSEC than in class					
N3	**I have done many of these activities before in class**					
N4	I have tried new activities at CSIROSEC					
N5	Science at CSIROSEC is different to the science we do in class					
N6	**Science at CSIROSEC is the same as at school**					
N7	We do science in a different way at CSIROSEC					
Inv1	I have to be involved in activities to make them work					
Inv2	I have to think about the activities I am doing at CSIROSEC					
Inv3	I handle the equipment to perform an activity					
Inv4	**I don't have to do much to complete each activity**					
Inv5	I use my skills to do the activities					
Inv6	I got involved in the activities here					
Inv7	I participate in activities using different skills					
Ind1	We collect our own data in each activity					
Ind2	I can reach my own conclusions from most activities					
Ind3	I am able to decide for myself what is happening in each activity					
Ind4	We can decide what we need to do in each activity					
Ind5	You can make up your own mind what each activity means					
Ind6	I don't need help from the teacher to complete most of the activities					
Ind7	**I need help from the teacher with most of the activities**					
S1	I work well with the members of my group					
S2	**I could get more work done by myself than in my group**					
S3	The members of my group cooperate with each other					
S4	I am able to depend on other members of my group for help doing activities					
S5	I help other members of my group					
S6	My group works as a team					
S7	It is easier to get the work done as a team than by myself					

Figure 5.1. Items for the Redrafted Instrument Grouped According to Scale.

Establishing Face Validity

Practitioners and other experts in the areas of SECSMs and learning environment research were used to establish the face validity of the items in the Redrafted Instrument. Face validity was determined by the extent to which experts were able to identify each item as belonging to its designated scale, as defined by the operational definition for each scale.

A randomised list of the items for the Redrafted Instrument and the operational definitions of each scale were sent to the managers of CSIROSECs (with replies received from 6 of the 9 managers), to an expert in science education centres and museums and an academic involved in the area of learning environments. Participants were asked to assign each item to its appropriate scale. The results are shown in Table 5.2 with an identification code added for convenience of interpretation by the reader.

The results show that, for the most part, items were assigned to the appropriate scale. For CSIROSEC managers, the degree of agreement of responses with the expected responses for the complete instrument varied from complete agreement through to one manager who differed on only five of the thirty-five items.

The expert in SECSMs had two differences, Independence 6 (I don't need help from the teacher to complete most of the activities) was perceived as belonging to the Involvement scale and Novelty 4 (I have tried new activities at CSIROSEC) as belonging to the Involvement scale.

As can be seen from Table 5.2 there was good general agreement by those involved in establishing face validity. Where disagreements with the assignment of a particular item to its scale have occurred this is limited to only one or two of the eight respondents. The disagreements are also spread across the scales, with no one scale predominant.

Table 5.2. Responses of Eight CSIROSEC Managers and Experts to Placement of Items into Scales.

	A – Affect N – Novelty Inv – Involvement Ind – Independent Interpretation S – Social Interaction	Affect	Novelty	Involvement	Independent Interpretation	Social Interaction
A1	I think science at CSIROSEC is fun	8				
A2	I would like to do science like this more often	7	1			
A3	Science is more fun than I thought	8				
A4	I would like our science class to visit CSIROSEC more often	8				
A5	**I don't like science at CSIROSEC**	8				
A6	The activities are interesting to me	7		1		
A7	I was really keen to do the activities	7		1		
Ind1	We collect our own data in each activity				8	
Ind2	I can reach my own conclusions from most activities				8	
Ind3	I am able to decide for myself what is happening in each activity				8	
Ind4	We can decide what we need to do in each activity				8	
Ind5	You can make up your own mind what each activity means				8	
Ind6	I don't need help from the teacher to complete most of the activities			1	7	
Ind7	**I need help from the teacher with most of the activities**			1	7	
Inv1	I have to be involved in activities to make them work			8		
Inv2	I have to think about the activities I am doing at CSIROSEC			5	2	
Inv3	I handle the equipment to perform an activity			8		
Inv4	**I don't have to do much to complete each activity**			7		
Inv5	I use my skills to do the activities			8		
Inv6	I got involved in the activities here			7	1	
Inv7	I participate in activities using different skills		1	7		
N1	The activities are different to the things we do in class		8			
N2	I use different equipment at CSIROSEC than in class		8			
N3	**I have done many of these activities before in class**		8			
N4	I have tried new activities at CSIROSEC	1	6	1		
N5	Science at CSIROSEC is different to the science we do in class	1	7			
N6	**Science at CSIROSEC is the same as at school**	1	7			
N7	We do science in a different way at CSIROSEC		8			
S1	I work well with the members of my group					8
S2	**I could get more work done by myself than in my group**				2	6
S3	The members of my group cooperate with each other					8
S4	I am able to depend on other members of my group for help doing activities					8
S5	I help other members of my group					8
S6	My group works as a team					8
S7	It is easier to get the work done as a team than by myself					8

The academic in the field of learning environment instruments reported difficulty placing a number of the Involvement scale items. There were no responses for items Involvement 2 and Involvement 4. The response to Involvement 7 concurred, but was accompanied by the annotation "unsure." The response to Involvement 6 was accompanied by the comment "could be either depending upon the emphasis," ie. the emphasis on *involved* or on *I* in the item "*I got involved in the activities here*" would determine its interpretation as an Involvement or an Independent Interpretation item.

Overall there was good general agreement with the assignment of items to their proposed scale establishing face validity of the instrument. It is appropriate, however, to recognise the difficulties experienced by the researcher in learning environments with placing items on the Involvement scale.

Administration to Students

The student instrument (Appendix 6) was administered to secondary school students visiting CSIROSECs in Hobart, Melbourne, Perth and Townsville. The items were arranged in groups of five. The first group contained, in order, the items Affect 1 (A1), Novelty 1 (N1), Involvement 1 (Inv1), Independence 1 (Ind1) and Social Interaction 1 (S1), the second group contained the items A2, N2, Inv2, Ind2 and S2, and so on up to the items in group 7. As before, a five-point Likert scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree) was adopted for responding to items. Items were scored 1 = strongly agree, 2 = agree, 3 = neither agree nor disagree, 4 = disagree, and 5 = strongly disagree. One negatively worded item was included for each scale, with the exception of Novelty which had two negatively worded items. Negatively worded items were reverse scored. A copy of the student form of the instrument is included as Appendix 5A. A list of the items, together with the appropriate identification code, is in Figure 5.1. The items shown in bold are negatively worded items.

The sample responding to the Redrafted Instrument is shown in Table 5.3 and involved classes ranging from grade 7 to grade 11, including coeducational, all girls' and all boys' classes. Schools were drawn from the government, private and Catholic sectors. The programs completed by the classes included Science and Technology, Forensic Science, Food Technology, Gene Technology and Electronics.

Table 5.3. Composition of Sample Completing Redrafted Instrument.

Type of School	No. of Classes	Year	Boys	Girls	Total
Government	1	7	14	13	27
	1	8	12	8	20
	1	9	10	10	20
Catholic Boys	1	9	26	0	26
Catholic Girls	1	10	0	17	17
Catholic Co-Ed	1	7	11	8	19
	1	9	10	4	14
	2	10	16	9	25
Private	4	7	47	50	97
	1	11	4	12	16
	1	12	9	11	20
Total	15	-	159	142	301

Issues such as permission to administer the instrument and the confidentiality of students' responses were handled in the same way as for the Pilot Study. Whilst instructions were given verbally to students, written instructions were placed on the reverse side of the instrument (see Appendix 5A). The attention of students was drawn to the written instructions, as well as the option of asking questions should the need arise. The instrument was administered to classes at the conclusion of the session, taking about 10 minutes to complete.

As for the Pilot Study, a code was assigned to each student's completed instrument to indicate the class, student number, and grade. Responses were manually entered into SPSS and negatively worded items were entered as reverse scored.

Results

The students' responses were analysed using SPSS. In contrast to the analysis of the Pilot Study Instrument, the scoring of items was reversed in SPSS so that 1 =

strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree, this gave scores which were more intuitive, in that higher scores related to a higher degree of agreement. Items were analysed to give percentage responses, means and standard deviations. Correlations were calculated among items, among items and the proposed scales, and between the proposed scales. A principal components analysis was conducted to obtain varimax rotated component loadings. The intention was to obtain information on the separation of items into components and to compare this with the proposed scale structure.

Item Analysis

The results of the item analysis are shown in Table 5.4. The frequency distributions for most items (see Table 5.4) tend to be skewed towards the "agree" end of the scale (remembering that negatively worded items are reverse scored). This is reflected in the mean values of items (items in the Redrafted Instrument are scored as 5 for strongly agree through to 1 for strongly disagree, therefore higher means indicate a greater degree of agreement), which range from 2.96 (Inv4, the only value less than 3) to 4.27 (N2).

Standard deviations for items range from 0.76 to 1.24 for items indicating a good range of responses. There were no choices of response on any item that did not attract a response. The skewness is reported in Table 5.4 for items and the values range from 0 to -1.34. As with the Pilot Study Instrument, it is likely that the degree of skewness is a result of the majority of students perceiving the learning environments at CSIROSECs very favourably.

Correlations Among Items

The inter-item correlation matrix is presented as Table 5.5. Correlations between individual items and the proposed scales have been calculated (see Table 5.6) and correlations between the mean item scores of the proposed scales are shown (see Table 5.7). These are discussed scale by scale to determine the extent to which items correlate with other items on their assigned scale or correlate with items on other scales. The intention is to produce an instrument in which the items for each scale show a much stronger correlation with items on their assigned scale than with items assigned to other scales.

Table 5.4. Percentage Responses, Means and Standard Deviations of Student Responses to the Redrafted Instrument.

	% Responses							
	1	2	3	4	5			
Item	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Mean	SD	Skewness
A1	2.0	5.3	24.9	50.2	17.6	3.76	0.87	-0.72
A2	3.3	6.6	24.3	24.3	41.5	3.94	1.11	-0.77
A3	3.3	11.6	34.9	35.5	14.6	3.47	0.99	-0.33
A4	5.0	9.0	21.9	28.6	35.5	3.81	1.16	-0.74
A5[a]	5.0	7.0	16.6	33.2	38.2	3.93	1.13	-0.99
A6	3.0	7.0	19.9	40.2	29.9	3.87	1.02	-0.83
A7	4.7	7.3	23.3	40.9	23.9	3.72	1.05	-0.77
N1	0.7	4.7	9.0	40.9	44.9	4.25	0.85	-1.21
N2	0.7	4.0	11.0	36.5	47.8	4.27	0.86	-1.18
N3[a]	3.7	8.6	20.3	40.9	26.6	3.78	1.05	-0.78
N4	4.0	3.0	12.6	40.5	39.9	4.09	1.00	-1.34
N5	3.0	5.6	14.3	44.9	32.2	3.98	0.98	-1.08
N6[a]	2.3	7.6	18.3	35.9	35.9	3.95	1.03	-0.85
N7	2.7	5.0	17.6	44.9	29.9	3.94	0.96	-0.97
Inv1	3.7	6.0	23.6	43.9	22.9	3.76	0.99	-0.80
Inv2	1.7	4.7	23.3	45.2	25.2	3.88	0.90	-0.70
Inv3	1.0	3.7	26.6	51.8	16.9	3.80	0.80	-0.55
Inv4[a]	9.6	22.9	37.2	22.3	8.0	2.96	1.08	0.00
Inv5	2.3	6.6	25.6	49.2	16.3	3.70	0.90	-0.71
Inv6	2.7	4.7	15.3	50.5	26.9	3.94	0.92	-1.08
Inv7	2.0	2.7	25.2	51.2	18.9	3.82	0.84	-0.76
Ind1	1.7	9.6	22.3	49.8	16.6	3.70	0.91	-0.66
Ind2	0.7	2.0	25.6	52.5	19.3	3.88	0.76	-0.44
Ind3	2.0	3.7	28.6	46.8	18.9	3.77	0.87	-0.62
Ind4	2.7	9.0	31.9	44.5	12.0	3.54	0.91	-0.54
Ind5	2.3	9.6	33.9	39.9	14.3	3.54	0.93	-0.38
Ind6	3.7	6.6	26.9	35.2	27.6	3.76	1.04	-0.65
Ind7[a]	3.3	7.3	25.2	34.2	29.9	3.80	1.05	-0.67
S1	1.0	2.3	11.6	43.9	41.2	4.22	0.82	-1.13
S2[a]	11.0	7.6	22.2	30.2	23.9	3.49	1.24	-0.57
S3	2.7	3.7	15.9	36.5	41.2	4.10	0.97	-1.14
S4	3.0	5.6	20.6	48.8	21.9	4.06	0.85	-1.26
S5	2.3	2.3	12.3	53.2	29.9	4.06	0.85	-1.26
S6	4.0	5.0	15.0	41.2	34.9	3.98	1.08	-1.12
S7	7.3	6.3	24.6	25.6	36.2	3.77	1.21	-0.76

[a] indicates negatively worded items which were reverse scored.

Affect

Items on the Affect scale have correlations with other Affect items which vary from a low of .43 to a high of .72 (see Table 5.5). The lowest correlation among Affect items is between item A3 (Science is more fun than I thought) and the negatively worded item A5 (I don't like science at CSIROSEC). Item A3 also had the lowest mean score (3.47) of the Affect items (see Table 5.4).

Individual Affect items have high correlations with the Affect scale of between .72 and .85. All of the Affect items also have moderate correlations with the Involvement scale of between .44 and .53 (see Table 5.6). This relationship is also reflected in the correlation between the scales for Affect and Involvement of .61 (see Table 5.7).

Items A1 (I think science at CSIROSEC is fun), A4 (I would like our science class to visit CSIROSEC more often) and A7 (I was really keen to do the activities) have correlations of greater than .40 with the Novelty scale (see Table 5.6). The correlation between the Affect and the Novelty scales is .49 (see Table 5.7).

Novelty

Correlations among individual items on the Novelty scale vary between .33 and .59 (see Table 5.5). The equal lowest correlations of .33 are between items N2 (I use different equipment at CSIROSEC than in class) and the negatively worded N3 (I have done many of these activities before in class) and between items N3 and N4 (I have tried new activities at CSIROSEC). However, item N3 also has low correlations of between -.05 and .18 with other scales (see Table 5.6). Furthermore, item N3 has the lowest mean score of 3.78.

Correlations are moderate between the Novelty and Involvement scales (.52) and the Novelty and Affect scales (.49) (see Table 5.7). Table 5.6 shows that there are correlations of greater than .40 between the Affect scale and items N1 (The activities are different to the things we do in class), N2 (I use different equipment at CSIROSEC than in class), N4 (I have tried new activities at CSIROSEC) and N7 (We do science in a different way at CSIROSEC), and between the Involvement scale and items N4, N5 (Science at CSIROSEC is different to the science we do in class) and N7.

Table 5.5. Correlation Matrix Showing All Items for Redrafted Instrument

	Affect = A							Novelty = N							Involvement = Inv							Independent Interpretation = Ind							Social Interaction =S						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
A1	1.00																																		
A2	.62	1.00																																	
A3	.52	.52	1.00																																
A4	.57	.63	.49	1.00																															
A5	.64	.57	.43	.47	1.00																														
A6	.68	.60	.55	.57	.64	1.00																													
A7	.58	.61	.54	.57	.52	.72	1.00																												
N1	.34	.32	.28	.33	.33	.30	.32	1.00																											
N2	.34	.40	.25	.38	.27	.32	.33	.53	1.00																										
N3	.17	.09	.09	.16	.15	.18	.16	.42	.33	1.00																									
N4	.40	.34	.31	.40	.37	.39	.35	.41	.38	.33	1.00																								
N5	.28	.26	.29	.31	.19	.21	.23	.59	.53	.51	.46	1.00																							
N6	.23	.21	.20	.22	.26	.17	.23	.52	.42	.46	.36	.53	1.00																						
N7	.38	.35	.31	.38	.31	.40	.49	.49	.52	.30	.45	.47	.44	1.00																					
Inv1	.25	.24	.26	.23	.22	.23	.23	.37	.25	.02	.28	.29	.21	.30	1.00																				
Inv2	.33	.29	.30	.29	.30	.34	.32	.34	.33	.22	.39	.40	.31	.35	.42	1.00																			
Inv3	.31	.33	.25	.28	.27	.30	.28	.19	.23	-.05	.22	.19	.15	.22	.33	.24	1.00																		
Inv4	.12	.04	.08	.08	.22	.09	.07	.18	.19	.21	.23	.20	.18	.17	.23	.28	.10	1.00																	
Inv5	.33	.33	.32	.40	.31	.45	.45	.17	.19	.16	.26	.27	.13	.30	.25	.33	.37	.14	1.00																
Inv6	.50	.45	.43	.39	.43	.52	.52	.25	.23	.03	.39	.24	.22	.41	.24	.36	.37	.18	.41	1.00															
Inv7	.40	.41	.33	.48	.36	.44	.49	.27	.27	.10	.32	.23	.20	.43	.23	.33	.30	.15	.49	.45	1.00														
Ind1	.24	.21	.27	.15	.19	.16	.21	.23	.18	-.05	.25	.23	.12	.29	.40	.24	.33	.23	.25	.31	.24	1.00													
Ind2	.29	.28	.29	.24	.23	.22	.21	.19	.15	.05	.16	.17	.17	.19	.21	.20	.30	.07	.25	.22	.26	.25	1.00												
Ind3	.32	.32	.25	.26	.30	.30	.26	.27	.24	-.07	.16	.17	.15	.21	.29	.22	.56	.07	.29	.34	.33	.25	.44	1.00											
Ind4	.11	.10	.15	.09	.06	.13	.14	.06	.03	-.09	.10	.08	-.02	.06	.06	-.00	.22	-.06	.15	.17	.14	.14	.27	.35	1.00										
Ind5	.18	.18	.19	.25	.12	.23	.25	.15	.18	.02	.24	.21	.13	.29	.27	.23	.29	.06	.37	.37	.35	.28	.21	.42	.37	1.00									
Ind6	.21	.31	.14	.25	.22	.22	.27	.13	.12	-.01	.16	.08	.16	.26	.10	.04	.16	-.14	.11	.26	.17	.12	.10	.25	.15	.22	1.00								
Ind7	.08	.20	.07	.12	.12	.01	.12	.10	.03	-.05	.04	.03	.19	.06	.03	-.03	.18	-.08	-.03	.14	.03	.08	.22	.28	.18	.11	.46	1.00							
S1	.21	.21	.20	.26	.16	.15	.23	.15	.14	-.08	.11	.12	.14	.16	.15	.10	.25	.12	.17	.30	.17	.25	.22	.23	.10	.19	.22	.16	1.00						
S2	-.03	-.02	-.07	-.03	.06	-.05	.05	-.03	-.03	.11	.04	.01	.03	.05	-.16	-.07	-.07	.13	-.09	-.02	-.05	.02	-.15	-.10	-.06	.01	.04	-.01	.27	1.00					
S3	.25	.22	.16	.27	.23	.23	.30	.16	.20	.07	.21	.17	.10	.22	.06	.06	.29	.05	.27	.27	.18	.28	.12	.20	.05	.18	.16	.08	.49	.31	1.00				
S4	.19	.15	.22	.21	.18	.26	.21	.08	.10	-.08	.24	.11	.01	.14	.12	.16	.22	.05	.19	.27	.16	.22	.08	.25	.11	.23	.18	-.01	.31	.14	.40	1.00			
S5	.33	.31	.26	.29	.33	.44	.48	.13	.21	.02	.27	.16	.12	.31	.20	.19	.40	.15	.48	.55	.44	.30	.21	.28	.19	.30	.14	.11	.30	.07	.43	.31	1.00		
S6	.37	.29	.27	.30	.31	.34	.40	.18	.16	.03	.26	.18	.18	.35	.18	.12	.31	.16	.34	.47	.35	.32	.14	.25	.07	.18	.25	.09	.54	.27	.66	.44	.51	1.00	
S7	.20	.10	.14	.15	.21	.17	.15	.14	.21	.05	.19	.14	.13	.24	.11	.13	.16	.20	.06	.23	.12	.13	.03	.19	.03	.18	.03	-.05	.23	.32	.29	.25	.22	.35	1.00

Table 5.6. Correlations of Items with Each Scale for Redrafted Instrument.

	Affect	Novelty	Involvement	Independent Interpretation	Social Interaction
A1	.82	.42	.50	.34	.32
A2	.82	.38	.46	.38	.26
A3	.72	.34	.44	.32	.24
A4	.78	.43	.48	.33	.30
A5[a]	.77	.37	.48	.29	.31
A6	.85	.38	.53	.30	.31
A7	.81	.41	.52	.35	.38
N1	.40	.76	.40	.26	.17
N2	.41	.72	.38	.22	.21
N3[a]	.18	.67	.16	-.05	.04
N4	.46	.67	.47	.26	.28
N5	.32	.81	.42	.23	.19
N6[a]	.27	.74	.32	.22	.15
N7	.47	.72	.49	.33	.32
Inv1	.30	.33	.62	.32	.13
Inv2	.39	.49	.68	.21	.14
Inv3	.36	.22	.59	.48	.31
Inv4[a]	.13	.27	.51	.02	.19
Inv5	.47	.29	.67	.32	.28
Inv6	.58	.35	.68	.43	.42
Inv7	.52	.35	.65	.36	.28
Ind1	.25	.24	.46	.50	.31
Ind2	.32	.21	.34	.56	.12
Ind3	.36	.21	.46	.70	.27
Ind4	.14	.04	.14	.58	.09
Ind5	.25	.24	.43	.62	.26
Ind6	.29	.17	.15	.59	.21
Ind7[a]	.13	.08	.05	.59	.07
S1	.26	.14	.28	.33	.65
S2[a]	-.01	.04	-.07	-.05	.57
S3	.30	.22	.26	.25	.77
S4	.26	.12	.26	.25	.60
S5	.44	.24	.53	.36	.58
S6	.41	.26	.43	.32	.81
S7	.20	.21	.23	.13	.62

[a] indicates negatively worded items which were reverse scored.

Table 5.7. Correlations Between Scales for Redrafted Instrument.

	A	N	Inv	Ind	S
Affect (A)	1.00				
Novelty (N)	.49	1.00			
Involvement (Inv)	.61	.52	1.00		
Independent Interpretation (Ind)	.41	.28	.47	1.00	
Social Interaction (S)	.38	.26	.39	.32	1.00

Involvement

Correlations among individual items on the Involvement scale vary between .10 and .49 (see Table 5.5). The lowest correlation is between item Inv3 (I handle the equipment to perform an activity) and the negatively worded item Inv4 (I don't have to do much to complete each activity). The item Inv4 has the lowest correlation of any Involvement item with the Involvement scale, but generally has lower correlations with other scales than other Involvement items (see Table 5.6).

Table 5.6 shows a number of correlations greater than .40 between Involvement items and other scales. These are Affect and Inv5 (I use my skills to do the activities), .47, Inv6 (I got involved in the activities here), .58 and Inv7 (I participate in activities using different skills), .52, Novelty and Inv2 (I have to think about the activities I am doing at CSIROSEC), .46, Independent Interpretation and Inv3, .48 and Inv6, .43 and Social Interaction and Inv6, .42. Table 5.7 shows that there are moderate to high correlations between the Involvement scale and all of the other scales.

Independent Interpretation

Correlations among individual items on the Independent Interpretation scale vary between .08 and .46 (see Table 5.5). There are, however, a number of low correlations among Independent Interpretation items, and several moderate correlations with items of other scales, particularly the Involvement scale.

Not surprisingly then, a number of items on the Independent Interpretation scale have correlations greater than .40 with the Involvement scale. These are Ind1 (We collect our own data in each activity), .46, Ind3 (I am able to decide for myself what is happening in each activity), .46 and Ind5 (You can make up your own mind what each activity means), .43 (see Table 5.6).

The Independent Interpretation scale has a correlation of .47 with the Involvement scale and .41 with the Affect scale (see Table 5.7).

Social Interaction

Correlations among individual items on the Social Interaction scale vary between .07 and .66 (see Table 5.5). The correlation of .07 is between the negatively worded item S2 (I could get more work done by myself than in my group) and item S5 (I help other members of my group). Item S5 has correlations greater than .40 with item A6 (The activities are interesting to me) and item A7 (I was really keen to do the activities).

Item S5 has moderate correlations with the Affect scale (.44) and the Involvement scale (.53), whilst item S6 has correlations of .41 with the Affect scale and .43 with the Involvement scale (see Table 5.6). Item S2 has very low correlations with all other scales (see Table 5.6).

The Social Interaction scale has correlations varying between .26 and .39 with the other scales (see Table 5.7).

Summary

Consideration of the correlation matrices has identified the items in each scale with the lowest correlation with their assigned scale; these being A3, N3 and N4 (equal), Inv4, Ind1 and S2. Other considerations have identified items which have high correlations with other scales compared to the correlation with their own scale; A7, N4, N7, Inv3, Inv6, Inv7, Ind1 and S5. Further information was sought by subjecting the data to a principal components analysis.

Principal Components Analysis

A principal components analysis with varimax rotation and Kaiser normalisation was performed on the data. As the instrument was designed to have five scales, a five component solution was extracted, and Eigenvalues and percent of variance accounted for by the first eight components are reported in Table 5.8. There are eight components with Eigenvalues greater than 1.0, however, there is a noticeable drop between 5 and 6 factors, so a five component solution may fit the data. The extraction of five components to represent the proposed scales accounts for 52.59 percent of the variance. To simplify the interpretation only loadings greater than 0.3 are shown in Table 5.9. The full matrix for the rotated five-component solution is shown in Table 5B.1 in Appendix 5B.

Discussion of Components

Component 1. The Affect items are loaded onto component 1 with loadings between .85 and .64 with no loadings greater than .3 on any other component (see Table 5.9). This is complemented by the low to trivial loadings on the other four components, as shown in Appendix 5B. These results reflect the high correlations among Affect items (see Table 5.5) and the high correlation of Affect items with the Affect scale (see Table 5.6). However, a number of other items also load on component 1.

There are four items of the proposed Involvement scale which have loadings greater than .3 onto component 1. They are Inv2, Inv5, Inv6 and Inv7. Inv2 also has loadings on components 2, 3 and 5. Inv5, Inv6 and Inv7 each have loadings on component 1 which are higher than loadings on component 3. These results indicate significant splintering of the Involvement scale.

Two of the Novelty items (N4 and N7) have loadings of .35 onto component 1, but both of these items have higher loadings onto component 2.

Two of the Social Interaction items have loadings onto component 1. S5 has a loading of .42 onto component 1, a loading of .36 onto component 3 and a loading of .45 onto component 4, which has loadings for all of the Social Interaction items. S6

Involvement items that are loaded onto component 3 have higher loadings on other components.

Table 5.9. Varimax Rotated Component Loadings for the Redrafted Instrument.

	Component				
Item	1	2	3	4	5
A1	.76				
A2	.76				
A3	.64				
A4	.71				
A5[a]	.70				
A6	.85				
A7	.78				
N1		.74			
N2		.65			
N3[a]		.69			
N4	.35	.52			
N5		.78			
N6[a]		.75			
N7	.35	.58			
S1				.64	
S2[a]			-.32	.63	
S3				.76	
S4				.53	
S5	.42		.36	.45	
S6	.31			.76	
S7				.55	
Ind1			.53		
Ind2			.52		
Ind3			.68		
Ind4			.52		
Ind5			.60		
Ind6					.66
Ind7[a]					.74
Inv1		.31	.53		
Inv2	.31	.43	.32		-.32
Inv3			.62		
Inv4[a]		.32			-.46
Inv5	.48		.41		
Inv6	.55		.36		
Inv7	.53		.35		

[a] indicates negatively worded items which were reverse scored
Note. Loadings > .3 are shown

Two of the proposed Social Interaction items have loadings on component 3, but both have higher loadings on other components.

Component 4. Component 4 only has loadings greater than .3 of items from the proposed Social Interaction scale. The loadings vary between .45 and .76 and all of the items have their highest loading on component 3.

Component 5. Component 5 contains only 4 loadings greater than .3. Ind6 (.66) and Ind7 (.74) from the proposed Independent Interpretation scale have their only loading greater than .3 on component 5. This suggests that these two items are tending to define their own component.

Two of the items from the proposed Involvement scale have loadings greater than .3 onto component 5, Inv2 (-.32) and the negatively worded Inv4 (-.46). Inv4 has its highest loading onto component 5.

Summary

The rotated 5-component solution shows that there are three of the proposed scales which have all of their items loaded at greater than .3 onto a particular component. Affect is loaded onto component 1, Novelty onto component 2 and Social Interaction onto component 4. The loadings of these items are greatest on the component they are associated with.

Component 3 contains five of the items from the proposed Independent Interpretation scale, and these items have no loadings greater than .3 on any other component. Items Ind6 and Ind7, which are loaded onto component 5, need to be reworked if they are to correlate more strongly with the remaining Independent Interpretation items.

Component 5 is not strongly associated with any of the proposed scales, rather it is defined by items Ind6 and Ind7 which are tending to define their own component.

Discussion of Proposed Scales

Affect. The Affect items are loaded onto component 1 with no loadings greater than .3 on any other component (see Table 5.9). This reflects the high correlations among Affect items (see Table 5.5) and the high correlation of Affect items with the Affect scale (see Table 5.6). These items seem to be forming a single scale.

Novelty. The novelty items essentially define their own component. Items N4 (I have tried new activities at CSIROSEC) and item N7 (We do science in a different way at CSIROSEC) have the weakest loadings and both also have low loadings on component 1, which contains the Affect items.

Involvement. Items from the proposed Involvement scale are loaded onto a number of different components with loadings greater than .3 (see Table 5.9). All items, excluding the negatively worded item Inv4 (I don't have to do much to complete each activity), are loaded onto component 3, but the first five Independent Interpretation items are also loaded on component 3.

Item Inv3 (I handle the equipment to perform an activity) is the highest loading Involvement item on component 3 with no loadings greater than .3 onto any other component.

Items Inv5 (I use my skills to do the activities), Inv6 (I got involved in the activities here) and Inv7 (I participate in activities using different skills) are loaded more strongly onto component 1 than component 3. Component 1 is the component on which the Affect items are loaded. This reflects the moderate correlations among these items and the Affect items (see Table.5.5).

The expert in learning environment instruments may have foreshadowed a potential problem with the discriminant validity of the Involvement scale. Previous instruments have also shown inferior discriminant validities for the Involvement scale, such as the *What is Happening in this Class?* (WIHIC) questionnaire developed by Fraser, McRobbie and Fisher (1996), which shows relatively lower factor loadings for some Involvement items when tested with Australian and Taiwanese students (Aldridge, Fraser, & Huang, 1999, Table 1). Both the *Classroom*

Environment Scale (CES) and *the College and University Environment Instrument Inventory* (CUCEI) have Involvement items with the highest mean correlation with other scales (0.40 and 0.47 respectively) (Fraser, 1998b, Table 2).

Independent Interpretation. Independent Interpretation items 1 to 5 are loaded onto component 3 with several Involvement items. Item Ind6 (I don't need help from the teacher to complete most of the activities) and the negatively worded item Ind7 (I need help from the teacher with most of the activities) are loaded together onto component 5. Upon closer inspection of the correlation matrix (Table 5.5) it can be seen that item Inv6 and Inv7 have the highest correlation among Independent Interpretation items, but lower correlations with other Independent Interpretation items. This has resulted in items Inv6 and Inv7 being loaded as a separate component.

Social Interaction. Items for Social Interaction are loaded onto component 4 of the rotated solution. Three items have low loadings on other components. The negatively worded item S2 (I could get more work done by myself than in my group) has a loading of -.32 onto component 3, item S5 (I help other members of my group) has loadings on components 1 and 3, and item S6 (My group works as a team) has a loading on component 1. These small loadings reflect the correlations of these three items with some of the items on the Affect scale (see Table 5.6).

Summary

The rotated 5-component solution shows that the items for Affect, Novelty and Social Interaction are loaded onto separate components. This suggests that these scales have reasonable discrimination. Independent Interpretation has five items that are loaded onto component 3, but items Ind6 and Ind7 are loaded onto a separate component, probably because of their strong similarity in wording. The majority of the Involvement items have loadings on the same component as Independent Interpretation items, but there are strong loadings onto other components as well. The Involvement scale has been poorly defined in the principal components analysis.

The rotated principal component analysis has reinforced a number of findings from the consideration of the face validity, the item analysis and the correlations among items and refined a number of other aspects, which shall be discussed below.

Discussion

One of the intentions expressed earlier in this chapter concerning the development of a learning environment instrument for CSIROSECs was to develop an instrument with six items per scale. The instrument tested thus far has had seven items per scale, allowing for the deletion of one item per scale. Considerations of the face validity, the item analysis, correlations among items and the rotated component analysis will assist in identifying the items that may best be deleted.

The responses from SECSM practitioners and other experts as a means of determining construct validity are useful. There is good general agreement with the assignment of items to their defined scales, but some of the weaker items have also been identified (N4, Inv6, Ind6, Ind7).

The response from the academic expert in the area of learning environment instruments reflected uncertainty with the Involvement scale, primarily items Inv2, Inv4, Inv6 and Inv7. This is reinforced in the inter-item correlations and the rotated component analysis with respect to these items. This concurs with the relative weakness of Involvement scales in existent learning environment instruments (eg. WIHIC, CES and CUCEI). Input from experts in this area would be useful in the construction and validation of learning environment instruments.

Affect

Item A3 with the lowest correlation with the proposed Affect scale (.72) is also the item that has the weakest loading on component 1 (.64). Item A3 (Science is more fun than I thought) may be the best item to delete.

Novelty

The negatively worded item N3 (I have done many of these activities before in class) and item N4 (I have tried new activities at CSIROSEC) have the equal lowest correlations with the proposed Novelty scale (.67). Items N4 and N7 (We do science in a different way at CSIROSEC) have correlations greater than .4 with both the Affect and Involvement scales. The rotated principal components analysis shows that, of items N3, N4 and N7, item N4 has the lowest loading onto component 2 (.52). Given all these results item N4 may be the best item to delete.

Social Interaction

The negatively worded item S2 (I could get more work done by myself than in my group) has the lowest correlation of Social Interaction items with the Social Interaction scale (.57). Item S5 (I help other members in my group) has a correlation of .58 with the Social Interaction scale. S5 also has a correlation of .53 with the Involvement scale and .44 with the Affect scale. S5 has the lowest loading on the rotated factor analysis of .45 with loadings of .42 onto component 1 with Affect items and .36 onto component 3 with Involvement and Independent Interpretation items. Accordingly, item S5 may be the best item to delete.

Independent Interpretation

Item Ind1 (We collect our own data in each activity) has the lowest correlation with the Independent Interpretation scale of .50. On the rotated component analysis Independent Interpretation items 1 to 5 are loading on component 3, but items Ind6 and Ind7 are loading strongly on component 5. These two items are very similar in that item Ind7 (I need help from the teacher with most of the activities) is the negatively worded version of Ind6 (I don't need help from the teacher to complete most of the activities). Ind6 and Ind7 have the highest intercorrelation between any of the Independent Interpretation items (.46) (see Table 5.5). The removal of either Ind6 or Ind7 could result in the remaining item to be loaded onto the same component as the other Independent Interpretation items. Of these two Ind6 has the lower factor loading (.66 compared to .74) and Ind7 has lower correlations with other scales than Ind6 (see Table 5.6), whilst having the same correlation with the Independent Interpretation scale (.59). Item Ind6 may be the best item to delete.

Involvement

The negatively worded item Inv4 (I don't have to do much to complete each activity) has the lowest correlation with the Involvement scale (.51), but it also has low correlations with the remaining scales (see Table 5.6). Item Inv6 (I got involved in the activities here) has a correlation of .68 with the Involvement scale, but also correlations with other scales of .58 with Affect, .43 with Independent Interpretation and .42 with Social Interaction. On the rotated component analysis Inv6 has a loading of .36 with five other Involvement items on component 3 and a loading of .55 with Affect items on component 1. Item Inv6 may be the best item to delete.

Factor Analysis with Six Items per Scale

A principal components analysis with Kaiser normalisation and varimax rotation was conducted on a reduced data set with six items for each of the proposed scales. Again, five components were extracted and eigenvalues and percent of variance accounted for by the components with eigenvalues greater than one are shown in Table 5.10. There are seven components with Eigenvalues greater than 1.0 and the extraction of 5 components accounts for 54.22 percent of the variance. Only loadings greater than .3 are shown in Table 5.11. The full matrix for the rotated five-component solution with six items for each of the proposed scales is shown in Table 5B.2 in Appendix 5B.

Table 5.10. Eigenvalues and Variance Explained for Redrafted Instrument with Six Items per Scale and with Five Components Extracted.

Component	Eigenvalues	% of Variance	Cumulative % of Variance
1	8.11	27.04	27.04
2	2.62	8.72	35.76
3	2.19	7.29	43.05
4	1.92	6.41	49.45
5	1.43	4.77	54.22
6	1.17	3.88	58.10
7	1.03	3.42	61.52

Consideration of the rotated component analysis with six items per scale reported in Table 5.11 shows that items for each of the proposed scales are loaded mostly onto separate components.

Component 1. All of the items for the proposed Affect scale are loaded onto component 1 with loadings between .72 and .85. Other items loaded onto component 1 include N7 (.36), S6 (.31), Inv5 (.48) and Inv7 (.54). However, the two Involvement items display their highest loading on component 1.

Component 2. All of the items for the proposed Novelty scale are loaded onto component 2 with loadings between .54 and .78. Only one other item has a loading greater than .3 on component 2, item Inv2 (.34), but this item has a higher loading on component 5.

Component 3. The only loadings on component 3 greater than .3 are items from the proposed Social Interaction scale. The loadings vary between .54 and .76.

Component 4. All of the items for the proposed Independent Interpretation scale are loaded onto component 4 with loadings between .36 and .72. Two of the items from the proposed Involvement scale have loadings on component 4, Inv1 (.31) and Inv3 (.57). The Inv3 item's only loading greater than .3 is on component 4.

Component 5. Five of the six items from the proposed Involvement scale have loadings on component 5, the exception being Inv3, mentioned above. The loadings vary between .32 and .59, but items Inv5 and Inv 7 have higher loadings on component 1. Three of the items from the proposed Independent Interpretation scale have loadings greater than .3 on component 5. Ind1 has its highest loading (.48) on component 5, whilst Ind5 has a loading of .33 and Ind7 a loading of -.48.

Loadings of the Items Related to the Proposed Scales.

The Affect items are loaded on component 1 only, and with one exception the Novelty items are loaded only on component 2. Item N7 also has a small loading of .36 onto component 1. The Social Interaction items are loaded onto component 3, with S6 loading on component 1 at .31. Independent Interpretation items are loaded onto component 4, however, the lowest loading item Ind1 (.36) is loaded more strongly onto component 5 (.48) with the majority of the Involvement items.

Table 5.11. Rotated Component Analysis for the Redrafted Instrument with items A3, N4, S5, Ind6 and Inv6 removed.

	Component				
Item	1	2	3	4	5
A1	.77				
A2	.77				
A4	.73				
A5	.72				
A6	.85				
A7	.78				
N1		.73			
N2		.64			
N3[a]		.71			
N5		.77			
N6		.78			
N7	.36	.54			
S1			.66		
S2[a]			.65		
S3			.76		
S4			.54		
S6	.31		.75		
S7			.55		
Ind1				.36	.48
Ind2				.59	
Ind3				.72	
Ind4				.62	
Ind5				.51	.33
Ind7[a]				.54	-.48
Inv1				.31	.59
Inv2		.34			.55
Inv3				.57	
Inv4[a]					.51
Inv5	.48				.42
Inv7	.54				.32

[a] indicates negatively worded items which were reverse scored and rescaled
Note. Loadings > .3 are shown

Five of the six Involvement items are loaded onto component 5. The exception is item Inv3 which loads on component 4 at .57. Item Inv2 also loads on component 2 with Novelty items. Both item Inv5 and Inv7 are loaded more strongly on component 1 with Affect items.

In sum then, the Redrafted Instrument has produced reasonable results for three scales, but Independent Interpretation and Involvement are still not performing well. Further refinement of items will be necessary to produce an instrument with improved discrimination between the proposed scales. The original Redrafted Instrument with all seven items, the associated statistical analyses, and the face validity from experts will be used as the basis for rewriting a small number of items.

Proposed Changes to the Redrafted Instrument

It was decided that several changes should be made to the instrument to improve its construct validity.

1. Item Ind1 (We collect our own data in each activity) is to be moved from the Independent Interpretation scale to the Involvement scale by rewriting it to read "We collect data in each activity". Ind1 was loaded strongly onto the same component as items from the Involvement scale (.64). This rewrite changes the emphasis from the independence of students "collecting our own" data to an emphasis on involvement in activities by collecting data.

2. Inv3 (I handle the equipment to perform an activity) will be moved from the Involvement scale to the Independent Interpretation scale by rewriting it to read "I can handle the equipment myself to perform an activity". Inv3 was loading more strongly onto the Independent Interpretation scale (.54) than the Involvement scale (.31). It is envisaged that the inclusion of the word "myself" into the item may change the emphasis from involvement to independence.

3. The operational definitions underwent minor modifications to accommodate the changes described above. The revised operational definitions are shown at the end of this section.

4. Involvement items 5, 6 and 7 were rewritten in an attempt to reflect more strongly the meaning of the Involvement scale.
    a. Inv5 (I use my skills to do the activities) has been rewritten to read "I have to put an effort into each activity".

    b. Inv6 (I got involved in the activities here) has been rewritten to read "The activities don't work unless I am involved".

    c. Inv7 (I participate in activities using different skills) has been rewritten to read "I participate in each of the activities".

5. N4 (I have tried new activities at CSIROSEC) was rewritten in an attempt to get it to cohere more strongly to the Novelty scale. The rewritten item reads: "I have tried different activities at CSIROSEC than I have done in class".

Refined Operational Definitions of Scales

Changes have been made to the operational definitions for Independent Interpretation and Involvement, and the other three definitions are unchanged.

Involvement has been changed with the deletion of "Students who are involved in the CSIROSEC experience will 1. use their own skills in each activity" and the inclusion of "Students who are involved in the CSIROSEC experience will 3. collect data and, 4. put effort into each activity".

Independent Interpretation has been changed by the deletion of "Groups of students who are working independently at CSIROSEC will 1. collect their own data", and its replacement with "Groups of students who are working independently at CSIROSEC will 1. operate the equipment themselves".

A full listing of the revised operational definitions of scales follows.

Affect is the attitude students have towards CSIROSEC and doing science activities at CSIROSEC.

A student who has a positive attitude to science at CSIROSEC
1. will think science at CSIROSEC is fun,
2. will find CSIROSEC activities interesting,
3. will be keen to do CSIROSEC type activities,
4. would like their class to visit CSIROSEC more often, and
5. will have an enhanced attitude to science following a visit to CSIROSEC.

Novelty is the extent to which students perceive the science activities and equipment at CSIROSEC to be different from those in their school.

Students who perceive a high level of novelty at CSIROSEC will think the learning environment is different from that in their own classroom in terms of
1. the kind of science they do at CSIROSEC,
2. the way science is done at CSIROSEC,
3. the type of science activities at CSIROSEC, and
4. the different equipment which they use at CSIROSEC.

Involvement is the extent to which students need to physically and mentally participate in activities at CSIROSEC.

Students who are involved in the CSIROSEC experience will
1. be involved in activities to make things happen,
2. be involved both mentally and physically,
3. collect data, and
4. put effort into doing each activity.

Independent Interpretation is the extent to which groups are able to perform activities independently and students are able to make their own interpretation of activities and their outcomes.

Groups of students who are working independently at CSIROSEC will

1. operate the equipment themselves,
2. decide what they need to do in each activity, and
3. proceed without help from the teacher.

At the individual level, students who are working independently at CSIROSEC will

4. make their own interpretation of what is happening in each activity, and
5. reach their own conclusions from each activity.

Social Interaction is the extent to which students collaborate/cooperate in groups to perform activities.

Students who demonstrate a high level of social interaction during their CSIROSEC visit will

1. work well with the members of their group,
2. realise the importance of teamwork and cooperation in completing each activity, and
3. work in a mutually helpful way.

The Redrafted Instrument with the proposed changes is shown In Figure 5.2 and now becomes known as the **Refined Instrument**.

Summary

The responses from SECSM practitioners and learning environment experts as a means of determining construct validity has been useful as a means of predicting potential problems. Analysis of the Redrafted Instrument of the LEI for CSIROSECs has revealed a number of weak items and an overall weakness with the Involvement scale. Several items have been rewritten in order to improve the internal discriminant validity of items and the coherence of all items to their assigned scale. This has resulted in the Refined Instrument of the LEI for CSIROSECs (Figure 5.2). The Refined Instrument was subjected to testing with further groups of students and this is reported in the following chapter.

	A = Affect N = Novelty Inv = Involvement Ind = Independent Interpretation S = Social Interaction	Refined Instrument changes made from the Redrafted Instrument
A1	I think science at CSIROSEC is fun	
N1	The activities are different to the things we do in class	
Inv1	I have to be involved in activities to make them work	
Ind1	I can handle the equipment myself to perform an activity	Rewritten from Inv3
S1	I work well with the members of my group	
A2	I would like to do science like this more often	
N2	I use different equipment at CSIROSEC than in class	
Inv2	I have to think about the activities I am doing at CSIROSEC	
Ind2	I can reach my own conclusions from most activities	
S2	**I could get more work done by myself than in my group**	
A3	Science is more fun than I thought	
N3	**I have done many of these activities before in class**	
Inv3	We collect the data in each activity	Rewritten from Ind1
Ind3	I am able to decide for myself what is happening in each activity	
S3	The members of my group cooperate with each other	
A4	I would like our science class to visit CSIROSEC more often	
N4	I have tried different activities at CSIROSEC than I have done in class	Rewritten
Inv4	**I don't have to do much to complete each activity**	
Ind4	We can decide what we need to do in each activity	
S4	I am able to depend on other members of my group for help doing activities	
A5	**I don't like science at CSIROSEC**	
N5	Science at CSIROSEC is different to the science we do in class	
Inv5	I have to put effort into each activity	Rewritten
Ind5	You can make up your own mind what each activity means	
S5	I help other members of my group	
A6	The activities are interesting to me	
N6	**Science at CSIROSEC is the same as at school**	
Inv6	The activities don't work unless I am involved	Rewritten
Ind6	I can do the activities myself without adult help	Rewritten
S6	My group works as a team	
A7	I was really keen to do the activities	
N7	We do science in a different way at CSIROSEC	
Inv7	I participate in each of the activities	Rewritten
Ind7	**I need help from an adult with most of the activities**	Rewritten
S7	It is easier to get the work done as a team than by myself	

Figure 5.2. Refined Instrument with Codes for Variables. Item Changes from the Redrafted Instrument are Indicated.

Chapter 6

The Refined Instrument and the Learning Environment Instrument for CSIRO Science Education Centres

Introduction

This chapter reports the field testing of the Refined Instrument of the LEI for CSIROSECs and its administration to students. It reports the data analyses, after which one item in each scale is identified for exclusion and the instrument is reduced to 6 items per scale and reanalysed to determine correlations, internal discriminant validity and internal consistency reliability of the scales. The instrument with six items per scale becomes the final version of the instrument, which is named the Learning Environment Instrument for CSIRO Science Education Centres (LEI for CSIROSECs). Comparisons of the LEI for CSIROSECs with existing learning environment instruments on a number of parameters are described to place the instrument's performance in perspective. Comparisons made between the results for different classes, teacher-student perceptions, primary and secondary student perceptions and programs are also described as a way of examining the sensitivity of the instrument.

The Refined Instrument

As a result of the analyses of the Redrafted Instrument and the resultant conclusions, a Refined Instrument has been produced (Figure 6.1). The slightly revised operational definitions of the scales were listed in Chapter 5.

	A = Affect N = Novelty Inv = Involvement Ind = Independent Interpretation S = Social Interaction
A1	I think science at CSIROSEC is fun
A2	I would like to do science like this more often
A3	Science is more fun than I thought
A4	I would like our science class to visit CSIROSEC more often
A5	**I don't like science at CSIROSEC**
A6	The activities are interesting to me
A7	I was really keen to do the activities
N1	The activities are different to the things we do in class
N2	I use different equipment at CSIROSEC than in class
N3	**I have done many of these activities before in class**
N4	I have tried different activities at CSIROSEC than I have done in class
N5	Science at CSIROSEC is different to the science we do in class
N6	**Science at CSIROSEC is the same as at school**
N7	We do science in a different way at CSIROSEC
Inv1	I have to be involved in activities to make them work
Inv2	I have to think about the activities I am doing at CSIROSEC
Inv3	We collect the data in each activity
Inv4	**I don't have to do much to complete each activity**
Inv5	I have to put effort into each activity
Inv6	The activities don't work unless I am involved
Inv7	I participate in each of the activities
Ind1	I can handle the equipment myself to perform an activity
Ind2	I can reach my own conclusions from most activities
Ind3	I am able to decide for myself what is happening in each activity
Ind4	We can decide what we need to do in each activity
Ind5	You can make up your own mind what each activity means
Ind6	I can do the activities myself without adult help
Ind7	**I need help from an adult with most of the activities**
S1	I work well with the members of my group
S2	**I could get more work done by myself than in my group**
S3	The members of my group cooperate with each other
S4	I am able to depend on other members of my group for help doing activities
S5	I help other members of my group
S6	My group works as a team
S7	It is easier to get the work done as a team than by myself

Figure 6.1. Refined Instrument with Items Arranged According to Scale.

Administration of the Refined Instrument

The Refined Instrument was administered to 374 students in 19 classes from the Tasmanian and Victorian CSIROSECs and included government and Catholic schools. As shown in Table 6.1, students were from grade 6 to grade 10, and single sex classes (both sexes) and co-educational classes were included. The instrument was used with classes studying a range of programs, including Science & Technology, Electronics, Forensic Science and A Physical World. Five teachers were asked to complete the instrument from what they thought would be the students' perceptions of the session to assist in analysing the instrument.

The items were arranged in the same way for the Refined Instrument as for the Redrafted Instrument (Appendix 6A). As before, students responded on a five point Likert scale. A list of the items, together with the appropriate identification code, is shown in Figure 6.1. The negatively worded items are shown in bold, and were reverse scored. The Refined Instrument was administered, and data recorded, in the same way as for the Redrafted Instrument.

Table 6.1. Composition of Sample Completing the Refined Instrument.

Type of School	No. of Classes	Year	Boys	Girls	Total
Government	4	6	41	37	78
	2	7	17	17	34
	1	8	16	4	20
	1	9	9	6	15
	1	10	7	13	20
Catholic Boys	1	9	24	0	24
	4	8	98	0	98
Catholic Girls	4	7	0	70	70
Catholic Co-Ed	1	10	12	3	15
Total	19	-	224	150	374

Results for the Refined Instrument

The data for the Refined Instrument were prepared and analysed in the same way as for the Redrafted Instrument. The items were scored so that higher means represent more positive responses.

Item Analysis

The item analysis in Table 6.2 shows that, once again, the frequency distributions for most items tend to be skewed towards the "agree" end of the scale. The skewness values for items vary between -0.03 (Inv4) and -1.50 (N2) for items. A skewness of zero is desirable for maximum discrimination among items. Items which have lower skewness values of between 0 and -0.50 are A3 (Science is more fun than I thought), -0.41, A4 (I would like our science class to visit CSIROSEC more often), -0.42, A7 (I was really keen to do most of the activities), -0.45, the negatively worded Inv4 (I don't have to do much to complete each activity), -0.03, Inv6 (The activities don't work unless I am involved), -0.26 and Ind3 (I am able to decide for myself what is happening in each activity), -0.44.

There are high mean values for each item (Table 6.2), as was the case with the Pilot Study Instrument and the Redrafted Instrument. The mean of items varied between 3.12 (Inv4) and 4.23 (N2) and it is noteworthy that these items also attracted the lowest and highest means for the Redrafted Instrument. As reported for the previous two versions of the instrument, it is likely that the degree of skewness and high mean values are the result of the majority of students favourably perceiving the learning environment at CSIROSEC.

The standard deviation values for items vary between 0.80 and 1.29 indicating a good spread of responses. All response choices to items attracted responses.

Correlations Among Items

The inter-item correlation matrix is presented as Table 6.3. Correlations between individual items and the proposed scales have been calculated and are shown in

Table 6.4. Correlations between the mean item scores for the proposed scales are shown in Table 6.5. These are discussed scale by scale.

Table 6.2. Percentage Responses, Means and Standard Deviations of Student Responses to the Refined Instrument.

	% Responses							
	1	2	3	4	5			
Item	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Mean	SD	Skewness
A1	5.3	7.5	30.5	45.5	11.2	3.50	0.97	-0.75
A2	9.1	9.6	23.8	29.4	28.1	3.58	1.24	-0.60
A3	9.4	10.4	34.0	30.7	15.5	3.33	1.14	-0.41
A4	12.3	10.4	27.8	27.3	22.2	3.37	1.28	-0.42
A5[a]	8.0	8.8	24.1	31.8	27.3	3.61	1.20	-0.65
A6	6.1	12.0	24.1	37.4	20.3	3.54	1.13	-0.57
A7	7.2	12.0	28.6	32.1	20.1	3.46	1.15	-0.45
N1	2.4	3.2	8.3	45.2	40.9	4.19	0.90	-1.46
N2	2.1	3.5	7.2	43.9	43.3	4.23	0.89	-1.50
N3[a]	4.5	6.1	15.5	44.1	29.7	3.88	1.05	-1.05
N4	5.1	5.3	15.0	46.8	27.8	3.87	1.04	-1.11
N5	2.9	7.5	15.5	48.4	25.7	3.86	0.98	-0.96
N6[a]	3.2	4.5	16.6	41.4	34.2	3.99	0.99	-1.06
N7	3.5	5.1	20.9	46.3	24.3	3.83	0.97	-0.91
Inv1	4.0	7.2	21.7	48.7	18.4	3.70	0.98	-0.86
Inv2	3.2	5.1	18.7	51.3	21.7	3.83	0.93	-1.00
Inv3	2.9	6.1	20.9	51.1	19.0	3.77	0.93	-0.89
Inv4[a]	7.2	20.6	36.9	23.8	11.5	3.12	1.09	-0.03
Inv5	2.7	5.6	25.7	55.1	11.0	3.66	0.85	-0.91
Inv6	8.0	17.1	32.9	31.0	11.0	3.20	1.10	-0.26
Inv7	1.9	5.1	13.4	55.6	24.1	3.95	0.86	-1.08
Ind1	1.6	5.9	20.3	44.4	27.8	3.91	0.92	-0.76
Ind2	1.3	4.8	23.8	52.1	17.9	3.80	0.83	-0.68
Ind3	0.3	6.1	25.1	52.1	16.3	3.78	0.80	-0.44
Ind4	3.5	13.1	28.1	46.5	8.8	3.44	0.95	-0.60
Ind5	2.1	10.7	27.3	48.9	11.0	3.56	0.90	-0.61
Ind6	5.1	9.9	25.1	39.3	20.6	3.60	1.08	-0.63
Ind7[a]	3.5	8.3	20.3	36.9	31.0	3.84	1.06	-0.78
S1	3.2	2.4	11.0	47.1	36.4	4.11	0.92	-1.40
S2[a]	12.0	8.8	21.4	31.6	26.2	3.51	1.29	-0.62
S3	3.2	4.5	13.4	47.3	31.6	3.99	0.96	-1.18
S4	4.0	7.0	19.5	48.4	21.1	3.76	0.99	-0.91
S5	3.5	2.9	13.1	57.8	22.7	3.93	0.89	-1.33
S6	4.8	8.0	15.8	39.8	31.6	3.85	1.10	-0.95
S7	6.4	6.7	17.4	37.2	32.4	3.82	1.15	-0.95

[a] indicates negatively worded items which were reverse scored.

Affect

Affect items are showing strong correlations with other Affect items with correlations ranging between .53 and .74 (see Table 6.3), this compares with correlations between .43 and .72 for the Redrafted Instrument. Table 6.4 shows that the lowest correlation between an Affect item and the Affect scale is with item A3 (Science is more fun than I thought), .78.

Individual Affect items have high correlations with the Affect scale of between .78 and .89 (see Table 6.4), this compares with .72 and .85 for the Redrafted Instrument (see Table 5.6). The Affect scale is showing moderate correlations with a number of items on other scales; N2, .42, N5, .42, N7 (We do science in a different way at CSIROSEC), .47 and Inv2, .47 (Table 6.4).

All of the Affect items for the Redrafted Instrument had moderate correlations with the Involvement scale of between .44 and .53 (see Table 5.6). The discrimination between these scales has improved with the Refined Instrument and the correlations now range from .28 to .46. The correlation between the scales for Affect and Involvement was .61 for the Redrafted Instrument (see Table 5.7). This has reduced to a correlation of .47 for the Refined Instrument. Correlations between the Affect scale and other scales have also been reduced, Independent Interpretation from .41 to .25, Social Interaction from .38 to .20, and less so for Novelty, from .49 to .46.

Novelty

The rewrite of item N4 from the Redrafted Instrument has slightly reduced its correlation with the Novelty scale from .67 to .64, but it has also reduced its correlations with other scales (see Table 5.6 and Table 6.4), thus improving the discrimination of the scale to some extent.

The correlations between the Novelty scale and other scales have improved from the Redrafted Instrument to the Refined Instrument. The correlation with the Affect scale has decreased slightly from .49 to .46, with the Involvement scale from .52 to .45, with the Independent Interpretation scale from .28 to .16, and with the Social Interaction scale from .26 to .19.

Whilst item N4 shows the lowest correlation with the Novelty scale (.64) item N7 has a correlation of .66, but displays higher correlations with other scales than item N4.

Involvement

The rewriting of items Inv3, Inv5, Inv6 and Inv7 has shown mixed results. The correlation of Inv5 with the Involvement scale is about the same, .67 compared to .68, but more noteworthy is the reduction in the correlations between Inv5 and other scales (see Table 5.6 and Table 6.4). Items Inv3, Inv6 and Inv7 have shown reductions in their correlations with the Involvement scale, but again there are large reductions in the correlations with other scales.

Correlations of Involvement items with the Involvement scale range from .69 for item Inv2 to .49 for the negatively worded item Inv4 (see Table 6.4). Item Inv2 also has moderate correlations with the Affect scale (.47) and the Novelty scale (.45) (see Table 6.4).

Correlations between the Involvement scale and other scales are less for the Refined Instrument than the Redrafted Instrument. The correlation between the Involvement scale and the Affect scale has reduced from .61 to .47, the Independent Interpretation scale from .41 to .25, the Social Interaction scale from .38 to .20 and the Novelty scale from .52 to .45 (compare Table 5.7 and Table 6.5).

Independent Interpretation

The rewriting of item Ind1 has improved its correlation with the Independent Interpretation scale from .50 for the Redrafted Instrument to .65 for the Refined Instrument. Likewise, the rewriting of item Ind6 has improved its correlation from .59 to .67. However, the rewriting of the negatively worded Ind7 has not changed its correlation from .59.

Table 6.3. Correlation Matrix Showing All Items for the Refined Instrument

	Affect = A							Novelty = N							Social Interaction =S							Independent Interpretation = Ind							Involvement = Inv						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
A1	1.00																																		
A2	.60	1.00																																	
A3	.64	.54	1.00																																
A4	.71	.70	.61	1.00																															
A5	.74	.59	.53	.71	1.00																														
A6	.66	.62	.66	.74	.63	1.00																													
A7	.68	.57	.58	.71	.65	.73	1.00																												
N1	.32	.23	.25	.32	.32	.30	.25	1.00																											
N2	.36	.34	.31	.44	.34	.37	.29	.61	1.00																										
N3	.12	.10	.01	.18	.14	.07	.12	.42	.40	1.00																									
N4	.33	.23	.28	.35	.28	.28	.29	.41	.47	.22	1.00																								
N5	.38	.29	.32	.42	.37	.34	.34	.51	.48	.47	.45	1.00																							
N6	.20	.16	.15	.27	.27	.22	.20	.47	.45	.48	.32	.49	1.00																						
N7	.33	.30	.29	.36	.34	.40	.38	.36	.44	.31	.32	.51	.37	1.00																					
S1	.12	.06	.13	.06	.09	.08	.13	.04	-.03	-.04	.04	.09	.03	.13	1.00																				
S2	.11	-.01	-.03	.02	.08	-.02	.04	.03	-.02	.11	.00	.09	.16	.01	.19	1.00																			
S3	.15	.04	.19	.09	.07	.16	.17	.08	-.07	.05	.03	.11	.07	.12	.48	.16	1.00																		
S4	.06	.02	.12	.08	.08	.09	.09	.05	.04	.05	.16	.17	.17	.16	.28	.26	.34	1.00																	
S5	.25	.15	.20	.18	.20	.20	.25	.09	.09	.02	.14	.19	.17	.16	.34	.15	.43	.37	1.00																
S6	.20	.11	.20	.15	.16	.19	.22	.11	.06	.06	.10	.15	.14	.16	.47	.24	.70	.43	.58	1.00															
S7	.17	.06	.19	.11	.12	.17	.12	.15	.05	.12	.13	.17	.24	.07	.30	.46	.36	.37	.28	.40	1.00														
Ind1	.12	.06	.11	.17	.12	.18	.21	.07	.02	-.01	.11	.11	.02	.14	.11	-.15	.10	.09	.23	.06	-.04	1.00													
Ind2	.16	.16	.15	.14	.13	.15	.19	.07	.13	.03	.07	.08	.04	.08	.05	-.16	.09	.05	.16	.10	-.08	.35	1.00												
Ind3	.16	.21	.18	.19	.20	.24	.24	.10	.12	-.04	.13	.12	.08	.19	.08	-.15	.12	.10	.23	.19	-.02	.31	.46	1.00											
Ind4	.11	.08	.16	.13	.14	.13	.19	.05	.02	.02	.08	.11	.05	.24	.17	-.02	.15	.24	.22	.20	.01	.29	.16	.26	1.00										
Ind5	.09	.10	.13	.13	.05	.14	.16	.08	.04	.06	.06	.15	.00	.18	.05	-.17	.08	.10	.12	.05	-.08	.29	.21	.32	.29	1.00									
Ind6	.04	.19	.10	.10	.02	.13	.17	-.01	-.00	-.09	.02	.01	-.04	.09	.08	-.14	.11	-.02	-.01	.09	-.07	.29	.31	.29	.24	.17	1.00								
Ind7	-.02	.13	.02	.09	.06	.08	.10	.07	.06	.03	.07	.08	.21	.11	.01	.03	-.00	.06	.06	.09	-.03	.24	.22	.21	.15	.10	.44	1.00							
Inv1	.26	.23	.23	.30	.23	.31	.35	.21	.25	.17	.20	.25	.22	.33	.08	-.05	.14	.12	.20	.18	.07	.22	.16	.14	.11	.09	.15	.11	1.00						
Inv2	.45	.32	.40	.41	.38	.43	.39	.33	.34	.21	.36	.39	.25	.37	.11	.02	.21	.18	.21	.25	.13	.16	.19	.28	.12	.09	.05	-.03	.34	1.00					
Inv3	.23	.15	.18	.14	.21	.16	.20	.16	.11	.06	.12	.21	.19	.20	.15	.02	.23	.07	.25	.25	.13	.25	.22	.22	.23	.12	.14	.08	.23	.28	1.00				
Inv4	.19	.06	.08	.19	.21	.12	.15	.11	.14	.19	.16	.16	.17	.14	.02	.17	.05	.09	.05	.07	.09	-.01	-.09	.02	.00	-.06	-.20	-.04	.07	.24	.14	1.00			
Inv5	.26	.16	.23	.29	.28	.34	.37	.20	.20	.18	.29	.29	.26	.31	.15	.04	.21	.15	.31	.26	.23	.15	.12	.18	.09	.11	-.02	-.05	.39	.48	.28	.26	1.00		
Inv6	.06	.03	.11	.12	.01	.13	.13	.08	.08	.04	.11	.06	-.03	.07	.00	-.03	.03	-.05	-.01	.01	-.04	.23	.19	.15	.11	.15	.22	.03	.32	.21	.17	.14	.16	1.00	
Inv7	.29	.24	.33	.29	.28	.36	.34	.18	.21	.06	.17	.20	.27	.27	.12	.06	.19	.14	.32	.31	.18	.15	.10	.15	.07	.02	.07	.17	.31	.33	.19	.09	.34	.16	1.00

Table 6.4. Correlations of Items with Each Scale for Refined Instrument.

	Affect	Novelty	Involvement	Independent Interpretation	Social Interaction
A1	.85	.41	.41	.14	.22
A2	.80	.33	.28	.22	.08
A3	.78	.32	.36	.19	.20
A4	.89	.47	.41	.22	.14
A5[a]	.83	.41	.38	.16	.17
A6	.86	.39	.43	.24	.18
A7	.84	.37	.46	.29	.21
N1	.34	.75	.30	.10	.12
N2	.42	.76	.31	.08	.03
N3[a]	.13	.67	.22	.00	.08
N4	.35	.64	.34	.12	.13
N5	.42	.78	.37	.15	.21
N6[a]	.25	.72	.31	.09	.22
N7	.41	.66	.40	.24	.16
Inv1	.33	.33	.64	.23	.15
Inv2	.47	.45	.69	.18	.23
Inv3	.22	.21	.54	.29	.23
Inv4[a]	.17	.22	.49	-.09	.12
Inv5	.33	.35	.68	.12	.28
Inv6	.10	.08	.55	.25	-.02
Inv7	.36	.27	.56	.17	.27
Ind1	.17	.09	.27	.65	.07
Ind2	.18	.10	.21	.61	.03
Ind3	.24	.14	.26	.64	.10
Ind4	.16	.12	.18	.56	.19
Ind5	.14	.11	.13	.54	.02
Ind6	.13	-.01	.10	.67	-.00
Ind7[a]	.08	.13	.06	.59	.04
S1	.11	.05	.14	.13	.63
S2[a]	.03	.08	.06	-.17	.57
S3	.15	.08	.25	.15	.72
S4	.09	.16	.16	.14	.64
S5	.24	.17	.31	.23	.64
S6	.21	.16	.31	.18	.80
S7	.16	.19	.18	-.07	.70

[a] indicates negatively worded items which were reverse scored.

Table 6.5. Correlations Between Scales for Refined Instrument.

	A	N	Inv	Ind	S
Affect (A)	1.00				
Novelty (N)	.46	1.00			
Involvement (Inv)	.47	.45	1.00		
Independent Interpretation (Ind)	.25	.16	.27	1.00	
Social Interaction (S)	.20	.19	.29	.10	1.00

The correlations of Independent Interpretation items with the Independent Interpretation scale range from .67 for Ind6 (I can do the activities myself without adult help) to .54 for Ind5 (You can make up your own mind what each activity means) (see Table 6.4). The highest correlation of any Independent Interpretation item with another scale is for item Ind1 with the Involvement scale (.27) (see Table 6.4).

Correlations of the Independent Interpretation scale with other scales are low, varying between .27 (Involvement) and .10 (Social Interaction) (see Table 6.5). The correlations of the Independent Interpretation scale with other scales for the Refined Instrument have been reduced when compared to the Redrafted Instrument (compare Table 5.7 and Table 6.5).

Social Interaction

The correlation of Social Interaction items with the Social Interaction Scale vary from .80 for S6 to .57 for the negatively worded S2 (see Table 6.4), and this is similar to the range for the Redrafted Instrument. The highest correlation of any Social Interaction item with another scale is shared by S5 and S6 at .31 (see Table 6.4), but these are lower than the correlations for the Redrafted Instrument.

Correlations of the Social Interaction scale with other scales vary between .29 (Involvement) and .10 (Independent Interpretation) (see Table 6.5), and, as with the other scales, the correlations between the Social Interaction Scale and other scales have been reduced from the Redrafted Instrument to the Refined Instrument.

Summary

Items with the lowest correlation with their assigned scales are A3, N4, Inv4, Ind5 and S2. A comparison of Tables 5.7 and 6.4 show that there are fewer moderate correlations between Items and scales other than their assigned scale for the Refined Instrument as compared to the Redrafted Instrument. This is also reflected in the lower correlations between scales for the Refined Instrument as compared to the Redrafted Instrument (Tables 5.7 and Table 6.5). The rewriting of items has resulted in correlations among items of the same scale that show great potential for an instrument with improved discriminant validity. This was tested by subjecting the data to a principal components analysis.

Principal Components Analysis

The data were subjected to a principal components analysis with varimax rotation and Kaiser normalisation. Variance accounted for and the eigenvalues of the first seven components are shown in Table 6.6. The extraction of five components with loadings greater than .3 is shown in Table 6.7. The full rotated principal components matrix is shown in Appendix 6B.

Table 6.6. Eigenvalues and Variance Explained for Refined Instrument with Five Components Extracted.

Component	Eigenvalues	% of Variance	Cumulative % of Variance
1	8.21	23.46	23.46
2	3.07	8.78	32.25
3	2.83	8.10	40.34
4	2.23	6.37	46.71
5	1.50	4.28	50.99
6	1.24	3.54	54.53
7	1.10	3.13	57.66

Eigenvalues greater than one extend to seven components, but the lowest two are only 1.24 and 1.10. The extraction of five components accounts for 50.99 percent of the total variance.

Table 6.7. Varimax Rotated Component Loadings for the Refined Instrument.

	Component				
Item	1	2	3	4	5
A1	.83				
A2	.79				
A3	.76				
A4	.84				
A5[a]	.79				
A6	.82				
A7	.78				
N1		.72			
N2	.31	.71			
N3[a]		.72			
N4		.53			
N5		.71			
N6[a]		.75			
N7		.53			
S1			.64		
S2[a]			.49	-.33	
S3			.74		
S4			.63		
S5			.64		
S6			.81		
S7			.65		
Ind1				.61	
Ind2				.61	
Ind3				.61	
Ind4				.49	
Ind5				.51	
Ind6				.69	
Ind7[a]				.55	-.30
Inv1					.51
Inv2	.37				.55
Inv3					.40
Inv4[a]					.43
Inv5					.65
Inv6					.57
Inv7	.30				.32

[a] indicates negatively worded items which were reverse scored
Note. Loadings > .3 are shown.

Discussion of Components

Items in the Refined Instrument are loaded most strongly onto components according to their designated scale. Some of the items are loading weakly and there are five items with loadings greater than or equal to.3 on more than one component.

Component 1. All of the Affect items are loaded onto component 1 with values between .76 and .84. All of the loadings are higher than for the Redrafted Instrument, with the exception of the negatively worded A5, whose loading has decreased from .79 to .70. Three other items have loadings greater than .3 on component 1, N2 (.31), Inv2 (.37) and Inv7 (.30). Once again this is an improvement from the Redrafted Instrument that had eight items with loadings greater than .3 on component 1 in addition to the Affect items. These included Inv2 and Inv7.

Component 2. The only items with values greater than .3 on component 2 are the Novelty items with loadings between .53 and .75. This is an improvement from the Redrafted Instrument where items Inv1, Inv2 and the negatively worded Inv4 were also loaded onto the same component as the Novelty items. Item N2 also has a loading of .31 on component 1.

Component 3. The only items loaded on component 3 are items from the Social Interaction scale with loadings between .49 and .81. Item S2 also has a loading on component 4 of -.33. This shows some improvement from the Redrafted Instrument where there were three Social Interaction items loaded on components other than component 4, which contained the Social Interaction items.

Component 4. All of the items from the proposed Independent interpretation scale are loaded on component 4 with loadings between .49 and .69. With the rewriting of items Ind6 and Ind7, they are now loading on the same component as the other Independent Interpretation items. The only other loading on component 4 is the negatively worded S2 (-.33), but this item is loaded more strongly (.49) on component 3 with the other Social Interaction items.

Component 5. All of the Involvement items are loaded on component 5, but some of the loadings are rather low, Inv3 (.40), Inv4 (.43) and Inv7 (.32). All of the

Involvement items have their strongest loadings on component 5, but two items have loadings greater than .3 on component 1 with the Affect items, Inv2 (.37) and Inv7 (.30). One other item, Ind7 (-.30), has a low loading on component 5.

Discussion of Scales

Affect. Items on the Affect scale are loaded quite strongly on component 1 with values greater than .76. This reflects the high correlations among Affect items (see Table 6.3) and between Affect items and the Affect scale (see Table 6.4). The item with the lowest loading (.76) is A3 (Science is more fun than I thought) and this item has the lowest correlation (.78) with the Affect scale (Table 6.4). Item A7 (I was really keen to do the activities) is the next weakest loading item (.78) and also has a moderate correlation (.46) with the Involvement scale. One of the items A3 or A7 should be considered for removal from the Affect scale.

Novelty. Item N2 (I use different equipment at CSIROSEC than in class) is loaded at .71 on component 2 with the Novelty items and at .31 on component 1 with the Affect scale. Reference to the full set of varimax rotated component loadings for the Redrafted Instrument shown in Appendix 6B reveals that N5 (Science at CSIROSEC is different to the science we do in class) is not much different from N2 (see Table 6B.1). Item N4 (I have tried different activities at CSIROSEC than I have done in class) which is loaded at .53 was rewritten from the Redrafted Instrument, where it was loading at .52 on the component with the Novelty items, but in the Redrafted Instrument it was also loaded at .35 on the same component as the Affect items. The rewriting of item N4 has improved its coherence to its designated scale. Item N7 (We do science in a different way at CSIROSEC) is loading at .53 on component 2 with the remainder of the Novelty items. In the Redrafted Instrument it was loaded marginally more strongly on the component with the Novelty items (.58), but was also loading at .35 onto the component with the Affect items. This reflects the correlation results which show that item N4 has the lowest correlation of .64 with the Novelty scale and item N7 has a correlation of .66 with the Novelty scale (see Table 6.4). The Novelty scale may be improved by the deletion of either item N2, N4 or N7.

Social Interaction. By comparing Table 5.9 and Table 6.7 it can be seen that items for the Social Interaction scale are loaded more strongly on one component in the Refined Instrument than in the Redrafted Instrument. Social Interaction items for the Refined Instrument are loaded at .63 or better, with the exception of the negatively worded item S2 (I could get more work done by myself than in my group). S2 is loaded at .49 on component 3 with the Social Interaction items and with a loading of -.33 on component 4 with the Independent Interpretation items. This reflects the correlation results which show that S2 has the lowest correlation (.57) of any Social Interaction item with the Social Interaction scale (Table 6.4). The Social Interaction scale may be improved by the deletion of item S2.

Independent Interpretation. The Independent Interpretation scale is loaded more strongly onto a single component in the Refined Instrument than in the Redrafted Instrument. The rewriting of items Ind6 (I can do the activities myself without adult help) and the reverse scored Ind7 (I need help from an adult with most of the activities) has resulted in these being loaded onto the same component as the remaining Independent Interpretation items. Ind6 is loading at .69 and Ind7 at .55 with a loading (-.30) onto component 5 with the Involvement items. Item Ind1 (I can handle the equipment myself to perform an activity), which was moved from the Involvement scale and rewritten, is loading satisfactorily (.61). The items which are loaded more weakly are item Ind4 (We can decide what we need to do in each activity), .49 and item Ind5 (You can make up your own mind what each activity means), .51. The Independent Interpretation scale may best be improved by the removal of item Ind7, which has a loading of .55, but has a loading on another component of -.30.

Involvement. The coherence of items to the Involvement scale has been improved considerably from the Redrafted Instrument. Generally, the rewriting of items has resulted in all items from the Involvement scale being loaded onto component 5. The items are, however, still loaded onto component 5 much less strongly than the other scales are loaded onto their respective components. Inv2 (I have to think about the activities I am doing at CSIROSEC) and Inv7 (I participate in each of the activities) are also loaded at greater than .30 onto component 1 with the Affect items.

The rewrite of item Ind1 (We collect our own data in each activity) from the Redrafted Instrument to include it as item Inv3 (We collect the data in each activity) has not proven to be successful to any large extent. It is loaded onto component 4 with the other Involvement items, but only at .40, however it does not have any loadings greater than .30 on any other component. The correlation between Inv3 and the Involvement scale is .54.

Item Inv7 (I participate in each of the activities) is loaded quite weakly at .32 with a loading of .30 on component 1 with the Affect items. Item Inv2 (I have to think about the activities I am doing at CSIROSEC) is loaded at .55 on component 5 with the Involvement items and .37 on component 1 with the Affect items. This reflects the correlation of the items with the Involvement scale. Inv2 has a correlation of .69 with the Involvement scale, but also has correlations of .47 with the Affect scale and .45 with the Novelty scale. Item Inv7 has a lower correlation of .56 with the Involvement scale and a correlation of .36 with the Affect scale. The reverse scored item Inv4 (I don't have to do much to complete each activity) is loaded at only .43 on component 5, but has no loadings greater than .30 on other components. Item Inv4 has the lowest correlation of any Involvement item with the Involvement scale (.49), but the highest correlation with any other scale, being .22 with the Novelty scale.

The involvement scale may be improved by the removal of either items Inv2, Inv3, Inv4 or Inv7.

Summary

The rewrite of items from the Redrafted Instrument to form the Refined Instrument has resulted in all items being loaded onto components in the rotated component analysis in accordance with their defined scale. Some items, namely N2, S2, Ind7, Inv2 and Inv7 still have loadings at greater than .30 onto other components.

The aim was to produce an instrument with six items per scale. A number of items have been identified for possible exclusion. These include A3, A7, N2, N4, N7, S2, Ind7, Ind2, Inv3, Inv4 and Inv7. The next section looks at the removal of items to produce the final version of the instrument, named the Learning Environment

Instrument for CSIRO Science Education Centres or LEI for CSIROSECs in acronym.

The LEI for CSIROSECs

This section reports how items were identified for removal from the Refined Instrument to develop the Learning Environment Instrument for CSIRO Science Education Centres (LEI for CSIROSECs). The resultant instrument with six items per scale was re-analysed to examine correlations, principal components analysis and internal consistency reliability. The results from the LEI for CSIROSECs are compared with various statistical parameters from other learning environment instruments.

The selection of items for removal was more obvious for some items than for others. The negatively worded item S2 (I could get more work done by myself than in my group) was removed because it had the lowest correlation with the Social Interaction scale (see Table 6.4), the lowest loading on the rotated component analysis and a loading (-.33) onto the same component as the Independent Interpretation items (see Table 6.7). The removal of item S2 will lead to a small increase in the Cronbach alpha measure of internal consistency, whereas the removal of any other Social Interaction item would lead to a small decrease (see Table 6C.3 in Appendix 6C). The removal of item S2 does not alter the meaning of the scale definition for Social Interaction and is consistent with the theoretical framework.

The negatively worded item Ind7 (I need help from an adult with most of the activities) was removed because it had a loading (-.30) onto the same component as the Involvement items (see Table 6.7), whilst its correlation with the Independent Interpretation scale (see Table 6.4) and its loading on the rotated component analysis see Table 6.7) were towards the lower end of the range for Independent Interpretation items. The Cronbach alpha measure of internal consistency for the Independent Interpretation scale is least affected by the removal of Ind7 (see Table 6C.4 in Appendix 6C). Item Ind7 is a negative worded version of item Ind6 so its removal does not change the scale definition.

Item A3 (Science is more fun than I thought) was removed because it had the lowest correlation with the Affect scale (see Table 6.4), the lowest corrected item total correlation (see Table 6C.1 in Appendix 6C), the lowest component loading on the same component as the other Affect items (see Table 6.7), and its removal will result in the best Cronbach alpha measure of internal consistency for the Affect scale in this data set. The removal of item A3 may make the achievement of the fifth operational definition for the Affect scale (A student who has a positive attitude to science at CSIROSEC will have an enhanced attitude to science following a visit to CSIROSEC) less directly measurable. This can, however, be inferred from responses to the remaining items.

Item N7 (We do science in a different way at CSIROSEC) was removed because of its relatively low correlation with the Novelty scale whilst having moderate correlations with the Affect scale (.41) and the Involvement scale (.40) (see Table 6.4). N7 had the equal lowest loading onto the component with the other Novelty items (see Table 6.7) and its removal will have little effect on the Cronbach alpha measure of internal consistency for the Novelty scale (see Table 6C.2 in Appendix 6C). The removal of item N7 does not affect the operational definition of the Novelty scale, since the meaning of this item is repeated in other items.

The negative worded item Inv4 (I don't have to do much to complete each activity) was removed because of its low loading (.43) onto the component with the Involvement items (see Table 6.7), whilst at the same time having the lowest correlation (.49) with the Involvement scale (see Table 6.4). The removal of item Inv4 will lead to a small increase in the Cronbach alpha measure of internal consistency for the Involvement scale, whilst the removal of any other item would lead to a decrease (see Table 6C.5 in Appendix 6C). The removal of item Inv4 does not alter the operational definition for the Involvement scale, since Inv4 is a negative worded item whose meaning is covered in other items.

Summary

The items which were removed from the Refined Instrument to form the LEI for CSIROSECs with six items per scale are:

A3 Science is more fun than I thought

N7 We do science in a different way at CSIROSEC

Ind7 I need help from an adult with most of the activities (-ve)

Inv4 I don't have to do much to complete each activity (-ve)

S2 I could get more work done by myself than in my group (-ve).

Analysis of Scales for the LEI for CSIROSECs

The data were reanalysed after deleting the five items to explore the properties of the new scales. The results are reported in Table 6.8. The mean item scores for each scale are biased towards the agree/strongly agree end of the scale, which reflects the results for the individual items. This can be seen directly from the mean item scores for the scales, which vary between 3.49 and 4.00, remembering that 5 is the highest score possible on each item. The bias of scores is also reflected in the values for skewness, which vary from –0.32 to –1.29.

Table 6.8. Statistics for Scales for the LEI for CSIROSECs.

	Affect	Novelty	Involvement	Independent Interpretation	Social Involvement
N	374	374	374	374	374
Mean	3.49	4.00	3.58	3.68	3.91
Std. Deviation	0.97	0.71	0.59	0.58	0.71
Skewness	-0.56	-1.29	-0.64	-0.32	-1.14
S.E. of Skewness	0.13	0.13	0.13	0.13	0.13

Correlations for the LEI for CSIROSECs

Correlations between items and scales (Table 6.9) and correlations between scales (Table 6.10) have been calculated for the LEI for CSIROSECs. A comparison of Tables 6.4 and 6.9 shows that, generally, the correlations between items and their assigned scale have increased, whilst correlations between items and other scales have decreased. In other words, the internal consistency and the discriminant validity have improved. The notable exception is that correlations between some items and the Social Interaction scale have increased slightly. Comparing Table 6.5 with Table 6.10 shows a trivial increase in the correlation between the Social Interaction scale and the Affect scale from .20 to .21. The correlation between the Independent Interpretation scale and the Social Interaction scale has increased from .10 to .18. All correlations between other scales have decreased. There are moderate correlations between a number of scales. Correlations exceeding .40 exist for Affect-Novelty (.43), Affect-Involvement (.45) and Novelty-Involvement (.42).

Table 6.9. Correlations of Items with Scales for the LEI for CSIROSECs.

	Affect	Novelty	Involvement	Independent Interpretation	Social Interaction
A1	.85	.39	.40	.17	.22
A2	.81	.30	.27	.21	.10
A4	.89	.45	.42	.23	.15
A5[a]	.83	.39	.36	.16	.17
A6	.85	.35	.44	.25	.21
A7	.78	.34	.46	.31	.23
N1	.35	.77	.29	.09	.12
N2	.43	.77	.32	.08	.03
N3[a]	.12	.69	.23	-.01	.06
N4	.34	.66	.35	.12	.14
N5	.42	.77	.35	.15	.21
N6[a]	.25	.73	.30	.03	.20
Inv1	.31	.29	.66	.23	.18
Inv2	.47	.42	.69	.21	.26
Inv3	.21	.19	.35	.31	.25
Inv5	.31	.33	.69	.16	.31
Inv6	.09	.07	.57	.28	-.01
Inv7	.35	.25	.57	.15	.29
Ind1	.15	.07	.24	.67	.12
Ind2	.17	.09	.18	.63	.08
Ind3	.23	.11	.23	.67	.16
Ind4	.15	.08	.14	.60	.22
Ind5	.12	.09	.11	.59	.07
Ind6	.12	-.03	.07	.63	.04
S1	.10	.03	.12	.14	.66
S3	.13	.06	.21	.17	.77
S4	.09	.15	.16	.14	.65
S5	.23	.16	.28	.24	.69
S6	.20	.14	.28	.18	.84
S7	.16	.20	.17	-.07	.66

[a] indicates negatively worded items which were reverse scored.

Table 6.10. Correlations Between Scales for the LEI for CSIROSECs.

	A	N	Inv	Ind	S
Affect (A)	1.00				
Novelty (N)	.43	1.00			
Involvement (Inv)	.45	.42	1.00		
Independent Interpretation (Ind)	.25	.10	.25	1.00	
Social Interaction (S)	.21	.18	.28	.18	1.00

Principal Components Analysis

A principal components analysis was conducted with varimax rotation and Kaiser normalisation. For convenience of interpretation, only items with a loading equal to or greater than .3 are shown in Table 6.12. The full matrix of rotated loadings is included in Appendix 6D.

Table 6.11. Eigenvalues and Variance Explained for LEI for CSIROSECs with Five Components Extracted.

Component	Eigenvalues	% of Variance	Cumulative % of Variance
1	7.36	24.55	24.55
2	3.00	10.00	34.54
3	2.49	8.31	42.85
4	2.00	6.66	49.51
5	1.34	4.47	54.00
6	1.00	3.33	57.31

The variance accounted for and the eigenvalues for the first six component are shown in Table 6.11. Five components have eigenvalues greater than 1.0, component 6 has been rounded up to 1.00.

Table 6.12 shows the rotated loadings after the extraction of five components and the separation of all items onto separate components according to their assigned scales.

Component 1. All of the Affect items are loaded onto component 1 with values between .85 and .78, indicating that Affect is forming a strong scale. Two other items, N2 (.30) and Inv2 (.35) also have small loadings on component 1.

Table 6.12. Varimax Rotated Component Loadings for the LEI for CSIROSECs.

	Component				
Item	1	2	3	4	5
A1	.82				
A2	.79				
A4	.85				
A5[a]	.80				
A6	.81				
A7	.78				
N1		.74			
N2	.30	.71			
N3[a]		.73			
N4		.55			
N5		.71			
N6[a]		.72			
S1			.66		
S3			.77		
S4			.63		
S5			.67		
S6			.83		
S7			.61		
Ind1				.63	
Ind2				.63	
Ind3				.66	
Ind4				.57	
Ind5				.61	
Ind6				.57	
Inv1					.66
Inv2	.35	.31			.50
Inv3					.36
Inv5					.61
Inv6					.62
Inv7					.52

[a] indicates negatively worded items which were reverse scored.
Note. Loadings > .3 are shown.

Component 2. The Novelty items are loaded onto component 2 with values between .74 and .71, with the exception of item N4 (I have tried different things at

CSIROSEC than I have done in class), which has a loading of .55. Item N2 has a loading of .71 on component 2 with the remainder of the Novelty items, but also has a loading of .30 on component 1 with the Affect items.

Component 3. The Social Interaction items are loaded on component 3 at between .83 and .61.

Component 4. Independent Interpretation items are loaded onto component 4 with values between .66 and .57.

Component 5. Involvement items are loaded onto component 5 with values between .66 and .50, except for Inv3 (We collect the data in each activity) which has a loading of .36. Inv2 has a loading of .50 on component 5, but also has a loading of .35 on component 1 with the Affect items and a loading of .31 on component 2 with the Novelty items. Involvement items remain the weakest scale overall and this reflects the correlation values shown in Table 6.9 and Table 6.10.

Internal Consistency

Alpha reliabilities have been calculated as a means of determining internal consistency of the scales. The Cronbach alpha reliability for each scale of the LEI for CSIROSECs is shown in Table 6.13. The alpha reliability analysis of the six item scales for the LEI for CSIROSECs is shown in the tables in Appendix 6E. This will give one basis for comparing statistics for the LEI for CSIROSECs with those of existing learning environment instruments.

Table 6.13. Cronbach Alpha Reliability Analysis for Scales of the LEI for CSIROSECs.

Affect	Novelty	Social Interaction	Independent Interpretation	Involvement
.92	.82	.80	.70	.69

Comparison of Statistics with Other LEIs

The statistics for the LEI for CSIROSECs are compared with those from the CES, CUCEI and SLEI. These three instruments have been chosen because each contains some of the scales used for the LEI for CSIROSECs. The parameters that are compared are internal consistency reliability (alpha coefficient), discriminant validity (using the mean correlation of a scale with the other scales in the same instrument as a convenient index), and the ability to differentiate between the perceptions of students from different classes (significance levels and Eta^2 statistic from ANOVAs) for the student actual form of instruments using the individual as the unit of analysis. All of the scales are shown for each of the instruments, rather than selected scales, because this gives a more accurate idea of the range of values for each parameter in each instrument. This enables the properties of the LEI for CSIROSECs to be compared more effectively with those of existing instruments. The data are shown in Table 6.14.

Highs and lows for each parameter have been summarised in Table 6.15. This shows that the data for the LEI for CSIROSECs fall within the range of data from the other existing instruments with which it is compared. From the statistics reported it can be seen that the LEI for CSIROSECs has values similar to those of existing instruments. The new instrument displays adequate internal consistency and discriminant validity (although, as with other instruments, the LEI for CSIROSECs appears to assess overlapping aspects) and has the ability to differentiate between classes. The LEI for CSIROSECs compares favourably with these existing instruments on these parameters.

The weakness of the discriminant validity of the Involvement scale is of some concern, but other researchers have encountered similar problems. Aldridge, Fraser and Huang (1999) had comparable factor loadings when testing the What Is Happening In This Class? Questionnaire (WIHIC) with classes in both Australia and Taiwan. Component loadings for the LEI for CSIROSECs on the rotated component matrix are also as good, if not better, than those obtained by Taylor, Fraser and Fisher (1997) for their study with the new version of the Constructivist Learning Environment Survey (CLES) with approximately 1,600 students in Dallas Public

Schools. Further refinement and testing may lead to improvements in the discriminant validity and internal consistency of the Involvement scale.

Table 6.14. Comparison of Internal Consistency (Alpha Reliability), Discriminant Validity (Mean Correlation of a Scale with Other Scales), and ANOVA Results for Class Membership Differences (Eta^2 Statistic and Significance Level) of LEI for CSIROSECs with CES, CUCEI and SLEI.

Scale	Alpha Reliability	Mean Correlation with Other Scales	ANOVA Results Eta^2
Classroom Environment Scale (CES)			
N=1083 students. Items per scale=10.			
Involvement	.70	.40	.29*
Affiliation	.60	.24	.21*
Teacher support	.72	.29	.21*
Task orientation	.58	.23	.25*
Competition	.51	.09	.18*
Order & organization	.75	.29	.43*
Rule clarity	.63	.29	.21*
Teacher control	.60	.16	.27*
Innovation	.52	.19	.26*
Personalization	.79	.28	.31*
Participation	.70	.27	.21*
Independence	.68	.07	.30*
Investigation	.71	.21	.20*
Differentiation	.76	.10	.43*
College & University Classroom Environment Inventory (CUCEI)			
N=372 students. Items per scale=7.			
Personalization	.75	.46	.35*
Involvement	.70	.47	.40*
Student cohesiveness	.90	.45	.47*
Satisfaction	.88	.45	.32*
Task orientation	.75	.38	.43*
Innovation	.81	.46	41*
Individualization	.78	.34	.46*
Science Laboratory Environment Inventory (SLEI)			
N=3727 students. Items per scale=6 or 7.			
Student cohesiveness	.77	.34	.21*
Open-endedness	.70	.07	.19*
Integration	.83	.37	.23*
Rule clarity	.75	.33	.21*
Material environment	.75	.37	.21*
Learning Environment Instrument for CSIROSECs			
N=374 students. Items per scale=6.			
Affect	.92	.34	.26*
Novelty	.82	.28	.38*
Social Interaction	.80	.21	.13*
Independent Interpretation	.70	.20	.17*
Involvement	.69	.35	.20*

* $p < 0.01$.

Note. Results for CES, CUCEI and SLEI taken from Fraser (1994, Table 17.2, p. 500).

Table 6.15. High and Low Values Alpha Coefficients, Mean Correlation with Other Scales and ANOVA Results for Class Membership Differences for Learning Environment Instruments.

Instrument	Alpha Coefficient		Mean Correlation with Other Scales		ANOVA Results Eta^2	
	High	Low	High	Low	High	Low
CES	.79	.51	.40	.07	.43*	.18*
CUCEI	.90	.70	.47	.34	.47*	.32*
SLEI	.83	.70	.37	.07	.23*	.19*
LEI for CSIROSECs	.92	.69	.35	.20	.38*	.13*

*p<.01.

Sensitivity of the LEI for CSIROSECs

One of the important potential uses of the LEI for CSIROSECs depends on its ability to collect data to compare the perceptions of the learning environment in CSIROSECs for different groups or for different programs. Such use might include comparisons between the perceptions of students in different classes, perceptions of teachers and students, perceptions of the learning environment for different programs, perceptions of urban and rural students, perceptions of primary and secondary students (or even students in different grades), perceptions of students of different socioeconomic status, perceptions of students visiting different CSIROSECs and so on. Achieving a greater understanding of students' perceptions of the learning environment under different circumstances may enable managers of CSIROSECs to modify programs and the way they are offered to better meet the needs of individual groups.

Comparison of Classes

It might be reasonable to assume that different classes will perceive similar situations in different ways. A better understanding of the perceptions of students from different classes may enable the learning environment to be customised in order to achieve a better match between students and the environment. It is necessary, however, to undertake sufficient research in order to enable generalisations to emerge.

Data from the present study include one group of four classes from the same grade and school who studied the Forensic Frenzy program and another group of three classes from the same grade and school who studied the Science and Technology program. The two groups were from different CSIROSECs. The mean scores for each scale for each class are plotted in Figures 6.2 and 6.3.

School, grade, CSIROSEC and program studied have been kept constant for each of the examples shown. There are other variables such as the teacher, possible streaming of classes and so forth which have not been controlled. Nevertheless, it is clear from the graph that there are discernible differences between the perceptions of the learning environment by different classes.

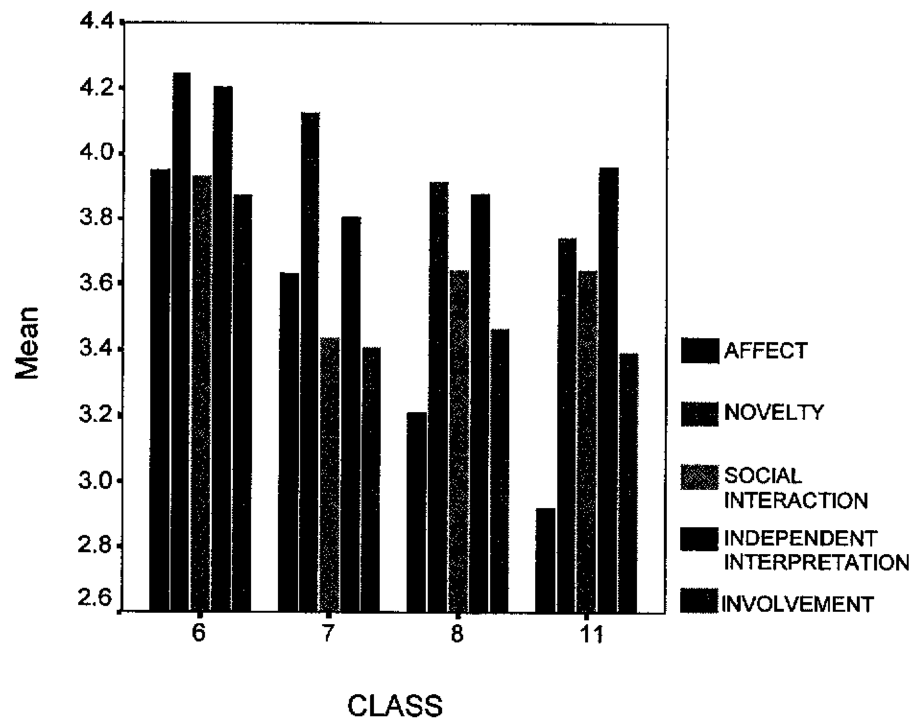

Figure 6.2. Class Mean for Scales for Classes 6, 7, 8 & 11 from CSIROSEC B, from the Same School, Same Grade and Studying the Forensic Frenzy Program.

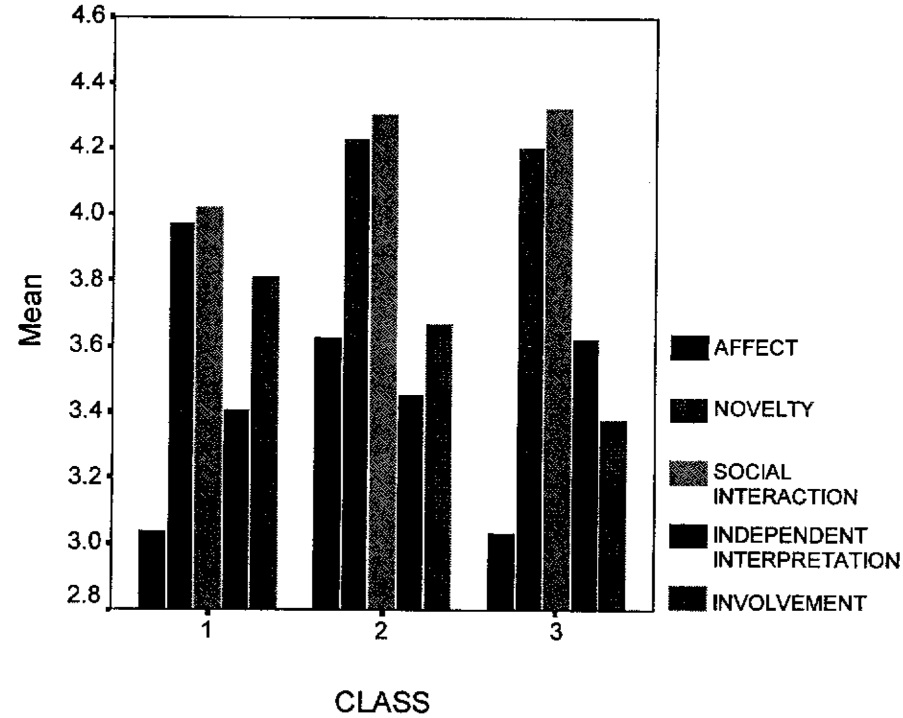

Figure 6.3. Class Mean for Scales for Classes 1, 2 & 3 from CSIROSEC A, from the Same School, Same Grade and Studying the Science & Technology Program.

Comparison of Teacher-Student Perceptions

Five teachers in a number of classes at CSIROSEC Tasmania were asked to complete the student version of the LEI for CSIROSECs. They were asked to do this based on their opinion of how their students may have perceived the visit. As can be seen from Figure 6.4, the teachers' perceptions of how their students may have perceived the learning environment were considerably more positive than the students' actual perceptions of the environment. However, teacher's more positive perceptions of the learning environment have been observed on a number of occasions and using a variety of learning environment instruments (Fraser, 1998b; Hofstein & Lazarowitz, 1986; Moos, 1979; Wubbles, Brekelmans, & Hooymayers, 1991).

Great care needs to be taken in assigning any great significance to this difference as only limited teacher data from one CSIROSEC were used (N=5). Nevertheless, the results indicate that further research is needed to investigate this phenomenon. This would require the development of a teacher version of the LEI for CSIROSECs as a research tool. Teachers decide if their class will visit CSIROSEC, it is rarely the students who are given the choice of venue for an excursion. It is important that data are collected from teachers concerning their perceptions of the learning environment at CSIROSECs. After all, one might hope that teachers would give a high priority to the nature of the learning environment when planning an excursion.

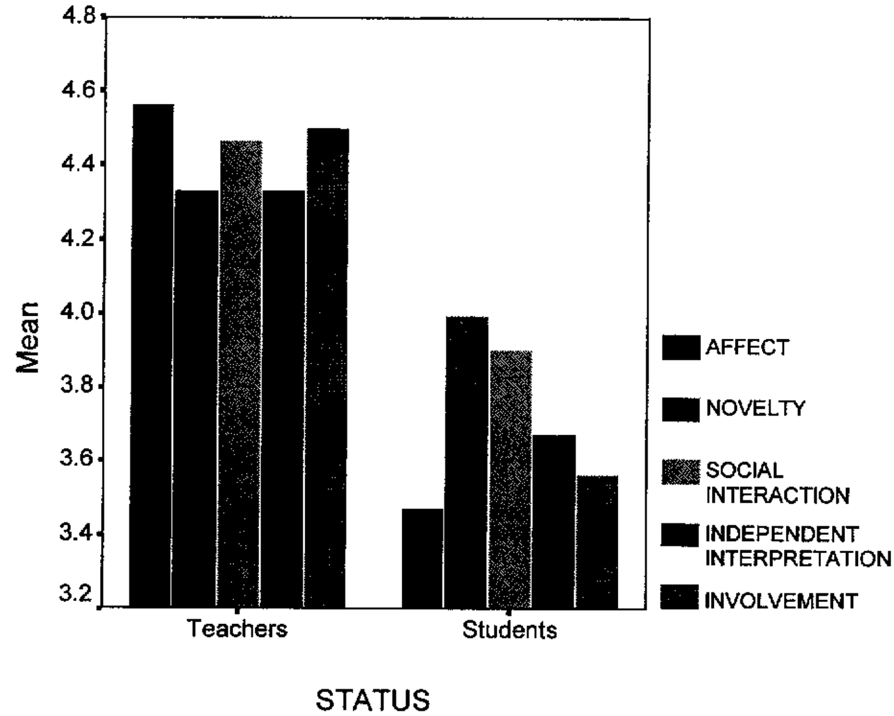

Figure 6.4. Mean Score for Scales for Teachers and Students at CSIROSEC Tasmania.

Comparison of Primary and Secondary Students

It was not the original intention of this research to use this version of the LEI for CSIROSECs with primary school students. However, the opportunity arose to do so with four classes of grade 6 students (N=81) towards the end of the school year; this is the final year of primary school in Tasmania. The data were collected at CSIROSEC in Tasmania and are compared here against secondary students (N=110) from CSIROSEC in Tasmania (Figure 6.5).

The two major differences, which are immediately apparent from Figure 6.6, are that primary students have a higher mean score for the Affect scale and secondary students have a higher mean score for the Social Interaction scale. A less obvious difference is that primary students scored higher on the Novelty scale. Students from both sectors scored similarly on the Independent Interpretation and Involvement scales. Overall, the patterns in the graph suggest different levels of perceptions by primary and secondary students on the scales of the LEI.

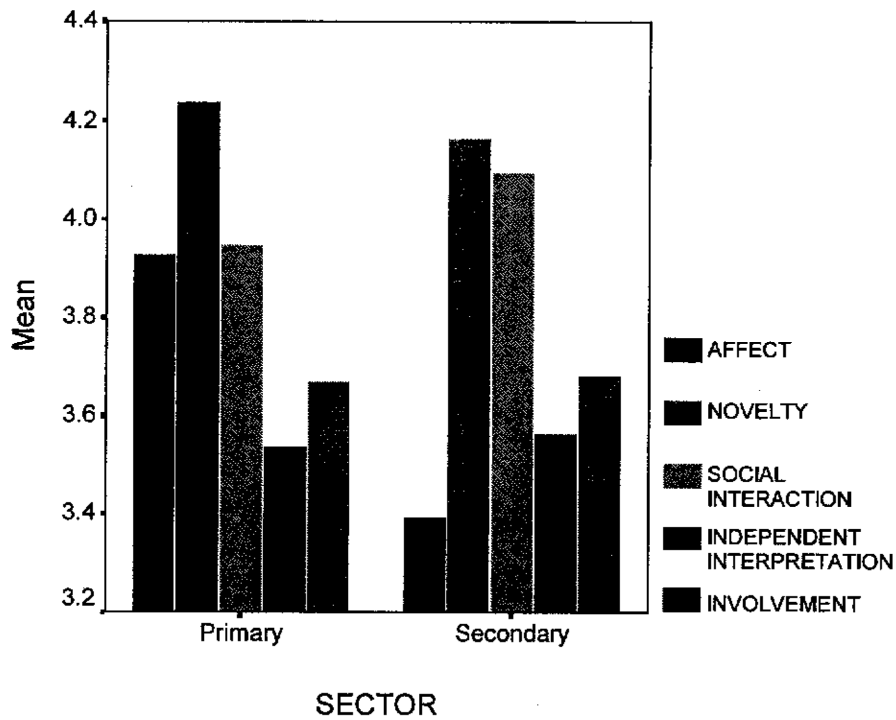

Figure 6.5. Mean Score for Scales for Primary and Secondary Students at CSIROSEC Tasmania.

Comparison of Programs

The ability of the LEI for CSIROSECs to differentiate between the students' perceptions of the learning environment in different programs would enable managers of CSIROSECs to compare and better understand the value of programs offered. This might be used, for example, to develop improved programs or to match the particular requirements of a visiting group to the program which best meets their needs.

There were a number of different programs used across two different CSIROSECs for the collection of data for the LEI for CSIROSECs. This instrument may have the potential to distinguish between the perceptions of learning environments for different programs. Figure 6.6 compares the mean scores of student responses from two programs at CSIROSEC Tasmania, 3 classes of Science and Technology (N=65) and 3 classes of Forensic Science (N=49).

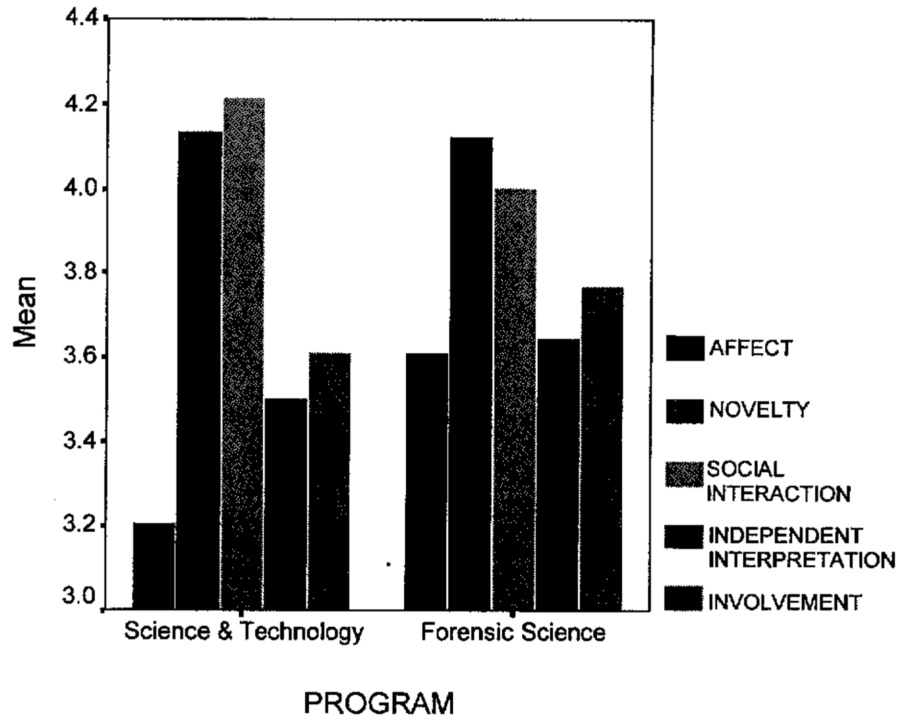

Figure 6.6. Mean Scores for Scales for Students doing Science & Technology and Forensic Science at CSIROSEC Tasmania.

Even allowing for the limited data available, the graph in Figure 6.6 shows visible differences between the scales for the learning environment for each of the programs. Forensic Science has higher scores for the Affect, Independent Interpretation and Involvement scales, whilst Science and Technology has a higher score for the Social Involvement scale. There is little difference between scores on the Novelty scale. This would need to be subjected to more stringent testing with a larger, controlled data pool.

Having developed both of these programs at CSIROSEC Tasmania and conducted sessions with many classes, the results shown as Figure 6.6 are most revealing, but in retrospect not surprising. However, the results have caused a re-examination of the students' perceptions of each of the programs, and this has been done armed with this new information. Students and teachers alike have generally expressed a high degree of enjoyment of the Forensic Science program. The Science and Technology program, on the other hand, has been seen more as the "nuts and bolts" of science, for example, data collection and treatment. In this respect, the latter program has been approached in a more work-like fashion. These observations of the relative enjoyment in each of the programs are reinforced by the students' perceptions on the Affect scale shown in Figure 6.6.

The differences in the students' perceptions on the Social, Independent Interpretation and Involvement scales may be linked to the nature of the activities in each program and the effect this has on the way students participate in them. In order to successfully complete the Science and Technology activities students are required to work together as a team. For example, in the Wind Resistance activity the first student handles the cart, the second measures the distance that it travels, while the third student records the results. Whilst group work is encouraged in the Forensic Science program, the activities can be completed just as easily by students working as individuals, and this results in less social interaction among the students in a group. Working individually requires increased independent interpretation of the activities and a greater degree of personal involvement.

Summary

Arising from the face validity and statistical analyses of the Redrafted Instrument the Refined Instrument has been developed. This has been trialled with 374 students from the CSIROSECs in Tasmania and Melbourne.

Statistical analyses have identified the item for each scale with the weakest discriminant validity and alpha reliability. These have been removed to produce an instrument with five scales and six items per scale, with, of course, due regard given to retaining a set of items which accurately represents the CSIROSEC learning environment. This instrument is known as the Learning Environment Instrument for CSIRO Science Education Centres, or LEI for CSIROSECs. All of the scales have acceptable discriminant validity. The Involvement scale has the weakest discriminant validity, but similar problems have been encountered with this scale on other instruments.

Correlations between the means of scales of greater than .4 exist for Affect-Novelty, Affect-Involvement and Novelty-Involvement. This may indicate that the enjoyment of the CSIROSEC experience, the novelty of the learning environment and the opportunity for involvement at both the mental and physical level (that is both hands-on and minds-on) are linked in some way. It may be that the very reason students enjoy the experience is because it is different and engaging.

Means of scales are generally high, with frequency distributions being skewed towards the 'agree' end of the scale. It is considered that the degree of skewness is a result of the majority of students favourably perceiving the learning environment at CSIROSEC.

A comparison of the LEI for CSIROSECs with existing instruments for internal consistency (alpha reliability), the mean correlation with other scales as a measure of discriminant validity, and class membership differences shows that this instrument compares favourably on all of these measures.

The LEI for CSIROSECs should display sufficient sensitivity to differentiate between classes, programs and so forth in CSIROSECs. Examples have been given in the use of the LEI for CSIROSECs for the comparison of classes, comparison of teacher-student perceptions, comparison of primary and secondary classes, and comparison of CSIROSEC programs.

In the final chapter, conclusions from the development and analysis of the LEI for CSIROSECs are summarised. Actions for further development of the instrument and implications for its use in further research are discussed.

Chapter 7

Summary, Conclusions and Implications

The main aim of this research was the development of a valid instrument to measure students' perceptions of aspects of the learning environments in CSIRO Science Education Centres. This chapter summarises stages in the development of this instrument and the efforts made to establish its validity, internal consistency, and sensitivity. Some reflections on the procedures used are given and the chapter concludes with implications for practice in CSIROSECs and for further research.

Development of the LEI for CSIROSECs

This study was motivated by a desire to ensure that the learning environment at CSIROSEC Tasmania conformed to best practice. The initial stages of this process were informal and consisted of comparing practice at CSIROSEC with the findings from research literature and modifying practice accordingly. Monitoring of the success, or otherwise, of this process relied upon the perceptions of the practitioners and informally gathered feedback from the other participants in sessions, including students, teachers and parents. Whilst it was considered that this procedure resulted in improvements in practice and the learning environment at CSIROSEC Tasmania, such improvements were perceived subjectively by those conducting the sessions. It became important to define the CSIROSEC learning environment more accurately and then to find some way to measure the students' perceptions of the learning environment. The researcher's experience working in a CSIROSEC suggested that the method for measuring the CSIROSEC learning environment would need to be economical in terms of time, human-power, cost and disruption to the session.

The development and validation of the Learning Environment Instrument for CSIROSECs proceeded through a number of stages. It began with a review of research into learning environments and the kinds of instruments developed to measure them. A more thorough and focussed literature search relating to science education centres and museums revealed a lack of attention to their environments for learning, but it was clear that there were relevant learning environment factors which matched those in other learning environments, particularly the relationship dimensions associated with Moos's work.

CSIRO Science Education Centres are unique in that they are positioned between a formal school science laboratory and the more traditional, widespread and informal science education centres and museums. As such, they tend to incorporate a number of aspects from informal learning environments within a more structured context. The distinction between formal and informal learning environments proposed by Wellington (1990) was modified (see Table 3.4) to show the nature of the CSIROSEC environment as somewhere between those two kinds of settings. It was also necessary, however, to suggest a flexible interpretation of the CSIROSEC learning environment as it varied from one CSIROSEC to another, and within CSIROSECs, depending upon the particular program which was under consideration. The unique nature and positioning of CSIROSECs between the formal and informal learning environments was well suited to utilising and/or adapting the types of research methods employed to investigate both classroom learning environments and SECSM learning environments.

Realistically, the development of a generic learning environment instrument for SECSMs may not be achievable at this time, because of the great diversity in their informal learning environments. It has been possible, however, to approach the problem from another direction, and it was because of their semi-formal learning environment that CSIROSECs have provided a convenient venue for doing this research. This research has attempted to provide the first stepping stone to bridge the gap between existing learning environment instruments for formal learning environments and the informal learning environments of SECSMs.

A pilot study was conducted to test the feasibility of producing a learning environment instrument for CSIROSECs. The Pilot Study Instrument was developed by first, identifying the learning environment factors in SECSMs from a literature review of SECSM research, second, relating this to the learning environment in a CSIROSEC based upon participatory experience, and third, utilising the resources from existing learning environment instruments developed for classroom use. The factors relevant in defining the learning environments in SECSMs that were synthesised from the literature are shown in Table 3.6. These factors were reduced to a manageable number for the production of the Pilot Study Instrument for CSIROSECs (see Table 3.7). The Pilot Study Instrument had six scales, Curiosity, Self-Developed Models, Innovation, Multi-Sensory Skills, Attitude and Active Learning. Table 4.1 gives a description of each of these factors, and Table 4.2 shows the five items which were written for each of the scales.

The Pilot Study Instrument was administered to 189 students attending sessions at CSIROSEC Tasmania. The responses to all items were skewed towards the "agree" end of the scale indicating a favourable perception of the learning environment at CSIROSEC Tasmania. This was to be a feature of all versions of the instrument up to, and including, the final version, the LEI for CSIROSECs.

The dimensionality of the instrument at each stage was examined using principal components analysis. A six-component rotated solution for the Pilot Study Instrument was inconclusive, in terms of establishing clear scales, with many items loading substantially onto more than one component. Further, items from some of the proposed scales, namely Curiosity, Attitude, Self-Developed Models and Innovation, had strong loadings on the same component. A four-component rotated solution revealed that the items for Curiosity and Attitude had loadings on the same component, and all of the items for Self-Developed Models and Innovation each had loadings on a separate component. The loadings of items from Multi-Sensory Skills and Active Learning were spread across a number of components, but three items from each of these proposed scales had loadings on the same component.

The pilot study confirmed the feasibility of developing a learning environment instrument for CSIROSECs, however, it was clear that considerable attention needed to be given to defining more clearly the dimensions of the learning environment. A number of recommendations were suggested that would improve the procedure for the next stage of development. These included the rewording of items to express more specifically the meaning of the scales that they represent, a process that would be improved by the formulation of operational definitions for each of the proposed scales. The face validity of the instrument could be established by asking managers of CSIROSECs and other experts to assign each item to its proposed scale by referring the operational definitions. The Pilot Study Instrument had too few items to do more than establish whether the process was feasible. Five items per scale were too few to allow flexibility in the development of an instrument. It was decided that there should be seven items per scale as this would allow for the deletion of one item per scale, resulting in a final instrument with six items for each of the five scales. This length would fit easily into the short time available for students to complete the instrument at the end of their CSIROSEC visit.

A number of changes were recommended for the nature of the scales in the Pilot Study Instrument to produce an instrument that would be more representative of the CSIROSEC experience. These changes are shown in Table 5.1. In summary, Curiosity and Attitude were combined into a new scale called Affect, Self-Developed Models was renamed Independent Interpretation, Innovation was renamed Novelty, Multi-Sensory Skills and Active learning were combined into a new scale called Involvement, and a new scale, Social Interaction, was included to represent the importance of the social experience in the CSIROSEC learning environment. These changes resulted in the Redrafted Instrument.

The Redrafted Instrument consisted of five scales with seven items per scale, the scales being Affect, Social Interaction, Novelty, Independent Interpretation and Involvement. The derivation of the scales from the literature review and the Pilot Study Instrument is shown in Table 5.1. The scales are explained by the operational definitions, which are listed in Chapter 5, immediately following Table 5.1. The operational definitions included student outcomes and guided the development of new items and the rewriting of items from the Pilot Study Instrument.

The managers of CSIROSECs and other experts in the areas of SECSMs and learning environment research were involved in establishing the face validity of the items in the Redrafted Instrument. Face validity was determined by the extent to which experts were able to assign each item to its designated scale, as defined by the operational definition for each scale. Of the practitioners working in CSIROSECs and SECSM responses, at worst, one misplaced five of the thirty-five items. The academic in the field of learning environment instruments reported difficulty placing two of the items from the proposed Involvement scale. Overall, however, there was good agreement with the placement of items onto their proposed scale thus establishing face validity for the Redrafted Instrument.

The Redrafted Instrument was administered to 301 students from the CSIROSECs in Tasmania, Melbourne, Townsville and Perth. The inclusion of data from a number of CSIROSECs was designed to increase generalisability of the resultant instrument. The rotated five-component solution for the Redrafted Instrument with seven items per scale revealed that the items for Affect, Novelty and Social Interaction were loading onto separate components. This indicated that these scales had reasonable discrimination. Independent Interpretation had five items that were loading on the same component, but two of the items, Ind6 and Ind7, had loadings on a separate component, probably because of their strong similarity in wording. The majority of the Involvement items had loadings on the same component as Independent Interpretation items, but there were strong loadings on other components as well. The Involvement scale was poorly defined in the principal components analysis, and this reflected the difficulty the academic expert in learning environment research had with the placement of a number of the Involvement items.

The reanalysis of the Redrafted Instrument data with one item deleted per scale resulted in a more orderly loading of items on components for each of the proposed scales. Reasonable results were obtained for three scales, Affect, Social Interaction and Novelty. However, Independent Interpretation and Involvement, whilst showing some improvement, were still not performing as well as hoped. The original Redrafted Instrument with seven items per scale, the results of the statistical analyses of the data collected, and the face validity data were used to rewrite a small number of items. This refinement of items produced the Refined Instrument, and it was hoped that this would result in improved discrimination between scales. The operational definitions underwent minor modifications to accommodate these changes. The revised operational definitions are shown towards the end of chapter 5.

Data for the Refined Instrument were collected from 374 students from classes attending the Tasmanian and Victorian CSIROSECs. The rewrite of items resulted in all items loading on components in the rotated component analysis in agreement with their defined scale, although five items had loadings greater than .30 on other components. One item per scale was removed, resulting in an instrument with six items per scale, and the data were reanalysed. Criteria for the removal of items included statistical factors such as discriminant validity, and internal consistency measured by Cronbach alpha. An important consideration, however, was to ensure that the removal of items retained the instrument's ability to reflect the learning environment in CSIROSECs. The resultant instrument with five scales and six items per scale is referred to as the Learning Environment Instrument for CSIRO Science Education Centres (LEI for CSIROSECs).

The LEI for CSIROSECs has acceptable discriminant validity, although, as with existing instruments, the Involvement scale has the weakest discriminant validity. The instrument measures separate, although overlapping, aspects of the CSIROSEC learning environment. This is reflected in the correlations of greater than .4 between the means of scales for Affect-Novelty, Affect-Involvement and Novelty-Involvement. This may indicate that the reason students enjoy CSIROSEC sessions is because they are both different and engaging. Furthermore, the means of scales are generally high, reflecting a favourable perception of the CSIROSEC learning environment by the majority of students.

Another means of determining the success of the development of the LEI for CSIROSECs has been to compare it with existing learning environment instruments that use similar scales (see Table 6.14). Statistics for the LEI for CSIROSECs compare favourably with these other instruments on internal consistency (alpha reliability), discriminant validity and class membership differences (also see Table 6.15).

Analyses have been conducted to demonstrate the sensitivity of the LEI for CSIROSECs. The instrument has demonstrated ability to discriminate between the perceptions of different class groups to the same program conducted in the same CSIROSEC. A comparison of the perceptions of teachers and students has shown that teachers feel that their students may perceive the experience more positively than they actually do on all scales. A comparison of primary and secondary school classes suggests that primary school students rate the experience more highly on the Affect scale than secondary school students, whilst secondary school students rate the experience more highly than primary school students on the Social Interaction scale. The LEI for CSIROSECs has also demonstrated a potential to differentiate between the learning environment of different programs within the same CSIROSEC.

Conclusions from Analysis of the LEI for CSIROSECs

The LEI for CSIROSECs finally developed displays high internal consistency and discriminant validity indices that are comparable with existing instruments. A comparison of the final version of the LEI for CSIROSECs with existing instrument statistics for reliability, the mean correlation with other scales, and class membership differences shows that this instrument compares favourably on all of these measures.

The Involvement scale has the weakest discriminant validity and lowest component loadings on the principal components analysis, but similar problems have been encountered with the Involvement scale on other instruments (Aldridge, Fraser, & Huang, 1999; Taylor, Fraser, & Fisher, 1997). Further refinement and trialling of items may improve the discriminant validity of the Involvement scale, but it may be that the variable of Involvement has so much overlap with other dimensions of the learning environment that it may not be possible to develop a scale that measures a unique dimension.

The frequency distributions of responses for most scales tend to be skewed towards the "agree" end of the scale and this can also be seen from the high mean values. It is concluded that the degree of skewness expresses the favourable perceptions of the learning environment at CSIROSEC by the majority of students.

The sensitivity of the LEI for CSIROSECs has been demonstrated with a number of examples showing the potential use of the LEI for CSIROSECs as a means of making comparisons between different groups. The examples included in this study are perceptions of students in different classes, comparisons of the perceptions of teachers and students, primary and secondary school students, and students who had experienced different CSIROSEC programs.

Further Development of the LEI for CSIROSECs

Whilst perceptual studies have a number of distinct advantages in defining the classroom environment, so do naturalistic and ethnographic methods. Often a more complete and accurate description of the environment can be obtained by triangulation resulting from the use of multiple methods.

The development of the LEI for CSIROSECs has provided an instrument to measure students' perceptions of the CSIROSEC experience. This can now be triangulated against other forms of research. This further research could look at the instrument as a means of providing a plausible account of students' perceptions of the environment. Accordingly, such research would require a more in-depth analysis utilising both quantitative and qualitative data. Qualitative data would be collected from participant observation, interviews with the education officer conducting the session, the supervising class teacher, participating parent helpers and the students. In response to a need to include analyses from both qualitative and quantitative data one could invoke a warrant of plausibility (Taylor, Fraser, & White, 1994) comprising the following criteria:

- The extent to which the LEI for CSIROSECs questionnaire generates *intelligible* and *dependable* responses from students.
- The extent to which student responses to groups of items (identified as scales) aggregate in a *coherent* and *meaningful* way.
- The extent to which the LEI for CSIROSECs questionnaire data are *consistent* with data from other sources.

A first step in this process could be the analysis of CSIROSEC managers' responses about the extent to which the results obtained from use of the LEI for CSIROSECs provide a meaningful description of students' perceptions of the CSIROSEC learning environment in their own CSIROSEC.

A longer form of the LEI for CSIROSECs could be developed to allow for the collection of more detailed data. The LEI for CSIROSECs developed in this thesis is a sufficiently economical instrument for administration to students at the conclusion of a CSIROSEC session. This has been an important consideration in ensuring a minimum of interference with the students' visit. However, the development of a longer form of the instrument would need to ensure that extraneous factors were not introduced that may interfere with the validity and reliability of the instrument. Different forms of the LEI for CISROSECs could also be developed in order to collect data about the perceptions of teachers and parent helpers attending CSIROSEC sessions. It is expected that the use of these additional instruments would provide a more complete and detailed picture of the CSIROSEC experience from a number of different perspectives. A major purpose of developing the instrument was to provide a tool for improvement and such data would allow the development of strategies aimed at improving the CSIROSEC experience.

Implications for Further Research

Applications of the LEI for CSIROSECs

Since the sensitivity of the LEI for CSIROSECs has been demonstrated, the instrument could be used in CSIROSECs to gather information about other aspects of the learning environment. For example, comparisons could be made between the perceptions of the learning environment by the different sexes, by English as a Second Language (ESL) students, by rural and urban students' perceptions, as well as comparisons of the learning environments in different CSIROSECs, and perceptions related to socioeconomic status. Further understandings of the perceptions of different groups of students may lead to the production of better programs and learning environments that are more closely aligned with the needs of specific groups.

The comparison of the learning environments in different CSIROSECs may appear initially to be a contentious issue, particularly if there was a possibility of bureaucratic interference. That is certainly not the intention of suggesting such a use for the LEI for CSIROSECs. There could be much to be learned by analysing the learning environments in different CSIROSECs and attempting to define the factors contributing to the relative perceptions of students in the different CSIROSECs. Questions such as "Why do students in one CSIROSEC perceive the environment as being more novel than in other CSIROSECs?" or "Why do students perceive they are more involved in the activities in a particular CSIROSEC compared to others?" could lead to a fertile interchange of ideas between CSIROSECs and lead to improvements in the learning environments in all CSIROSECs.

Different students respond to different learning environments in different ways. Whilst students may behave in one way in the formal classroom environment, other qualities may become evident in more informal learning situations, such as on field trips. At an anecdotal level, over many years there have been frequent instances of teachers remarking about the involvement of particular students during CSIROSEC sessions. The stories generally go something like this. "See Claire over there, she always sits back in class and rarely gets involved, but she is really getting into things here. This is a side of her I have not seen before." Or, "James is usually a real behaviour problem in class, he is always mucking around and disturbing others. Here he has taken charge of his group and is showing leadership qualities I didn't know he had." The constructive involvement of these otherwise "difficult" students is sufficiently obvious for it to be commented upon by their teachers. Some aspect of the CSIROSEC learning environment must be responsible for this increased level of involvement. It is not the scope of this research to investigate such causes, but by providing an additional research tool, the LEI for CSIROSECs may assist in studies comparing the levels of involvement of students in diverse learning environments.

An important implication of the development of the LEI for CSIROSECs is that it is an initial step towards the development of similar learning environment instruments for other informal learning environments such as those found in museums and public science centres. Each institution has its own unique environment, and whilst each institution experiences different barriers to the measurement of its learning environment, there may be useful information in this thesis which may assist in the initiation of the process. Such research may take some time, and this must be a process of evolution rather than revolution.

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Appendix 2A

A Brief History of CSIROSEC Tasmania and its Programs

In order to understand the motives, purposes and objectives of CSIROSEC Tasmania it is necessary to understand its background. This will give important insights into its modus operandi and relative priorities. It also establishes the nature and complexity of the learning environment and the forces that have shaped its environment.

The idea for a CSIRO Science Education Centre in Tasmania was conceived as a joint venture between CSIRO and the Education Department of Tasmania in late 1985. A Senior Master was seconded from the Education Department to fill the role of Manager and work commenced in February of 1986.

Part of the initial agreement was that CSIRO would provide a venue for the operation of the CSIRO Science Education Centre. A shortage of space at the CSIRO Marine Laboratories resulted in CSIRO not being able to fulfil this part of their commitment, at this time. Negotiations with the Education Department resulted in a disused canteen at the site of the former Hobart College in Letitia Street, North Hobart being identified as suitable and subsequently refurbished. The basic refurbishment was carried out by the Education Department's work crew. Custom benches were designed by the Manager, constructed by the apprentices at Pasminco and funded by the Tasmanian Chamber of Mines. Work was completed in late 1986.

The Letitia Street site was initially proposed as an interim venue for two years, during which time it was foreshadowed by CSIRO that it would acquire additional space for the CSIRO Marine Laboratories, CSIROSEC being relocated into part of this space, as per the original agreement. Neither the acquisition nor the relocation eventuated and CSIROSEC remained a guest of the Education Department at its initial site for almost nine years.

In 1995 the Education Department sold the former Hobart College site in Letitia Street. This included the building housing the CSIRO Science Education Centre.

This particular building was subject to a thirty day vacation clause, which immediately established a tight time-frame for the relocation of CSIROSEC.

By this time the section of CSIRO responsible for CSIROSECs was renamed CSIRO Education Programs. As before, CSIRO Education Programs was unable to meet its original agreement of providing a venue for CSIROSEC, nor was it able to negotiate a site for the relocation of CSIROSEC. The manager of CSIROSEC Tasmania again negotiated with the Education Department and was provided with another venue at Church Street in North Hobart, little more than a kilometre from the original site.

Structurally, this site was clearly an improvement over the previous one, but it required refurbishing and certain modifications to turn it into a functional science education centre. The Education Department, having provided CSIROSEC with the building, was not keen to provide additional funding, but were eventually forthcoming with funding for security, communication and electrical works.

CSIRO Education Programs was still unable to negotiate funding for refurbishment with CSIRO Property, because the new location was not a CSIRO site. CSIRO Education Programs provided a small, but inadequate, amount of funding for essential items such as carpet (there was vinyl on the floor, much too noisy to be functional).

Under the circumstances some Tasmanian ingenuity was called for. CSIROSEC classes were postponed and rescheduled. Staff used their own vehicles to move equipment from one site to the other in order to save on costs. The staff painted out the entire interior of the new building and put up display boards. Relatives and friends were recruited to assist. With no funding for purpose built benches, those at the original site were removed, remodelled and fitted into the new building by CSIROSEC staff. The provision of water in rooms and additional electricity outlets (beyond the minimum necessary) would need to be postponed and provided from subsequent funding.

Initially, space had to be provided on-site for the Duke of Edinburgh Award Scheme staff. A room was set aside for this purpose. Due to the nature of the building, and security concerns by CSIROSEC, the Education Department installed a toilet and water for Duke of Edinburgh staff. In any event, the Duke of Edinburgh Award Scheme folded in Tasmania during term 1 of the next year and CSIROSEC acquired this additional room and toilet.

In subsequent years, CSIRO Education Programs has provided funding for the installation of water into some rooms, the covering of an enclosed area between the "labs" and the office, and the conversion of a small storeroom into a preparation room and chemical store.

The significance of mentioning all of the foregoing is to emphasise the commitment of the CSIROSEC staff to go above and beyond the call of duty in order to ensure the continuation of a Science Education Centre in Tasmania. Furthermore, to ensure that the Centre is the best that it can be within the limits of the available and obtainable resources. The concept of bricolage pervades the CSIROSEC in Tasmania.

The relocation of CSIROSEC to Church Street had other, more important, implications for the future of CSIROSEC.

The Letitia Street site, whilst large, was open plan and had little space for storage. Programs of hands-on activities were conducted in a large open area. Activities for all of the programs at that stage (mostly grade 5-8 science and technology) were set-up in this area. To minimise confusion and to assist students find their activities a system of pathways was established for each program and students were issued with maps of their pathway prior to their visit. Another aspect of this layout was that only one group could visit CSIROSEC at any given time.

The new site at Church Street did not have the impressive, large, open area of the previous venue, but eventually (ie. after the departure of the Duke of Edinburgh Scheme) CSIROSEC obtained five rooms for setting-up programs, as well as an office area, storage area and a preparation area. It was now possible to locate individual programs in different rooms and to run concurrent programs.

This provided the impetus to develop additional programs and the ability to cater for new markets. The use of markets as a terminology is deliberate, since by this time, the continued decrease in funding to the Centre had resulted in viewing CSIROSEC as not just an education centre but also a commercial enterprise. It was necessary to adopt a philosophy emphasising that future security resided in greater self-funding and less reliance upon CSIRO Education Programs and other sources of external funding. Additionally, sponsorship was now viewed as a bonus, if it eventuated, but at best a short-term source of revenue, which could be used for the creation of programs rather than their conduct and maintenance.

History of CSIROSEC Tasmania Programs

Eureka

Over a period of many years there had been numerous requests from teachers outside of the grade 5-8 range for CSIROSEC to provide programs for their classes. The vast majority of these requests emanated from primary school teachers. It was decided that grade 3-4 children should be the focus of CSIROSEC's next program. At the commencement of term 3 in 1996 *Eureka* was launched for grade 3-4 classes. This proved to be so successful that it was necessary to develop *Eureka Too* to run in 1997 for classes that had already visited *Eureka* in the previous year. The programs thereafter alternated each year. Furthermore, on the years that *Eureka Too* was running At CSIROSEC *Eureka* was used as one of the CSIROSEC travelling programs, and vice versa.

Forensic Science

At the same time, a scenario-based *Forensic Science* program was developed to cater for grade 9-10 classes. The development of this program was made considerably easier by basing it upon already established programs from Sydney and Adelaide. This program, despite its sound educational basis, never attracted the numbers to CSIROSEC as those achieved by *Eureka* and *Eureka Too*. Surveys re-established that this was a function of organisational and funding difficulties inherent to secondary schools, a matter that had been established earlier in the history of

CSIROSEC. *Forensic Science* was never destined to attract large numbers to CSIROSEC, but it proved a valuable program in two other respects. It continues to be a valuable program for travelling sessions to other parts of Tasmania. It also formed the basis for the development of a 5-day certificate course in forensic science which is conducted during school vacations.

There was a third, incidental benefit arising from *Forensic Science*. Observation of reactions by students and teachers to the structure of the program suggested that the scenario-based format was well-received. It provided a common thread to draw all of the activities together, it had a defined end-point, students were motivated by the desire to solve the crime and it encouraged hypothesis making and testing against the evidence.

A primary forensic science program developed at CSIROSEC Tasmania has been adopted by CSIROSEC Adelaide and formed the basis of their *Lab on Legs* program for 2000. The *Lab on Legs* program travels out to country schools in South Australia. *Forensic Frenzy* is set up and conducted in the schools.

Moon Rescue

It was a priority to develop a program of hands-on activities for grade 1-2 classes. What started at 9am one morning as the development of this grade 1-2 program was, by noon of the same day, the start of a new scenario-based program for grade 5-7 classes. The program, *Moon Rescue*, thereafter developed quickly and has since proven to be highly successful. The development of the *Moon Rescue* program is discussed in more detail in Appendix 2B, since it is gives an insight into the development process of programs at CSIROSEC Tasmania and it is one of the programs used by visiting groups during the pilot study.

Another issue now became an important matter for consideration. Feedback from schools was indicating that CSIROSEC's programs were extremely worthwhile and much valued. The programs were considered good value, but for many schools it was costing them more to bus the students to CSIROSEC than it was costing for the visit. Funding for excursions was becoming an increasingly important issue in schools and one that could not be ignored. An analysis revealed that given appropriate programs, CSIROSEC could travel to local schools and conduct programs (as distinct from the already established week-long CSIROSEC travelling programs to other regions of Tasmania). This could prove to be more cost-efficient for schools and, with the addition of a small premium, cost-neutral for CSIROSEC.

Balloon Science

A thematic program, entitled *Balloon Science*, was developed with the intention that it becomes the first of a number of programs to be taken out to schools. This proved to be a great learning experience. The program was sound and very popular with schools, but there were problems. The program took a long time to pack and unpack and to set-up, adding to the costs for CSIROSEC. A more important issue was the occupational health and safety factor associated with the transport of gases. An adequate solution to this latter problem was far from cost-effective and in the end *Balloon Science* became another CSIROSEC-based program.

Gene Technology & Food Technology

At the same time as all of this was going on, two programs developed interstate were also being introduced at CSIROSEC. These programs targeted upper secondary grades, *Gene Technology* for grades 10-12 and *Food Technology* for grades 9-12. Previous experiences had indicated that the potential number of visiting groups would be low and it was decided, therefore, to offer each of these programs for a limited period of time. Accordingly, each program was offered for a two week run. All of the *Gene Technology* sessions were booked out and most sessions for *Food Technology*. Interestingly, *Food Technology* attracted mostly non-science classes, with groups from Food Studies, Hospitality, Tourism etc.

Cool Chemistry

Another program, *Cool Chemistry*, which was developed at the Brisbane CSIROSEC, was adapted for use after trialing with Double Helix Science Club members and at family science sessions. *Cool Chemistry* sessions are run in tandem with *Balloon Science*. Each program is set up in a separate room for a period of two weeks each term. The target group is grade 5-6. This approach was adopted as a means of reducing travelling costs for groups coming to CSIROSEC. A school can fill a bus with two classes (costs are usually for the hire of the bus, not the number of passengers) and whilst one class attends *Cool Chemistry* the other goes to *Balloon Science*. After a break the groups change over.

Puzzlemania

Puzzlemania, as with *Balloon Science*, arose out of a vacation program conducted at CSIROSEC. Strictly speaking, *Puzzlemania* is not a science program. The content of the puzzles is not scientific. The program's science connection arose out of an article in the Rational Enquirer (1990), which outlined the 20 attitudes of top scientists. One of these stated that scientists are addicted puzzle-solvers. This coincided nicely with the view expressed by the author in answer to the question "What is science?", that is, "Science is an organised method of problem-solving." The real value inherent in *Puzzlemania* is its ability to encourage students to think and develop problem-solving skills in a motivational context.

The initial idea for the *Puzzlemania* program germinated in 1996 from observations of students using some of the *Eureka* hands-on activities. One such activity was the *Chicken-Corn-Fox* puzzle. This puzzle is traditionally worked out in the mind or on a piece of paper. For the *Eureka* program it was desirable to have a greater degree of multisensory input. This was achieved by constructing a model with riverbanks, a river, a small boat with a person in it, and models of the chicken, the corn and the fox. Students could physically manipulate the various components. This added tactile and visual input to the solution of the problem. It also gave other members of the group a view of the steps being taken, an insight into the thinking of the solver of the problem and an opportunity to contribute to the thinking process via discussion.

Puzzlemania should not to be confused with a program of pen and paper puzzles. An essential component of *Puzzlemania* is the provision of props for each of the puzzles. This is a true multisensory program with a high tactile component and a large degree of social interaction and collaborative problem-solving.

With the experiences gained from *Balloon Science*, *Puzzlemania* was developed as a program specifically designed to travel out to schools with a CSIROSEC staff member. For this reason it had to be easily transportable and quick to set-up and pack away. The 1999 program of *Puzzlemania* could be contained within two plastic bins, set-up in 20 minutes and packed away in 15 minutes. *Puzzlemania 2000* was developed as a completely new set of puzzles and likewise can be packed into two bins and set-up and packed away in a similar time-frame.

One of the very important aspects of *Puzzlemania* is the amount of feedback from participants. People (parents and teachers, as well as students) are strongly self-motivated to share their successes with the presenter. People are encouraged to do this. They are also encouraged to seek assistance if they are experiencing difficulties. They are warned, however, not to seek easy answers from the presenter. Hints, tips and clues will be given to help guide the participants to their own solutions. This is considered essential if participants are to leave the session feeling empowered as potential problem-solvers. To assist in this respect it has been important to include puzzles with a wide range of degrees of difficulty so as to allow every participant to experience at least some success.

The Little Learner's Lab

By early 1999, CSIROSEC Tasmania had still not developed its foreshadowed grade 1-2 program of hands-on activities. Ideas had been accumulating in a folder for the previous two years and informal market research had indicated that there would be strong support for such a program. It was time to get tough and impose some motivation to get the program up and running. A timeline was established which committed to a launch at the end of term 2 (late August) and the commencement of school groups in term 3. The *Little Learner's Lab* was launched, on time, to an amazing response from teachers.

The *Eureka* and *Little Learner's Lab* programs differ in one major respect from the other programs conducted by CSIROSEC Tasmania. These sessions are not supported by a presenter. Teachers attend a pre-visit professional development session to familiarise themselves with the activities and how best to conduct the session themselves. Teachers are provided with both pre-visit and post-visit materials and activities. Teachers are strongly encouraged to involve as many parents as possible in the experience. Amongst many other benefits (which have been extensively covered in educational sociology and psychology texts), this helps to keep student groups focused on the current activity throughout the visit.

From an educational stance this may not be the most desirable way to conduct these sessions. In running a science education centre, however, there are other more pragmatic considerations, such as financial survival. The format for these sessions has undertones of a mercenary motivation. It allows CSIROSEC to reach out and provide activities for grade 1-4 children (altruistic enough) whilst incurring no staff costs for the conduct of each session. Schools groups are required to pay to attend sessions, with this income being used for the development of more programs and to support the less cost-effective programs and activities at CSIROSEC.

A new program of *Little Learner's Lab* activities has been developed for 2001.

Illusions – Science Meets Art

Illusions marked a further diversification in the operational nature of CSIROSEC programs. Whereas previous programs had focused on the class group as the functional unit for sessions, this program was designed to cater for public groups and groups of up to 60 students. *Illusions* is a mix of displays, interactive models and hands-on activities related to optical illusions. For school groups there are presenter-led introductory and wrap-up sessions on optical illusions and perception. *Illusions* derives its ability to motivate participants from the way in which so many of the activities can convincingly fool the senses, and the fascination people have with this phenomenon.

Appendix 2B

The Moon Rescue Program

The Development and Conduct of Moon Rescue

Moon Rescue had an almost accidental birth. The intention, during some rare spare time at CSIROSEC Tasmania, was to develop a hands-on program of activities for grade 1-2 children. This program was to be based around a scenario, in order to draw all of the activities together. A concept map of potential activities was constructed. Many of these activities relied upon existing equipment at CSIROSEC, as there was insufficient funding to develop a program without this consideration. It became quickly obvious that the educational level of the program would be beyond grade 1-2 students, but ideal for grade 5-7 students. It was decided to proceed on this basis.

A brainstorming session of staff at CSIROSEC quickly produced a large list of additional, potential activities, mostly using existing resources. The next step was to develop a scenario using the given resources.

From the start the intention was not to produce a program rich in cognitive information. The intended aim of the program was to interest and motivate students, and to provide starting points for further in-depth studies back in the school environment.

Thus, the scenario is a fictitious one. Space travellers are trapped on the Moon. Students have to undertake basic astronaut training to go and rescue them. A one page story is sent to the school for students to read prior to their visit. This story sets the scenario for the visit.

The number, range and differing lengths of the activities allow for the movement away from the traditional and more rigid format at CSIROSEC. Students are free to pursue the activities they want, in their own order and time. This is designed to move the learning environment more towards the informal end of the spectrum and to give the students greater independence during the session.

Worksheets for individual activities have been replaced with bold, colourful signs beside each activity. The signs have been designed with minimalism in mind and contain basic instructions, limited to one, two or three sentences, in large bold print.

Student progress is guided by three single sheets – Moon Facts, Astronaut Registration and Answer Sheet.

The Moon Facts sheet allows students to retrieve information about the Moon from a computer-based encyclopedia and to record these facts for use back in their classroom.

Astronaut Registration draws together a whole series of activities about the student themselves. It has been shown in previous programs that students like to find out about themselves and, in some cases, to compare themselves with their peers or adults.

The Answer Sheet provides a convenient means for students to record quickly and briefly their findings from each activity. As previously stated, *Moon Rescue* is not designed as a cognitive rich program and therefore, extensive information gathering during the session is not deemed important. To this end, the answer sheet acts as both a guide to activities completed, and those still to be completed, and as a means of directing students to the important facets of an activity. This latter aspect should not be seen as limiting students' freedom to explore and investigate, but as a means of providing some security and direction for students requiring this (ie. "What am I supposed to be doing here?", "What is important in this activity?").

Within the limits of the resources available and architectural constraints an attempt has been made to create an appealing physical environment. The corridor leading to the *Moon Rescue* room has been darkened. The overhead lights have been switched off in the room. Light comes from a series of fairy lights suspended from the ceiling, flashing coloured lamps which respond to sound and movement, coloured lamps under one of the benches (which create coloured shadows), the lamps used for photovoltaic and microscope activities and the lamps used to illuminate the rocket and shuttle models. Large colourful posters have been placed around the room with subjects ranging from a map of the Moon's surface to pictures of aliens. There are models of spacecraft and models of the planets.

The intention of this physical environment is to encourage children to feel that they have, for the moment, stepped out of the real world. It is hoped that this increases the effectiveness of the fictitious scenario and allows students to focus more directly on the tasks at hand.

To further assist with the transition from reality to the fictitious scenario each session begins with an introduction by the presenter. The presenter reinforces the fictitious scenario and the aim of the exercise (to undertake preliminary training as an astronaut). The presenter quickly explains the use of equipment, where this may be required, and puts activities into the context of the scenario.

Students work around the activities at their own pace in groups of two or three.

For the last 15 minutes of the visit students adjourn to the lecture/demonstration room for a series of demonstrations on rockets and space travel. These demonstrations include spectacular explosions, culminating in the explosion of a hydrogen-filled balloon. This ensures that students leave on a high note.

The remainder of this appendix contains the printed materials that are sent out to teachers prior to their class attending a session of Moon Rescue at the CSIRO Science Education Centre Tasmania. A brief description of each sheet is provided for the reader, together with the page on which it can be located.

A2-14 A very brief explanation of the content and format of the Moon Rescue program is provided on this promotional sheet. It also includes an internet activity that teachers can pursue with their students at school.

A2-15 The "Guidelines for the Moon Rescue Program" sheet deals with administrative arrangements relating to the visit.

A2-16 This sheet is a summarised overview of the hands-on activities and demonstrations in the Moon Rescue program.

A2-17 Answer Sheet: Students will record their answers to the majority of the activities on this sheet.

A2-18 Moon Facts: On this sheet students will record facts about the Moon, which they gather from an electronic encyclopaedia.

A2-19 Astronaut Registration: Students record facts about themselves on the Astronaut Registration sheet.

A2-20 Word Change Puzzles: This sheet is provided to teachers to use as a pre-visit activity.

A2-21 Crashed On The Moon: This information has been taken directly from the internet. It is provided to teachers to be used as a post-visit activity.

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THE MOON RESCUE PROGRAM

Moon Rescue is a scenario-based program of activities designed for grade 6 and grade 7 students.
Some astronauts have become stranded on the moon and volunteers (your students) have been called to train for the rescue mission.

Students will explore, discover and record aspects about sugar measurement, temporary batteries, electricity generators, a Peltier device, a muscle stimulator and series and parallel circuits and even decipher 'hidden messages'. They will also attempt to unravel the method for remotely controlling a battery-operated vehicle, use stereo microscopes and hunt for microscopic labels hidden in the matrix of a microprocessor.

Activity sheets will be used to collect results and details about their own physical characteristics - their weight on the earth and moon, their hand and chest strength and their foot surface area and thumbprint impressions.

The session concludes with a noisy series of demonstrations about jet propulsion, the combustion of solid fuel and gas expansion and ends with the classic hydrogen explosion!

Do you want to be able to see (and encourage your students to watch for) .. satellites, the MIR and the International Space Stations, the Space Shuttle (when in flight) and the bright flares from the Iridium Corporation satellites?

Then go to ... **http://www.heavens-above.com/**

On the 'Welcome to Heaven-Above' page you must specify your geographic location. You can opt to enter your latitude and longitude or decide to choose one of the sites available from the cities, towns and suburbs listed in their database.

If you choose 'Selecting from our huge database' .. the next screen prompts you to select a country .. eg Australia, then a town in Australia .. eg 'Hobart'. Once this has been typed in and 'submitted' a town search will reveal (in the case of Hobart) the result 'Hobart' and 'Neighbours'. If you click on 'Neighbours' then about 15 locations are presented adjacent to Hobart. Click on the closest suburb to your location and click 'Submit'.

The next page is headed 'Heavens-Above Main Page' and the first dot point will show the location which was finally selected from the previous page.

Bookmark this page with your location for future use.

You can now choose the time predictions for visible satellites for the next 24 hours, 10 day predictions for MIR, and the ISS and 7 day predictions for the Iridium Corporation satellite flares. It's useful to print these pages and refer to them on nights when the skies are clear.
(Be aware that normally our time zone is GMT+10. In summer our time is GMT+11. Times shown in the prediction sheets may be set at GMT+10 even in the summer months.. so you will need to add another hour to the predicted times!)

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GUIDELINES FOR THE MOON RESCUE PROGRAM

1. Enter the site at 36 Church Street through the gate.

2. There is some off-street parking for cars and small buses. Parking in the street is limited to two hours.

3. Smoking is not permitted inside the building.

4. There is a toilet available on site.

5. **Teachers accompanying the class are expected to assist fully with the hands-on activities.**

6. Parents are welcome to attend. They can be most helpful in assisting with a specific activity or with the less able or more difficult groups.

7. Students may work in groups of 2 or 3. **Make sure you have photocopied enough worksheet sets for each group (or for each person) but provide sufficient 'Astronaut Registration' sheets for each student.**

8. It would be useful for students to prepare for their visit by ...

   (a) reading the Moon Rescue Program sheet which describes how the activities relate to the program's theme.

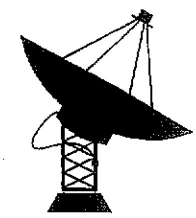
   (b) surveying the 'Answer Sheet', 'Astronaut Registration' and 'Moon Facts' sheets which they will work through during the session.

   (c) considering aspects of 'Crashed on the Moon' as a class activity and perhaps attempting the Word Change Puzzles.

9. The school will be invoiced for the visit. The current charge is $3.25 (including GST) per student. A minimum fee of $81 (including GST) applies for groups of less than 25. Cheques should be made payable to CSIRO Science Education Centre, Tasmania.

A joint initiative of CSIRO and the Department of Education, Tasmania

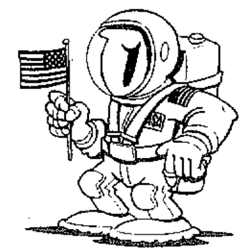
MOON RESCUE



MOON RESCUE PROGRAM

A scenario-based series of hands-on science activities for grade 6 and 7 students.

You must prepare to travel to the Moon to rescue several astronauts who have become lost.
Some even suspect that aliens may be involved!



ASTRONAUT REGISTRATION

Before you leave you have to be a registered astronaut, so you will need to provide some information about yourself and pass some tests which will reveal ..
how hard you can pull and push,
what you weigh on both the Earth and the Moon,
how high you can jump and you will complete some other details like your hair and eye colour.

CODE ROOM

You have two secret messages that have been sent to you.

Message 1

This message is written with an ink which is only visible under an ultraviolet light.

Message 2

This message is hidden in a random dot stereogram. you must focus correctly on the image if you are to see this message

COMPUTER LABORATORY

You must find out and record some important facts about the Moon which will enable you to complete the Moon Facts sheet.

LANDING THE LUNAR MODULE

Use a computer to try your skill at landing the lunar module on the Moon's surface without crashing!

MICROSCOPE LABORATORY

You have to identify the manufacturers of several damaged microchips. Replacements can then be obtained and transported to the Moon to repair broken equipment.

CARGO ROOM

You need to work out how much cargo you can carry to the Moon. There is a scale model of the spacecraft's cargo hold. The small wooden blocks represent the containers which must be packed for the flight. How many of these can you pack into the hold? How can you work this out without actually filling the box?

MAGNETICS LABORATORY

1. You will need to sort some brown paper parcels into 3 groups, magnets, pieces of steel and non-magnetic items.
2. Examine and describe the material which can be extracted from 'Lunar sand'.
3. Learn about the effect which magnetic fields can have on electronic recording tape.

MOON BUGGY TRAINING

You must be able to remotely control a Moon Buggy. This vehicle works in a strange way. Can you meet the challenge and unravel its mysteries?

NUTRITION LABORATORY

On the rescue mission you will need food. You have a number of liquids containing different concentrations of sugar. You must work out what the percentage of sugar is in each sample using a sugar refractometer.

COMMUNICATIONS ROOM

You have a radio transmitter with which you can send messages and these can be received on a radio receiver.
You must carry out tests to discover the maximum range you can achieve with this equipment.

ELECTRICAL LABORATORY

Whilst away from the Earth you cannot plug into a socket to get electrical energy. The batteries which you carry will go flat eventually so you will need to use this source of energy wisely.
You must investigate some other options for generating electrical energy.

ELECTRICIAN TRAINING

On the Moon one light globe operating off a single battery will not be bright enough. You must work out how to link 3 battery cells to 3 globes so that you can achieve the brightest light!

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EMERGENCY BATTERY

Your batteries do go flat but you have some salt water and samples of several different types of metals.
You must discover which two metals will provide the greatest current reading

SOLAR CELLS

You must investigate the use of a photovoltaic (solar) cell to convert the Sun's energy into electrical energy which can be used to run a motor.

GENERATOR ROOM

Turn a bicycle wheel to operate a generator and record the voltage reading when the lights are off and then switched on.

SIEBECK PROJECT

Discover the properties of the Peltier device which can generate an electrical current from hot and cold water.

DEMONSTRATIONS

The Moon Rescue Program will conclude with demonstrations using the PET bottle rocket, combustion and expansion equipment, gunpowder and ... the great hydrogen explosion!

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MOON RESCUE

ANSWER SHEET

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.CSIRO Science Education Centre
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CARGO ROOM

Number of modules which will fit in the cargo hold. [ ]

Number of earth modules to be left on the Moon. [ ]

CODE ROOM

Message #1:

Message #2:

NUTRITION LABORATORY

A	B	C	D	E
%	%	%	%	%

COMMUNICATIONS ROOM

What difference does an antenna make to the radio reception?

MOON BUGGY TRAINING

Place a tick in the box if you can successfully move the buggy by radio control from '1' to '2' to '3' and back to '1'. [ ]

MAGNETICS LABORATORY

1. List the numbers printed on the packages which contain..

Magnets: [ ] Steel items: [ ] Non-Magnetic items: [ ]

2. What effect does the magnet have on the cassette tape?

3. Describe the material which you separated from the sand.

MICROSCOPE LABORATORY

Write the names of the semiconductor manufacturers.

1

2

3

ELECTRICIAN TRAINING

On the back of this sheet draw a circuit diagram to show how the 3 batteries and 3 lights must be connected to give the brightest light.

ELECTRICAL LABORATORY

What voltage could you achieve with the bicycle wheel generator firstly with the lights turned off and then with the lights turned on?

Voltage with lights off [ ] Voltage with lights on [ ]

SOLAR CELLS

How far could you move the photovoltaic cell from the light before the propeller just stopped turning?

Distance = [ ] cm

EMERGENCY BATTERY

Which two metals gave the greatest meter reading?

1. ______

2. ______

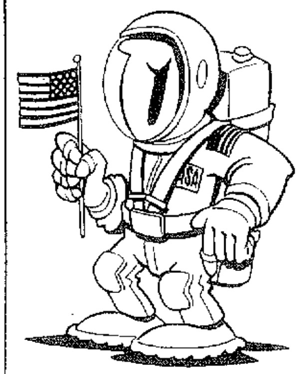
SIEBECK PROJECT

How long did it take after the module was placed in the hot water before the propeller began to turn?

[ ] seconds

How long did the propeller turn after the module was removed from the water?

[ ] seconds



MOON FACTS

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Distance from Earth

Shortest ______ km

Greatest ______ km

Mean ______ km

Diameter ______ km

Age ______ km

Temperature

highest ______ °C

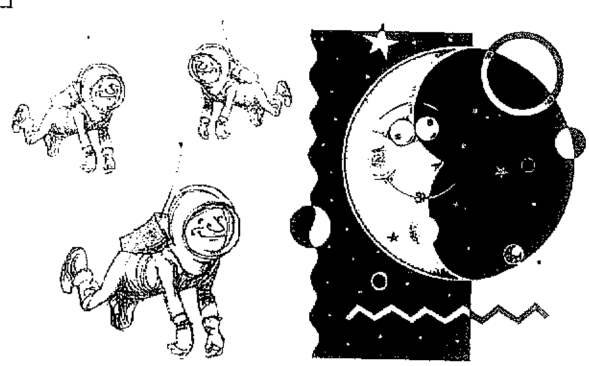
lowest ______ °C

Circumference ______ km

Rotation period about axis ______ days ______ hours ______ minutes

Revolution around Earth ______ days ______ hours ______ minutes

Length of day and night ______ Earth days each



Surface gravity ______ that of Earth

Atmosphere ______ that of Earth

Mass ______ that of Earth

Volume ______ that of Earth

ASTRONAUT REGISTRATION

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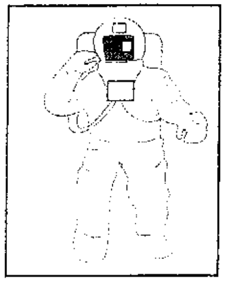
NORTH HOBART 7000



Family Name: Given Names:

Male [ ] Female [ ] Age [ ] Years [ ] Month [ ] Days

Weight on the Earth [ ] kg Weight on the Moon [ ] kg

Vertical Jump on Earth [ ] cm Vertical Jump on Moon [ ] cm

Height [ ] cm Hair Colour [ ]

Eye Colour [ ] Complexion [ ]

Distinguishing Features (if any)

Squeeze Strength

Right Hand [ ] → Ranking [ ] %

Left Hand [ ] → Ranking [ ] %

Chest Strength

Push Strength [ ] → Ranking [ ] %

Pull Strength [ ] → Ranking [ ] %

Skin Surface Areas

Right foot surface area [ ] cm^2 Total body surface area [ ] cm^2

Signatures and Thumb Prints

Signature with Left Hand

Signature with Right Hand

Left Thumb Print

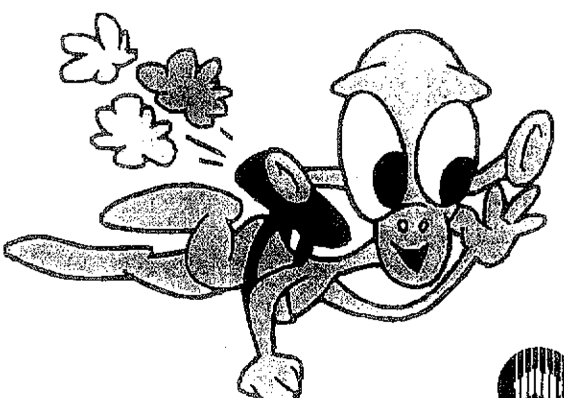
Right Thumb Print

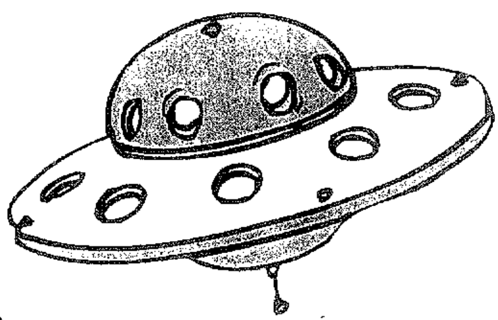
WORD CHANGE PUZZLES

You must change the top word in each group to the bottom word by changing only one letter at a time. Each new word must be a real word. You cannot rearrange any of the letters. The first one is completed as an example

WARM	BOAT	STAR
WARD	______	______
WORD	______	______
CORD	______	______
COLD	CASH	FEET

MORE	FISH	SICK
______	______	______
______	______	______
______	______	______
LESS	MEAT	WELL





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Note: For copyright reasons, pages A 2-21 to A 2-22 of Appendix 2B have not been reproduced.

Lesson Plan #:AELP-SPA0005
CRASHED ON THE MOON
Author: Claudia Todd-Sonnichsen, Ponca City School District, Ponca City, OK.

(Co-ordinator, ADT Project (Bibliographic Services), Curtin University of Technology, 10/10/03)

Appendix 2C

Heat Conduction Worksheet from CSIROSEC Tasmania.

137 **HEAT CONDUCTION**

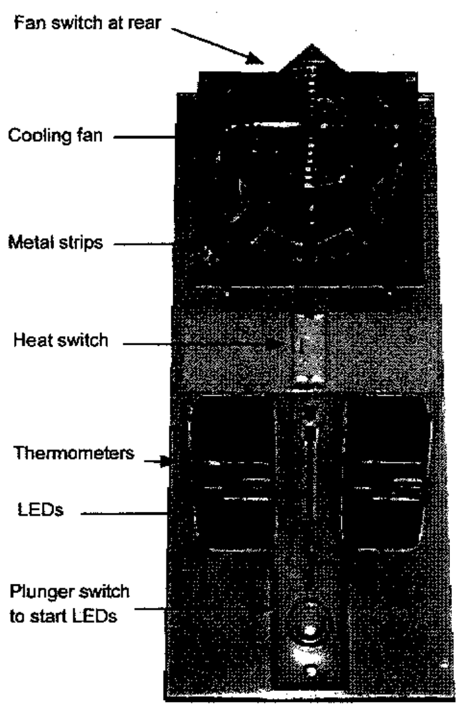
CSIRO

1. Record the starting temperature for each metal. Change from one metal to another by pressing the button next to its name.

2. Turn on the heat switch on top of the apparatus and push down the plunger switch. The small LEDs will begin to move upward. When the jumbo LED lights, a buzzer will sound - read the temperature of each of the metals.

   Work as a team.

3. When you have taken your 20th reading turn off the heat switch on the top and turn on the fan.



COOL

HEAT SWITCH ON (Time 0–20)

HOT

FAN ON (Time 20–30)

COOL

Time	Metal Temperatures °C			
	Copper	Brass	Aluminium	Iron
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
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30				

FOLLOW-UP Plot a graph of Temperature versus Time for each metal.

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Appendix 4A.

Student Version of the Pilot Study Instrument and Student Instructions.

Learning Environment Instrument for CSIRO Science Education Centres

DIRECTIONS

The purpose of these questions is to find out about your visit to the CSIRO Science Education Centre. This is not a "test". You are asked to give your honest opinions about your visit to CSIROSEC.

Record your name, class and school on the top of the sheet in the spaces provided.

Record your answers on this sheet. Answer every question.

In answering each question. go through the following steps.

1. Read the statement carefully.

2. Think about how well the statement describes your visit to CSIROSEC.

3. Indicate your answer by placing a cross in the box which best suits your opinion - strongly agree, agree, neither agree nor disagree, disagree or strongly disagree.

For example -

Question 1 says

I am curious to find out what is happening with the activities.

If you were very curious you would put a cross under *strongly agree*
If you were mildly curious you would put a cross under *agree*
If you were not curious you would put a cross under *disagree*
If you were not at all curious or interested you would put a cross under *strongly disagree*

Some questions need more thought

I have done many of these things in class

If you have done all of the activities in class you would put a cross under *strongly agree*
If you have done many of the activities in class you would put a cross under *agree*
If you have done only some of the activities in class you would put a cross under *disagree*
If you have done none of the activities in class you would put a cross under *strongly disagree*

Do not use the option *neither agree nor disagree* as a quick way out. Try to choose a definite option.

If you change your mind about an answer, erase the cross and put another under your new choice.

Be sure you answer all questions. Make sure you have written your name, class and school on the sheet.

Thank you for your participation.

Name: ______ Class: ______ School: ______	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
1. I am curious to find out what is happening with the activities					
2. I need help to understand what is happening in each activity					
3. Many of the activities are different to the things we do in class					
4. I have to touch and handle things to make them work					
5. I think this kind of science is fun					
6. I have to do something to make things happen in each activity					
1. Most of the activities are boring					
2. I can reach my own conclusions from most activities					
3. Many of these activities are things I have not done in class					
4. I have to do things different ways in different activities					
5. I would like to do science like this more often					
6. I have to investigate to find out what will happen in each activity					
1. Most of the activities are interesting					
2. I am able to decide for myself what is happening in each activity					
3. I have done many of these things in class					
4. I get to practise different science skills					
5. Science is more fun than I thought					
6. I make measurements in many of the activities					
1. I was really keen to do many of the activities					
2. Once you do an activity it is easy to work out what it means					
3. I have been able to try new things here					
4. Many of the activities are done in much the same way					
5. Our class should come here more often					
6. I don't have to do much in many of the activities					
1. I was interested to find out what happened in each activity					
2. You can make up your own mind what each activity means					
3. This type of science is different to the science we do in class					
4. I have to use many science skills to do all of the activities					
5. I don't like this kind of science					
6. I found out how things happened by doing things					

Figure 4A.1. Student Version of the Pilot Study Instrument.

Appendix 4B

Rotated Principal Component Matrices for Pilot Study

Table 4B.1. Rotated Principal Component Matrix for Pilot Study Instrument Components Solution.

	Component					
Item	1	2	3	4	5	6
C1	.62	.10	.39	-.05	.12	-.10
C2[a]	.67	.03	.01	-.03	.13	.22
C3	.71	-.13	.04	.19	.03	-.07
C4	.70	.09	.27	.00	.01	.09
C5	.61	.11	.38	.11	.02	.24
S1[a]	.02	.54	-.35	-.02	-.13	.24
S2	.06	.65	.10	.16	.07	-.14
S3	.11	.74	.15	.08	-.03	.13
S4	.18	.43	.00	.39	.23	-.03
S5	.03	.64	.20	.08	.10	.01
I1	.19	-.03	.31	.05	.57	-.19
I2	.12	.09	-.03	.08	.70	-.09
I3[a]	.00	.00	-.27	.05	.60	.32
I4	.29	.04	.14	.42	.25	.47
I5	.02	.08	.15	.04	.69	.30
M1	-.06	-.04	.46	.29	.21	-.23
M2	-.06	-.01	.33	.56	.06	.16
M3	.39	.17	.26	.09	-.08	.40
M4[a]	.20	-.39	.07	.07	-.03	.49
M5	.05	.14	.64	.08	.04	-.02
A1	.77	-.01	-.03	.26	-.02	-.04
A2	.77	.09	-.18	.10	.17	-.10
A3	.72	.07	.07	.22	.00	.26
A4	.51	.40	.02	-.19	.07	.13
A5[a]	.80	.08	-.09	.14	.11	.10
L1	.11	.10	.23	.73	.17	-.02
L2	.14	.14	.64	.16	-.10	.23
L3	.17	.23	-.10	.63	-.04	.02
L4[a]	.03	.11	-.11	.00	.16	.69
L5	.33	.02	.26	.44	-.18	.38

Table 4B.2. Rotated Principal Component Matrix for Pilot Study Instrument Showing Four Components Extracted.

Item	Component			
	1	2	3	4
C1	.57	.26	.07	.02
C2[a]	.68	-.03	-.02	.18
C3	.70	.10	-.12	.03
C4	.71	.18	.07	.00
C5	.65	.34	.09	.04
S1[a]	.07	-.31	.55	.02
S2	.04	.16	.66	.04
S3	.15	.14	.73	.00
S4	.18	.22	.46	.27
S5	.04	.20	.63	.08
I1	.11	.31	-.05	.43
I2	.05	.06	.08	.64
I3[a]	.02	-.14	-.02	.71
I4	.39	.36	.06	.40
I5	.03	.19	.04	.71
M1	-.09	.56	-.03	.09
M2	.13	.59	.03	.12
M3	.48	.23	.15	.02
M4[a]	.30	.09	-.40	.11
M5	.06	.57	.11	-.07
A1	.76	.07	.01	.02
A2	.72	-.12	.10	.19
A3	.77	.15	.08	.10
A4	.51	-.12	.36	.09
A5[a]	.80	-.03	.09	.18
L1	.15	.62	.16	.21
L2	.22	.59	.12	-.12
L3	.21	.26	.31	.09
L4[a]	.16	-.07	.10	.37
L5	.45	.43	.05	-.03

Appendix 5A.

Student Version of the Redrafted Instrument and Student Instructions.

Learning Environment Instrument for CSIRO Science Education Centres

You are being asked to participate in a research study being conducted as part of a program at Curtin University. Your responses are confidential. Students in other classes at this, and other CSIROSECs in Australia, are participating in this study.

DIRECTIONS

The purpose of this study is to find out about ***your*** visit to the CSIRO Science Education Centre. This is **not** a test. You are asked to give your honest opinions about your visit to CSIROSEC. Do not consult with other students about your responses.

Record your name, class and school on the top of the sheet in the spaces provided. Do this now.

Record your responses on this sheet. Respond to *every* statement.

For each response you will go through the following steps.

1. Read the statement carefully.
2. Think about how well the statement describes ***your*** visit to CSIROSEC.
3. Make your response by placing a cross in the box that best suits your opinion – strongly agree, agree, neither agree nor disagree, disagree or strongly disagree.

For example –

The first statement says

I think science at CSIROSEC is fun.

If you think it was really fun put a cross in the box under *strongly agree*
If you think it was fun put a cross in the box under *agree*
If you think it was OK but not exactly fun then put a cross in the box under *neither agree nor disagree*
If you did not think it was fun put a cross in the box under *disagree*
If you did not think it was fun at all put a cross in the box under *strongly disagree*

Some statements need more thought

I don't like science at CSIROSEC

If you really did not like science at CSIROSEC put a cross in the box under *strongly agree*
If you did not like science at CSIROSEC put a cross in the box under *agree*
If you neither liked nor disliked science at CSIROSEC then put a cross in the box under *neither agree nor disagree*
If you liked science at CSIROSEC put a cross in the box under *disagree*
If you really liked science at CSIROSEC put a cross in the box under *strongly disagree*

If you change your mind about an answer, erase the cross and put another under your new choice.

Be sure to respond to all statements.

Thank you for your participation.

Name: ______ **Class:** ______ **School:** ______	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I think science at CSIROSEC is fun					
The activities are different to the things we do in class					
I have to be involved in activities to make them work					
We collect our own data in each activity					
I work well with the members of my group					
I would like to do science like this more often					
I use different equipment at CSIROSEC than in class					
I have to think about the activities I am doing at CSIROSEC					
I can reach my own conclusions from most activities					
I could get more work done by myself than in my group					
Science is more fun than I thought					
I have done many of these activities before in class					
I handle the equipment to perform an activity					
I am able to decide for myself what is happening in each activity					
The members of my group cooperate with each other					
I would like our science class to visit CSIROSEC more often					
I have tried new activities at CSIROSEC					
I don't have to do much to complete each activity					
We can decide what we need to do in each activity					
I am able to depend on other members of my group for help doing activities					
I don't like science at CSIROSEC					
Science at CSIROSEC is different to the science we do in class					
I use my skills to do the activities					
You can make up your own mind what each activity means					
I help other members of my group					
The activities are interesting to me					
Science at CSIROSEC is the same as at school					
I got involved in the activities here					
I don't need help from the teacher to complete most of the activities					
My group works as a team					
I was really keen to do the activities					
We do science in a different way at CSIROSEC					
I participate in activities using different skills					
I need help from the teacher with most of the activities					
It is easier to get the work done as a team than by myself					

Figure 5A.1. Student Version of the Redrafted Instrument.

Appendix 5B.

Rotated Principal Component Matrices for the Redrafted Instrument.

Table 5B.1. Rotated Principal Component Matrix for the Redrafted Instrument Showing All Items.

	Component				
Item	1	2	3	4	5
A1	.76	.21	.12	.12	.05
A2	.76	.19	.13	.05	.22
A3	.64	.15	.19	.04	.01
A4	.71	.23	.11	.10	.12
A5[a]	.70	.19	.05	.14	.05
A6	.85	.12	.11	.09	-.03
A7	.78	.16	.11	.19	.07
N1	.21	.74	.16	.03	.07
N2	.26	.65	.12	.07	.01
N3[a]	.09	.69	-.23	-.02	-.08
N4	.35	.52	.15	.16	-.10
N5	.12	.78	.17	.07	-.04
N6[a]	.08	.75	.06	.06	.16
N7	.35	.58	.18	.20	.00
S1	.10	.05	.21	.64	.19
S2[a]	-.11	.07	-.32	.63	.03
S3	.17	.07	.10	.76	.08
S4	.18	-.05	.22	.53	-.04
S5	.42	-.01	.36	.45	-.10
S6	.31	.07	.17	.76	.03
S7	.07	.17	.04	.55	-.13
Ind1	.08	.16	.53	.28	-.15
Ind2	.20	.12	.52	-.05	.18
Ind3	.20	.08	.68	.10	.24
Ind4	.04	-.08	.52	-.07	.25
Ind5	.12	.11	.60	.16	.03
Ind6	.22	.10	.15	.17	.66
Ind7[a]	.01	.09	.23	.03	.74
Inv1	.15	.31	.53	-.02	-.21
Inv2	.31	.43	.32	-.03	-.32
Inv3	.24	.06	.62	.19	.05
Inv4[a]	.02	.32	.12	.19	-.46
Inv5	.48	.07	.41	.13	-.23
Inv6	.55	.12	.36	.29	-.03
Inv7	.53	.15	.35	.11	-.11

Table 5B.2. Rotated Principal Component Matrix for the Redrafted Instrument Showing Six Items per Scale.

	Component				
Item	1	2	3	4	5
A1	.77	.19	.13	.13	.07
A2	.77	.18	.07	.21	-.05
A4	.73	.21	.12	.15	.04
A5	.72	.17	.14	.06	.05
A6	.85	.09	.08	.07	.13
A7	.78	.16	.18	.11	.07
N1	.22	.73	.04	.16	.13
N2	.29	.64	.08	.10	.14
N3[a]	.10	.71	-.03	-.24	.02
N5	.11	.77	.07	.12	.22
N6	.09	.78	.07	.11	.00
N7	.36	.54	.18	.11	.24
S1	.11	.05	.66	.27	-.01
S2[a]	-.09	.07	.65	-.26	-.15
S3	.19	.07	.76	.13	.00
S4	.17	-.11	.54	.16	.20
S6	.31	.05	.75	.14	.12
S7	.07	.14	.55	-.04	.18
Ind1	.06	.09	.27	.36	.48
Ind2	.21	.14	-.03	.59	.04
Ind3	.23	.07	.12	.72	.13
Ind4	.04	-.06	.00	.62	-.04
Ind5	.12	.06	.14	.51	.33
Ind7[a]	.04	.17	.05	.54	-.48
Inv1	.14	.21	-.03	.31	.59
Inv2	.29	.34	-.05	.08	.55
Inv3	.25	.03	.19	.57	.26
Inv4[a]	.00	.25	.17	-.13	.51
Inv5	.48	.02	.09	.22	.42
Inv7	.54	.10	.08	.23	.32

Appendix 6A.

Student Version of the Refined Instrument and Student Instructions.

Learning Environment Instrument for CSIRO Science Education Centres

You are being asked to participate in a research study being conducted as part of a program at Curtin University. Your responses are confidential. Students in other classes at this, and other CSIROSECs in Australia, are participating in this study.

DIRECTIONS

The purpose of this study is to find out about ***your*** visit to the CSIRO Science Education Centre. This is **not** a test. You are asked to give your honest opinions about your visit to CSIROSEC. Do not consult with other students about your responses.

Record your name, class and school on the top of the sheet in the spaces provided. Do this now.

Record your responses on this sheet. Respond to *every* statement.

For each response you will go through the following steps.

1. Read the statement carefully.
2. Think about how well the statement describes ***your*** visit to CSIROSEC.
3. Make your response by placing a cross in the box that best suits your opinion – strongly agree, agree, neither agree nor disagree, disagree or strongly disagree.

For example –

The first statement says

I think science at CSIROSEC is fun.

If you think it was really fun put a cross in the box under *strongly agree*
If you think it was fun put a cross in the box under *agree*
If you think it was OK but not exactly fun then put a cross in the box under *neither agree nor disagree*
If you did not think it was fun put a cross in the box under *disagree*
If you did not think it was fun at all put a cross in the box under *strongly disagree*

Some statements need more thought

I don't like science at CSIROSEC

If you really did not like science at CSIROSEC put a cross in the box under *strongly agree*
If you did not like science at CSIROSEC put a cross in the box under *agree*
If you neither liked nor disliked science at CSIROSEC then put a cross in the box under *neither agree nor disagree*
If you liked science at CSIROSEC put a cross in the box under *disagree*
If you really liked science at CSIROSEC put a cross in the box under *strongly disagree*

If you change your mind about an answer, erase the cross and put another under your new choice.

Be sure to respond to all statements.

Thank you for your participation.

Name: ______ Class: ______ School: ______	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I think science at CSIROSEC is fun					
The activities are different to the things we do in class					
I have to be involved in activities to make them work					
I can handle the equipment myself to perform an activity					
I work well with the members of my group					
I would like to do science like this more often					
I use different equipment at CSIROSEC than in class					
I have to think about the activities I am doing at CSIROSEC					
I can reach my own conclusions from most activities					
I could get more work done by myself than in my group					
Science is more fun than I thought					
I have done many of these activities before in class					
We collect the data in each activity					
I am able to decide for myself what is happening in each activity					
The members of my group cooperate with each other					
I would like our science class to visit CSIROSEC more often					
I have tried different activities at CSIROSEC than I have done in class					
I don't have to do much to complete each activity					
We can decide what we need to do in each activity					
I am able to depend on other members of my group for help doing activities					
I don't like science at CSIROSEC					
Science at CSIROSEC is different to the science we do in class					
I have to put effort into each activity					
You can make up your own mind what each activity means					
I help other members of my group					
The activities are interesting to me					
Science at CSIROSEC is the same as at school					
The activities don't work unless I am involved					
I can do the activities myself without adult help					
My group works as a team					
I was really keen to do the activities					
We do science in a different way at CSIROSEC					
I participate in each of the activities					
I need help from an adult with most of the activities					
It is easier to get the work done as a team than by myself					

Figure 6A.1. Student Version of the Refined Instrument.

Appendix 6B.

Rotated Principal Component Matrix for the Refined Instrument.

Table 6B.1. Rotated Principal Component Matrix for the Refined Instrument Showing All Items.

	Component				
Item	1	2	3	4	5
A1	.83	.17	.12	.00	.15
A2	.79	.14	-.01	.14	-.05
A3	.76	.08	.13	.09	.12
A4	.84	.25	.02	.09	.11
A5[a]	.79	.22	.08	.01	.09
A6	.82	.15	.08	.13	.17
A7	.78	.13	.12	.17	.20
N1	.20	.72	.02	.04	.08
N2	.31	.71	-.10	.03	.08
N3[a]	-.06	.72	.01	-.07	.09
N4	.24	.53	.03	.05	.20
N5	.26	.71	.12	.07	.13
N6[a]	.07	.75	.18	.00	.02
N7	.28	.53	.10	.20	.18
S1	.06	-.06	.64	.10	.03
S2[a]	.00	.13	.49	-.33	-.12
S3	.06	-.06	.74	.12	.15
S4	-.01	.14	.63	.08	.00
S5	.15	.04	.64	.19	.19
S6	.11	.03	.81	.13	.13
S7	.09	.16	.65	-.21	.00
Ind1	.05	.00	.04	.61	.25
Ind2	.10	.02	-.01	.61	.14
Ind3	.16	.03	.08	.61	.16
Ind4	.07	.05	.23	.49	.05
Ind5	.04	.05	.00	.51	.11
Ind6	.09	-.05	.00	.69	-.13
Ind7[a]	.01	.21	.06	.55	-.30
Inv1	.20	.21	.06	.22	.51
Inv2	.37	.28	.14	.07	.55
Inv3	.09	.11	.22	.28	.40
Inv4[a]	.09	.19	.06	-.27	.43
Inv5	.20	.21	.23	.01	.65
Inv6	-.01	-.02	-.13	.26	.57
Inv7	.30	.15	.26	.11	.32

[a] indicates negatively worded items which were reverse scored

Appendix 6C.

Internal Consistency Analysis for the Refined Instrument.

Table 6C.1. Internal Consistency Analysis for the Affect Scale with Seven Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
A1	20.88	35.61	.80	.91
A2	20.80	34.02	.71	.92
A3	21.05	35.16	.70	.92
A4	21.01	32.11	.84	.91
A5	20.76	33.85	.76	.92
A6	20.84	34.03	.81	.91
A7	20.92	34.12	.78	.91

Reliability Coefficients 7 items
Alpha = .93 Standardised alpha = .93

Table 6C.2. Internal Consistency Analysis for the Novelty Scale with Seven Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
N1	23.66	17.71	.65	.80
N2	23.62	17.66	.66	.80
N3	23.97	17.73	.52	.82
N4	23.98	18.00	.49	.83
N5	24.00	16.94	.68	.80
N6	23.86	17.49	.60	.81
N7	24.02	18.13	.52	.82

Reliability Coefficients 7 items
Alpha = .84 Standardised alpha = .84

Table 6C.3. Internal Consistency Analysis for the Social Interaction Scale with Seven Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
S1	22.87	19.11	.49	.77
S2	23.47	18.36	.35	.80
S3	22.99	18.09	.60	.75
S4	23.23	18.67	.49	.77
S5	23.05	19.14	.51	.76
S6	23.13	16.51	.69	.73
S7	23.16	17.39	.54	.76

Reliability Coefficients 7 items
Alpha = .79 Standardised alpha = .80

Table 6C.4. Internal Consistency Analysis for the Independent Interpretation Scale with Seven Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
Ind1	22.03	11.98	.48	.67
Ind2	22.13	12.54	.45	.68
Ind3	22.16	12.45	.50	.67
Ind4	22.50	12.56	.36	.70
Ind5	22.38	12.79	.36	.70
Ind6	22.33	11.30	.48	.67
Ind7	22.10	12.01	.37	.70

Reliability Coefficients 7 items
Alpha = .71 Standardised alpha = .72

Table 6C.5. Internal Consistency Analysis for the Involvement Scale with Seven Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
Inv1	21.53	11.72	.45	.63
Inv2	21.40	11.54	.53	.61
Inv3	21.46	12.61	.35	.66
Inv4	22.11	12.67	.24	.69
Inv5	21.57	11.90	.53	.61
Inv6	22.03	12.16	.31	.67
Inv7	21.28	12.67	.38	.65

Reliability Coefficients 7 items
Alpha = .68 Standardised alpha = .69

Appendix 6D.

Rotated Principal Component Matrix for the LEI for CSIROSECs.

Table 6D.1. Rotated Principal Component Matrix for the LEI for CSIROSECs.

	Component				
Item	1	2	3	4	5
A1	.82	.18	.12	.05	.13
A2	.79	.12	-.01	.12	.02
A4	.85	.24	.03	.11	.12
A5[a]	.80	.21	.09	.05	.06
A6	.81	.13	.09	.05	.06
A7	.78	.11	.12	.18	.23
N1	.19	.74	.03	.05	.08
N2	.30	.71	-.09	.03	.10
N3[a]	-.04	.73	.01	-.04	.05
N4	.23	.55	.05	.06	.07
N5	.26	.71	.13	.10	.09
N6[a]	.08	.72	.16	-.04	.11
S1	.05	-.06	.66	.09	.01
S3	.03	-.05	.77	.09	.14
S4	-.02	.15	.63	.10	-.06
S5	.15	.06	.67	.17	.16
S6	.10	.02	.83	.08	.15
S7	.07	.16	.61	-.22	.07
Ind1	.05	.00	.05	.63	.23
Ind2	.08	.03	-.01	.63	.16
Ind3	.16	.04	.10	.66	.09
Ind4	.06	.06	.25	.57	-.08
Ind5	.04	.10	.03	.61	-.06
Ind6	.08	-.13	-.04	.57	.11
Inv1	.18	.17	.06	.12	.66
Inv2	.35	.31	.16	.09	.50
Inv3	.07	.12	.23	.29	.36
Inv5	.19	.22	.25	.00	.61
Inv6	-.05	-.02	-.16	.28	.62
Inv7	.28	.09	.25	-.02	.52

[a] indicates negatively worded items which were reverse scored.
Note. Loadings > .3 are shown.

Appendix 6E.

Internal Consistency Analysis for the LEI for CSIROSECs.

Table 6E.1. Internal Consistency Analysis for the Affect Scale with Six Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
A1	17.55	26.31	.79	.91
A2	17.47	24.83	.71	.92
A4	17.68	23.17	.84	.90
A5	17.44	24.57	.77	.91
A6	17.51	25.00	.79	.91
A7	17.59	24.93	.77	.91

Reliability Coefficients 6 items
Alpha = .92 Standardised alpha = .92

Table 6E.2. Internal Consistency Analysis for the Novelty Scale with Six Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
N1	19.83	13.07	.66	.78
N2	19.79	13.13	.65	.78
N3	20.14	13.08	.52	.81
N4	20.15	13.37	.48	.82
N5	20.16	12.64	.65	.78
N6	20.03	12.93	.59	.79

Reliability Coefficients 6 items
Alpha = .82 Standardised alpha = .83

Table 6E.3. Internal Consistency Analysis for the Social Interaction Scale with Six Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
S1	19.36	14.01	.51	78
S3	19.48	12.95	.65	.75
S4	19.71	13.78	.49	.79
S5	19.54	13.93	.55	.78
S6	19.62	11.64	.73	.73
S7	19.65	13.19	.46	.80

Reliability Coefficients 6 items
Alpha = .80 Standardised alpha = .81

Table 6E.4. Internal Consistency Analysis for the Independent Interpretation Scale with Six Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
Ind1	18.19	8.58	.48	.64
Ind2	18.29	9.04	.45	.65
Ind3	18.32	8.94	.51	.63
Ind4	18.66	8.98	.38	.67
Ind5	18.54	9.11	.38	.67
Ind6	18.49	8.43	.39	.67

Reliability Coefficients 6 items
Alpha = .70 Standardised alpha = .70

Table 6E.5. Internal Consistency Analysis for the Involvement Scale with Six Items.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item Total Correlation	Alpha if Item Deleted
Inv1	18.41	8.80	.50	.63
Inv2	18.28	9.00	.51	.62
Inv3	18.34	9.82	.34	.68
Inv5	18.45	9.30	.51	.63
Inv6	18.91	9.41	.31	.70
Inv7	18.16	9.76	.40	.66

Reliability Coefficients 6 items
Alpha = .69 Standardised alpha = .70

Appendix 7A.

Student Version of the LEI for CSIROSECs and Student Instructions.

Learning Environment Instrument for CSIRO Science Education Centres

Your opinions about your visit to CSIROSEC are important to us. This information is being used to monitor the quality of, and to continually improve, the CSIROSEC learning experience.

DIRECTIONS

The purpose of this study is to find out about ***your*** visit to the CSIRO Science Education Centre. This is **not** a test. You are asked to give your honest opinions about your visit to CSIROSEC. Do not consult with other students about your responses.

Record your name, class and school on the top of the sheet in the spaces provided. Do this now.

Record your responses on this sheet. Respond to *every* statement.

For each response you will go through the following steps.

1. Read the statement carefully.
2. Think about how well the statement describes ***your*** visit to CSIROSEC.
3. Make your response by placing a cross in the box that best suits your opinion – strongly agree, agree, neither agree nor disagree, disagree or strongly disagree.

For example –

The first statement says

I think science at CSIROSEC is fun.

If you think it was really fun put a cross in the box under *strongly agree*
If you think it was fun put a cross in the box under *agree*
If you think it was OK but not exactly fun then put a cross in the box under *neither agree nor disagree*
If you did not think it was fun put a cross in the box under *disagree*
If you did not think it was fun at all put a cross in the box under *strongly disagree*

Some statements need more thought

I don't like science at CSIROSEC

If you really did not like science at CSIROSEC put a cross in the box under *strongly agree*
If you did not like science at CSIROSEC put a cross in the box under *agree*
If you neither liked nor disliked science at CSIROSEC then put a cross in the box under *neither agree nor disagree*
If you liked science at CSIROSEC put a cross in the box under *disagree*
If you really liked science at CSIROSEC put a cross in the box under *strongly disagree*

If you change your mind about an answer, erase the cross and put another under your new choice.

Be sure to respond to all statements.

Thank you for your participation.

A = Affect N = Novelty Inv = Involvement Ind = Independent Interpretation S = Social Interaction	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I think science at CSIROSEC is fun					
The activities are different to the things we do in class					
I have to be involved in activities to make them work					
I can handle the equipment myself to perform an activity					
I work well with the members of my group					
I would like to do science like this more often					
I use different equipment at CSIROSEC than in class					
I have to think about the activities I am doing at CSIROSEC					
I can reach my own conclusions from most activities					
It is easier to get the work done as a team than by myself					
I would like our science class to visit CSIROSEC more often					
I have done many of these activities before in class					
We collect the data in each activity					
I am able to decide for myself what is happening in each activity					
The members of my group cooperate with each other					
I don't like science at CSIROSEC					
I have tried different activities at CSIROSEC than I have done in class					
I don't have to do much to complete each activity					
We can decide what we need to do in each activity					
I am able to depend on other members of my group for help doing activities					
The activities are interesting to me					
Science at CSIROSEC is different to the science we do in class					
I have to put effort into each activity					
You can make up your own mind what each activity means					
I help other members of my group					
I was really keen to do the activities					
Science at CSIROSEC is the same as at school					
The activities don't work unless I am involved					
I can do the activities myself without adult help					
My group works as a team					

Figure 7A.1. Student Version of the LEI for CSIROSECs.