

Science and Mathematics Education Centre

**Virtual Field Trips:
Using Information Technology to Create an
Integrated Science Learning Environment**

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ABSTRACT

This study evaluated a new Integrated Science Learning Environment (ISLE) that bridged the gaps between the traditionally separate classroom, field trip, and information technology milieus. The ISLE model involves a multi-faceted design to address the three basic forms of learning: acquisition of knowledge, change in emotions or feelings, and gain in physical or motor actions or performance. A holistic approach to teaching at the university level encompassed a step-wise, cumulative strategy that reinforced all scales of the Constructivist Learning Environment Survey (Personal Relevance, Uncertainty of Science, Shared Control, Critical Voice, and Student Negotiation) and minimised the potentially detrimental effects of information overload and non-linear processing.

By addressing individuals and recognising limitations, the same conceptual and logistical frameworks were applied to teachers and to students uniformly in the classroom and in the field. This key factor of the ISLE program broadened all participants' horizons and enabled them to see their role within the 'big picture'. Thus, the common elements (knowledge) and basic components (understanding) in each realm became evident and the power of transfer for both content and concept was realised. A process approach to information technology provided a logical and meaningful mechanism for continuously scaling the program perspective from the classroom setting to the unique global environment of the World Wide Web. The final product of the ISLE program (virtual field trip) was constructed by linking the elements common to the supporting learning environments (university classroom, field trip, and information technology) at their basic levels: newness, massiveness, and appropriateness.

A combination of qualitative methods and quantitative measures provided insight into the field trip milieu and evaluation of the near- and far-term effects of exposure to constructivist pedagogy answering the general question of whether changing teachers' learning environments might affect a change in their respective students' learning environments. Quantitative assessment through learning environment dimensions, attitude scales, and concept map analyses was supported by qualitative data derived from reflective field journals, interviews, and observations to investigate the impact of the emergent model. Data were collected from classroom teachers and their students to assess the impact of the ISLE program in terms of

promoting a constructivist classroom learning environment, teachers' attitudes toward information technology, and teachers' conceptual development. School teacher and student subgroups were compared in terms of the teachers' university/field trip program experience and content background.

To this end, three new versions of the Constructivist Learning Environment Survey (CLES) were shown to be valid and useful in secondary schools and graduate university courses in Texas. Data from 1079 students in 59 classes in north Texas were subjected to principal components factor analysis confirmed the factor structure, internal consistency reliability, discriminant validity, and the ability to distinguish between different classes and groups for the comparative student form (CLES-CS). Descriptive statistics supported the usefulness of the comparative teacher (CLES-CT) and adult (CLES-A) forms. Administration of these versions of the same instrument was used to characterise the learning environment of the ISLE university/field trip program, as well as the public/private school classrooms.

Further analysis and interpretation of these data suggest that the ISLE program was effective in terms of the degree of implementation of constructivist teaching approaches in the teachers' school classrooms as assessed by teachers' perceptions of the learning environment of their current classroom environment relative to other classes taught by them previously and students' perceptions of the learning environment of their classroom environment relative to classes taught by other teachers in their school classrooms. Additional data suggest that the ISLE program was effective in terms of teachers' perceptions of the university/field trip learning environment; changes in teachers' attitudes to information technology; and teachers' conceptual development. When an ANOVA was used to compare students' perceptions of THIS and OTHER classes, statistically significant differences were found for some CLES scales. In particular, students whose teachers had attended the ISLE program (THIS) perceived higher levels of Personal Relevance and Uncertainty of Science in their classrooms relative to the classrooms of other teachers in the same schools (OTHER).

From a practical point of view, this study documents a new model for improving learning and understanding in the field of education, specifically science education. Participation in the ISLE program provided a tangible opportunity for teachers to gain organised knowledge to make practical changes in their school classrooms. From a research point of view, this study makes a unique contribution to

the field of learning environments by evaluating a comprehensive professional development program that used information technology to initiate teacher change from the central perspective of the learning environment. Development and validation of the CLES-CS contributes to a useful range of instruments for a variety of classroom contexts within the burgeoning field of learning environments research.

The real world is where theory and practice come together and science becomes relevant, making sense that leads to understanding. The conceptual and logistical frameworks of the ISLE model seamlessly merged theory and practice with science and education through effective applications of information technology to create a rich learning environment. Virtual field trips, based on the ISLE model, can enable the principles of student-centred inquiry and constructivism to be practised for the benefit of all styles and ages of lifelong learners.

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I extend my gracious thanks to many unnamed individuals and organisations for their continued impact on the development of science education through the action of dedicated teachers and administrators who influence the lives of our students every day.

Technology is the application of creative thinking and ingenuity to the solution of definable and practical problems in all fields of endeavour.

Haydn Williams, Director
Western Australia Institute of Technology (1967-1979)
(now Curtin University of Technology)

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Chapter 1

ISLE PROGRAM AND THESIS OVERVIEW

Give a man a fish and he eats for a day.
Teach a man to fish and he eats for a lifetime.

Mother Teresa

...unless he doesn't know what bait to use!

(Ledbetter, 2001)

Teachers know how to 'fish'; the Integrated Science Learning Environment (ISLE) provides a structure that helps them 'choose the bait'. The influence and ability of teachers impact every person within the respective city, county, state, country, and ultimately the global community. Because we live in a closed system, each of us must appreciate and value the natural world. As citizens of this age, we must also be able to understand and judge the science within it. Learning is not a time-constrained event. It is a process that continues throughout each person's life. Effective educators enable individuals to realise their potential, developing lifelong learners – and leaders.

The ISLE model fosters a multi-faceted learning environment that makes content and pedagogy relevant. It binds the basic strands of science, research, and science education together through a deliberately designed program of study. Real-world experience, presented in an openly versatile, inquiry-based product, weaves a single tapestry that prepares our teachers to lead our students powerfully and wisely. Theory does not effect change; people do. Teachers, in particular, must be encouraged to exercise playfulness, ingenuity, and creativity. Always a matter of context, 'play' is the free spirit of exploration, doing and being for its own pure joy. Technique is acquired by "the practice of practice, by persistently experimenting and playing with our tools and testing their limits and resistances" (Nachmanovitch, 1990, p. 42). The ISLE program provides a tangible opportunity for teachers to gain organised knowledge to make practical changes in education.

This chapter is comprised of four main sections. The following section, 1.1, describes the rationale for developing a new model, including the significance of the research study (section 1.1.1) and the influence of the researcher's personal

experience on the development and evaluation of the ISLE model (section 1.1.2). Section 1.2 states the specific research questions investigated in this study, explains the organisation of this thesis (section 1.2), and defines terminology as used specifically within the ISLE model (section 1.2.2). Section 1.3 presents an overview of the research study in terms of the Phase I (section 1.3.1) and Phase II (section 1.3.2) classroom learning environments. And finally, section 1.4 summarises this overview of the research study.

1.1 Rationale for Developing a New Model

New learning environments are either being created or are presently evolving to supply the demands of local business and the global society. Time and space no longer limit the possibilities for lifelong learning. Compared to the rapid pace of everyday operations fuelled by the ‘information explosion’, advances in science education are slow-going, at best (Kuhn, 1970). To keep up with today’s ‘Nintendo Generation’, educators need a new perspective – and they need it now! The information revolution has provided overwhelming opportunities and options for virtually anyone who is interested (Nix, 1998).

Placing new content in personally-relevant contexts is the ultimate challenge of learning. Subjects traditionally perceived as a series of distinct facts, such as the sciences, are particularly difficult to internalise and to apply in meaningful ways across variable situations. This ability to transfer knowledge and skills is critical in today’s changing society. In addition, decisions are no longer black or white, right or wrong. Choices are typically based on the better selection of several possibilities. The ability to perceive the ‘bigger picture’ with innovative critical thinking and creative problem-solving skills is a new requirement for success.

The purpose of this study was to evaluate a new teaching model for long-term professional development designed to foster a constructivist approach (Harper & Hedberg, 1997; Neimeyer & Mahoney, 1999; Novak, Mintzes, & Wandersee, 2000a; Taylor, 1996; Tobin, 1990; von Glaserfeld, 1993, 1995) to science education. Maintaining a comfortable, non-intrusive, team-oriented environment (Henton, 1996; Jackson & Ruderman, 1999; Jelinek, 1998; Luckner & Nadler, 1997; Sakofs & Armstrong, 1996) is critical to achieving the desired outcomes. Making the case for development of a comprehensive ‘theory of education’, Novak (1998) emphasises that: “Successful education must focus on more than the learner’s thinking. Feelings

and actions are also important” (p. 9). Therefore, the ISLE model involves a multifaceted milieu to address the three basic forms of learning: acquisition of knowledge, change in emotions or feelings, and gain in physical or motor actions or performance. The effective program outcome (pertaining to cognitive learning) was to develop an Integrated Science Learning Environment (ISLE) that supports individual understanding of essential science knowledge and skills. The affective program goal (pertaining to emotions or feelings) was to encourage innovation and creativity for the practical implementation of unique ideas across interdisciplinary fields to realise a comprehensive perspective. Each of these outcomes was mechanistically (pertaining to physical action or performance) enhanced by the immediacy and concreteness of feedback in field settings. Significant and sustained increases in self-esteem and reductions in anxiety can be realised in the inherently empowering natural environment, especially for women (Cole, Erdman, & Rothblum, 1994).

Such holistic (effective and affective) transformation can be exponentially promoted in the public/private school classroom through established teacher education programs (Rillero, 1993). For instance, recent advances in information technology offer exciting opportunities to facilitate the transfer of university coursework into the school classroom (Brauch, Gerhold, & Patt, 1996). The ISLE model employed a virtual field trip to develop both the content and the context of ecology, geology, and environmental change for use in primary and secondary education. Real-world applications of relevant information technology (a broad term including all types of scientific and educational tools and resources – not limited to computers and peripherals) were covertly employed to merge the university classroom and the field trip experience. A recent study by Pohl (1999) supports the use of process skills and constructivist techniques with real-life problem solving to improve science learning. Although classroom implementation was further influenced by each teacher’s unique school classroom learning environment, the teachers had a true sense of constructivist teaching and the benefit of a new community of peers to support their common view.

Once people overcome the anxiety of using various techniques and tools, they are able to see the benefits and apply the options in amazingly effective and efficient ways to solve their unique problems. Taking advantage of these newly discovered resources becomes an exciting and automatic ‘second nature’. The same holds true for classroom teachers charged with integrating and implementing educational

applications of information technology into their teaching. A process approach to applying information technology within the context of science education was used to make the hardware and software virtually invisible. The focus was thereby shifted from ‘figuring out how to use a new toy’ to finding ways to improve teaching and enhance learning through the most appropriate method(s).

1.1.1 Significance of the Research Study

In terms of program development, this study examines a novel combination of influences from the fields of science education (constructivism and concept mapping), psychosocial cognition (experiential training and knowledge transfer), and information technology (data management and web-based presentation). Deliberate in design, this model encourages individual communication, collaboration, and creativity to develop a sense of ownership in and a personal relevance of a complex group product. Such skills are critical to the success of both teachers and students in today’s rapidly advancing information-driven society.

From a practical point of view, this study documents a new model for improving learning and understanding in the field of education, specifically science education. Ever-changing societal needs necessitate new roles for both teachers and students. By supporting the teachers’ initiative in the design and development of an inquiry-based Internet product, participants see how the same content can be discovered through unique pathways. They are then able to support learners in addressing various elements at multiple levels. A seamless learning environment links complex multidisciplinary content through clearly defined inter-relationships to meet or exceed the demands of a diverse range of learning, teaching, and evaluation styles effectively and efficiently.

From a research point of view, this study makes a unique contribution to the field of learning environments by evaluating an integrated milieu that envelops three classically distinct learning environments. Previously, dimensions of learning environment research have not been used frequently in program evaluation (Fraser, 1998a). However, approaching learning holistically requires the integration of the physical, intellectual, and emotional portions of the learning psyche. Therefore, this study combines several research techniques to provide a comprehensive evaluation of the proposed model. Triangulating the data internally (through multiple versions of a single instrument), as well as externally (through various sample stratifications

and statistical methods), enables the multidimensional assessment of this new integrated learning environment.

1.1.2 Influence of Personal Experience on the Model and Study

I, the educational researcher for this study and information technology assistant for the ISLE program, received my Master of Arts in Teaching degree (MAT) in Science Education with the full benefit of several incredible field trip experiences from Monterey, Mexico to Santa Fe, New Mexico; Belfast, Northern Ireland to Belize, Central America; uninhabited islands in the Sea of Cortez to the British Virgin Islands; national parks between Big Bend, Texas and Yellowstone, Wyoming; and the Grand Canyon in Arizona to the Rocky Mountains in Colorado. All the classroom preparation and laboratory research came together, making natural sense, in the field. I could practise my observation and learned skills, exercise my logic and reasoning, and demonstrate my understanding of complex processes in a real-world, systems-based environment.

This unique background developed and encouraged my individual abilities that proved exceptionally valuable in a variety of work environments, including retail sales, international petroleum exploration, technical documentation, corporate training, and business marketing in diverse arenas. I applied my knowledge and skills with great satisfaction in each of those settings. Personally, I do not particularly care for information technology in and of itself, but I do love the wonderful things it has enabled me to accomplish. This was the perspective on information technology that I saw lacking in most settings. Education was the perfect area in which to maximise this advantage, as there are so many benefits to be gained through the appropriate application of information technology by both teachers and students. So, I returned to continue my work in my multi-favoured field of science education.

Virtual field trips have always been a dream career for me. Even as a child, I designed a 'Teachers' Video' program that would take me all over the planet to see – *and share* – the wonders of the real world. But, it had to be much more than just a sensationalised travel brochure. The goal was to show how each of the parts works together to create the whole. (This is the same approach that I chose to nurture my personal wellness. By mixing a variety of physical, intellectual, and emotional techniques, both the body and the mind can be treated as a single functional unit.) To complete my Texas state teacher certification in 1986, I produced a series of 35-

millimeter slide presentations based on the same idea, calling them ‘Friday Field Trips’. As a Master’s candidate in 1996, a similar format was developed as an electronic presentation and finally labelled as a ‘Virtual Field Trip’. With the recent advances in technology and reform movements surfacing in education, the timing for this doctoral thesis could not have been better.

I first investigated the feasibility of using the World Wide Web as a delivery mechanism for such a resource. The results were encouraging. Next, I looked at what similar products were already available on the Internet. Classroom materials – specifically, science-related virtual field trips – were not being created by classroom teachers. *Were they used by classroom teachers?* I suspected not, simply because of how teachers were being trained, particularly their introduction to information technology and their conditioning to ‘teach to the test’. Indeed, a computer kiosk could certainly replace a teacher if you are willing to settle for rote memorisation of millions of bits of information. I expect more for my niece and nephew. Information technology is a gift that we are called upon to put to good use. It should not be the epitome of our laziness, manifest as the ultimate automated scapegoat. So, I sought a way to bring the two seemingly disparate worlds together. In 1998, as a university instructor, I found that this endeavour would be even more complex than I imagined.

Changing the way in which I talked about information technology in the light of science education did change the teachers’ attitudes toward new tools and techniques. In fact, by *not* talking about it, the teachers became interested in the potential and were motivated to explore new options and experiment with innovative ideas. They simply needed to see anyone teach something that effectively integrated any technology. For this reason, the Community Juggling activity (Nix, 2000b) became a powerful metaphor for managing information overload and for processing information in a non-linear environment (see Appendix I).

In essence, the ISLE program showed teachers how a field ecology instructor, information technology assistant, and educational researcher teamed to create, deliver, and assess an effective model. The end product, a comprehensive web-based virtual field trip, offers a useful resource to many teachers, not just those who actually experienced the field trip. The joint implementation of the latest trends in science teaching (modelling constructivism), information technology (developing the virtual field trip), and educational research (combining qualitative and quantitative data) effected a change in the teachers that will ultimately affect their students.

1.2 Specific Research Questions

The study focused particularly on science education because of the researcher's training and access to an established program. The general question asked concerned whether or not a teacher's participation in the Integrated Science Learning Environment program would lead to the teachers' implementation of constructivist learning environments in their respective students' school classrooms. The aim of the study was to evaluate the ISLE program in terms of promoting a more constructivist classroom learning environment, teachers' attitudes toward information technology, and teachers' conceptual development. This involved quantitative assessment through learning environment dimensions, attitude scales, and concept map analysis. The interpretation of these results was supported by inferences based on qualitative data derived from reflective field journals, interviews, and observations. The ISLE data were also compared to similar data collected prior to implementation of the ISLE program to suggest the impact of the emergent model.

Specifically, the research addressed the following questions:

- Question 1: Are new versions the Constructivist Learning Environment Survey (CLES) valid and useful in secondary schools and graduate university courses in Texas?
- Question 2: How effective is the Integrated Science Learning Environment (ISLE) university/field trip course in terms of the degree of implementation of constructivist teaching approaches in the teachers' school classrooms as assessed by:
- (a) teachers' perceptions of the learning environment of their current classroom environment relative to other classes taught by them previously;
 - (b) students' perceptions of the learning environment of their classroom environment relative to classes taught by other teachers in their school; and
 - (c) various qualitative methods (i.e., observation, interview, journal)?
- Question 3: How effective is the Integrated Science Learning Environment (ISLE) university/field trip course in terms of:
- (a) teachers' perceptions of the university/field trip learning environment;

- (b) changes in teachers' attitudes to information technology; and
- (c) teachers' conceptual development?

1.2.1 Organisation of the Thesis

This thesis is comprised of nine chapters. Chapter 1 introduces the Integrated Science Learning Environment (ISLE) program. Previous sections described the rationale for developing a new model and provided an overview of the research study. This section states the specific research questions investigated. The organisation of the thesis and the terminology used specifically in the ISLE model are defined in the following sections of this chapter.

Chapter 2 describes the context of the ISLE model in terms of significant trends in scientific methodology and pedagogical practice that are pertinent to today's educational environment, supporting the rationale for this research. After discussing the call for educational reform on a global scale, specific issues in education in the United States are introduced. Particularly relevant to this study (conducted in north Texas), the state of science education in Texas is further addressed in terms of teacher preparation and certification, and curriculum research and development. And finally, the role of field trips in science education is reviewed.

To further explain the Integrated Science Learning Environment, Chapter 3 details the conceptual framework of the ISLE model. Each learning environment impacting the integrated milieu is independently described with respect to information technology, classrooms, and field trips. The Integrated Science Learning Environment (ISLE) is then described in terms of factors that influence a holistic implementation of field-based programs and expectations for programs based in the ISLE model. In parallel, Chapter 4 provides a thick description of the logistical framework of the ISLE program to elucidate the physical parameters that influenced the model design and research study. The pre-trip coursework and local day trips, extended field trip, and post-trip coursework and follow-up activities are detailed in a chronological fashion.

Chapter 5 explores the growing field of learning environments research. To place the ISLE model into this context, the assessment and evaluation of learning environments and the applications of the resultant classroom environment research is reviewed. In addition, the implications and application of existing learning

environments research with respect to the ISLE program are discussed to aid in the interpretation of data pertaining to Research Question 1. Delineation of the Integrated Science Learning Environment in terms of the separate milieus it encompassed aids in the interpretation of data pertaining to Research Question 2. Chapter 6 reviews the present and past literature that influenced the design and implementation of the ISLE model. To aid in the interpretation of data pertaining to Research Question 3, trends in curriculum and instruction brought about by the advent of information technology are described. Separate case studies were conducted to isolate and test each of the critical factors seamlessly combined within the ISLE model to aid in the interpretation of data.

Chapter 7 summarises the research methods used in this study to evaluate the ISLE program. It explains how various quantitative measures were supported by qualitative measures to provide insight into the field trip milieu and evaluation of the near- and far-term effects of exposure to constructivist pedagogy. The development and use of each instrument used in the ISLE program evaluation are detailed independently for reference. Then data collection procedures and purposes are explained with respect to the specific research questions asked in Chapter 1. Limitations of this study are discussed in terms of sample selection, scheduling issues, course credits, external variables, and instrument administration.

Following a detailed description of the various sample groups examined, Chapter 8 presents the results of this research study of the ISLE program. Data concerning the validity and usefulness of the new versions of the Constructivist Learning Environment Survey (CLES) in north Texas are presented to answer Research Question 1. This includes the validity of the comparative student form (CLES-CS) for use in secondary schools, the usefulness of the comparative teacher form (CLES-CT) in secondary schools, and the usefulness of the adult form (CLES-A) in universities. Data concerning the effectiveness of the ISLE program for implementation of constructivist teaching in schools are presented to answer Research Question 2 in terms of teachers' perceptions of their school classroom teaching and students' perceptions of their school classroom learning. A case study then compares one ISLE teacher's and her respective students' perceptions of constructivist practice in the science classroom.

Also in Chapter 8, data concerning the effectiveness of the ISLE university/field trip program are presented to answer Research Question 3 in terms of

teachers' perceptions of the constructivist nature of the university instructors' learning environment (Research Question 3a) and changes in teachers' attitudes toward information technology (Research Question 3b). And, data concerning the effectiveness of the ISLE program for teachers' conceptual development are presented to answer Research Question 3c in terms of the participants' development of concepts during the ISLE program and content representation in teacher-generated concept maps. Finally, a case study illustrates one teacher's transition from creating concept maps based on a linear structure to creating concept maps based on a non-linear format.

Chapter 9 closes with conclusions and recommendations offered in light of this evaluation of the Integrated Science Learning Environment (ISLE). Correlations among the instruments used in this evaluation are examined and the ISLE program design is discussed in terms of individual participation in pre-trip, field trip, and post-trip activities. The implications of this study for further research and other applications of the ISLE model are also suggested.

1.2.2 Definition of Terms

What exactly is a virtual field trip? Think about any trip you have taken to any place for any reason. Was there a sense of awe or wonder? Can you feel the excitement of a journey or the intrigue of a new place? Do images or sounds of the visit flash through your mind even today? Which specific aspects do you remember about that personal life experience? A virtual experience can inspire the same sensations.

Webster's online dictionary defines virtual as "being such in essence or effect though not formally recognized or admitted" and field trip as "a visit (as to a factory, farm, or museum) made (as by students and a teacher) for purposes of firsthand observation" (Merriam-Webster Online, 1999). With an intentionally professional perspective, one educator suggests that teachers "start thinking about electronic field trips as an ITV [Instructional TeleVision] model that works out with weights 30 hours a week" (Coletti, 1999, Introduction, ¶ 2). Another organisation defines a virtual field trip as "a guided and narrated tour of web sites that have been selected... and arranged in a 'thread' that students can follow from site to site with the click of a single button" (Virtual Blackboard, 1999, Curriculum, ¶ 2).

For the purpose of this study, a virtual field trip is an inter-related collection of images, supporting text, and/or other media, delivered electronically via the World Wide Web in a format that can be professionally presented to relate the essence of a visit to a time or place. The virtual experience becomes a unique part of the participants' life experiences.

Specifying the virtual field trip as an application centred in the experience of the student places it in the learning technology sector of educational technology as defined at a National Science Foundation workshop on the impact of information technology on undergraduate education in science, mathematics, engineering, and technology. A focused group of instructors, students, academic administrators, publishers, and industry professionals characterised effective use of information technology as application(s) that:

- 1) stimulate students and engage them with the material, such as role-playing simulations;
- 2) illustrate the workings of complex systems by exploring cause-and-effect relationships, or demonstrate microscopic, molecular, or hypothetical scenarios;
- 3) encourage collaboration with other individuals, teams, or institutions to coordinate a group effort while exposing students to different ideas and perspectives (e.g., electronic mail for communicating with classmates or instructors);
- 4) foster development of critical thinking skills, visualization, conceptualization, integration of disparate data and resolution of patterns within data;
- 5) utilize the World Wide Web for research, advertising, and posting material. (National Science Foundation, 1998, p. 14)

Throughout this thesis, 'instructors' refers to university classroom educators at the postgraduate level and professional trainers in a respective field; 'teachers' refers to preservice and inservice classroom teachers in public/private schools; 'educators' refers to instructors, teachers, and other professional trainers; and 'students' refers to K-12 children in public/private school classrooms. Additional terms used specifically in this study are defined in Table 1.

Table 1. **Integrated Science Learning Environment (ISLE) Terminology**

Term	Definition
Critical Voice*	Extent to which a social climate has been established in which participants feel that it is legitimate and beneficial to question the leader's pedagogical plans and methods and to express concerns about any impediments to their learning
Everest Syndrome	Tendency to feel the need to use technology, simply because it exists; includes overwhelming nature of massive amounts of information resources and tools available
Experiential Learning	Builds on physical activity structured to affect an emotional response and intellectual awareness through a cycle of experience, reflection, generalisation, and application (ERGA)
Information Explosion	Creation of massive amounts of bits of data
Information Technology	IT; a broad term including all types of scientific and educational tools and resources – not limited to computers and peripherals
Last-Day Phenomenon	Characterised by rising inhibitions and withdrawal for personal protection against separation from group and re-entry into respective daily roles
Me-Too Phenomenon	Tendency of participants to flock together
Novelty Factor	The excitement of a field trip and the newness of an area
Personal Relevance*	Extent to which program leaders relate science to participants' out-of-school experiences
Shared Control*	Extent to which participants are invited to share with the leader control of the learning environment, including the articulation of their own learning goals, design and management of their learning activities, and determining and applying assessment criteria
Student Negotiation*	Extent to which opportunities exist for participants to explain and justify to other participants their newly developing ideas and to listen and reflect on the viability of other participants' ideas
Three-Day Phenomenon	Period of adjustment typically required for individuals to feel comfortable as a part of the functional field trip group
Uncertainty of Science*	Extent to which opportunities are provided for participants to experience scientific knowledge as arising from theory dependent inquiry, involving human experience and values, evolving and non-foundational, and culturally and socially determined
Virtual Field Trip	An inter-related collection of images, supporting text, and/or other media, delivered electronically via the World Wide Web, in a format that can be professionally presented to relate the essence of a visit to a time or place

* Scales of the Constructivist Learning Environment Survey (CLES)

1.3 Design of the Research Study

As stated in section 1.2, the purpose of this research study was to determine the impact of the teachers' participation in the ISLE program on their respective students' learning environments. The primary sample consisted of 12 classroom

teachers and one administrator from the Dallas-Fort Worth metroplex area, representing 773 science students. The study was conducted in two distinct phases. Phase I involved investigating the university classroom and extended field trip. Phase II involved investigating the impact of the ISLE program on public/private school classrooms.

1.3.1 Phase I: University Classroom/Extended Field Trip

Phase I involved investigation of the university classroom and extended field trip learning environments. Figure 1 illustrates how the data-collection instruments used in Phase I link the specific research questions to the overall study. Focused on the university classroom and extended field trip learning environment, the research design for Phase I combined the use of a new version of the Constructivist Learning Environment Survey (CLES), the Teachers' Attitudes Toward Information Technology (TAT) questionnaire, and participant-generated concept maps and qualitative data from interviews, observations, and reflective field journals.

To partially answer Research Questions 1 and 3a, the adult form of Constructivist Learning Environment Survey (CLES-A) was used to determine the participants' perceived effectiveness of the university classroom/extended field trip course in terms of modelling constructivist practice. These data were also used to qualitatively evaluate the usefulness of the CLES-A for universities in the north Texas area.

To partially answer Research Question 3b, qualitative data from the participants' reflective field journals and the field ecology instructor and information technology assistant's observations were used to determine the effectiveness of the university classroom/extended field trip course in terms of the instructors' integration of information technology. Also, quantitative data from the Teachers' Attitudes Toward Information Technology (TAT) questionnaire were used to determine the effectiveness of the university classroom/extended field trip course in terms of changes in teachers' attitudes toward information technology. And, to partially answer Research Question 3c, qualitative data and individual concept maps created by the university classroom/extended field trip course participants were used to determine the effectiveness of the university classroom/extended field trip course in terms of the participants' conceptual development.

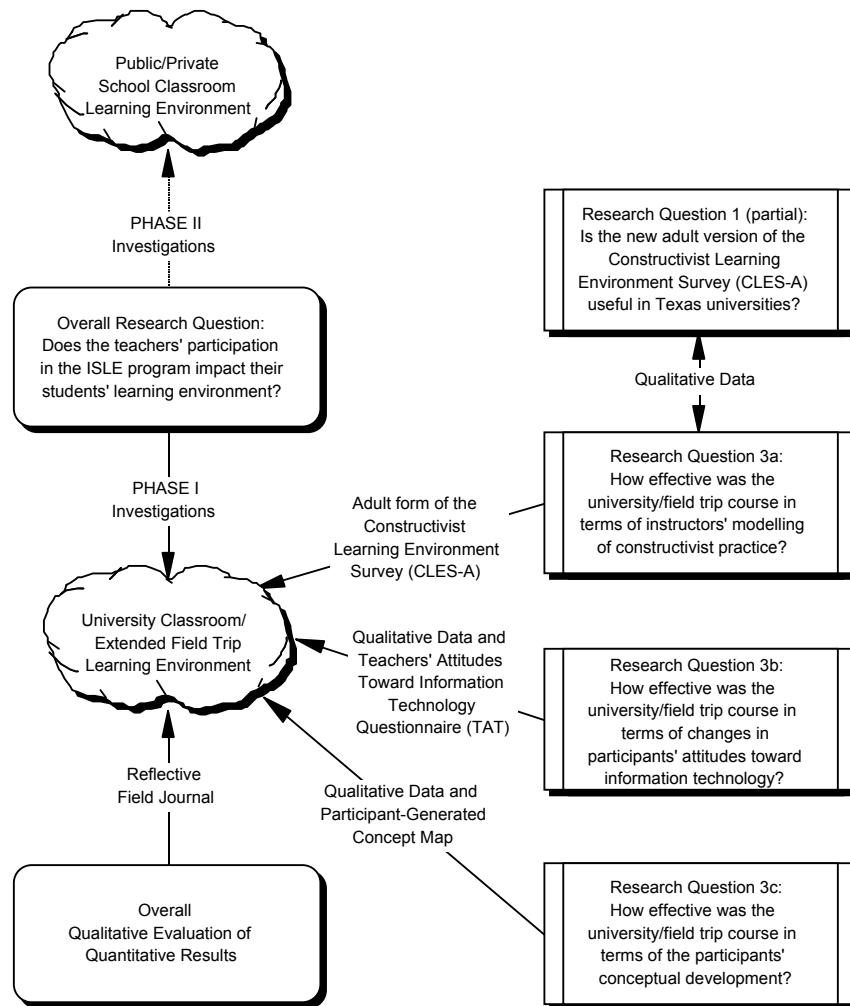


Figure 1. **Phase I Research Design: Examining the University Classroom/Extended Field Trip Learning Environment**

1.3.2 Phase II: Public/Private School Classrooms

Phase II investigated the individual public/private school classroom learning environments. Figure 2 illustrates how the data collection instruments used in Phase II link the specific research questions to the overall study. Focused on the public/private school classroom learning environment, the research design for Phase II combined the use of two new versions of the Constructivist Learning Environment Survey (CLES) and qualitative data from interviews, observations, and reflective field journals.

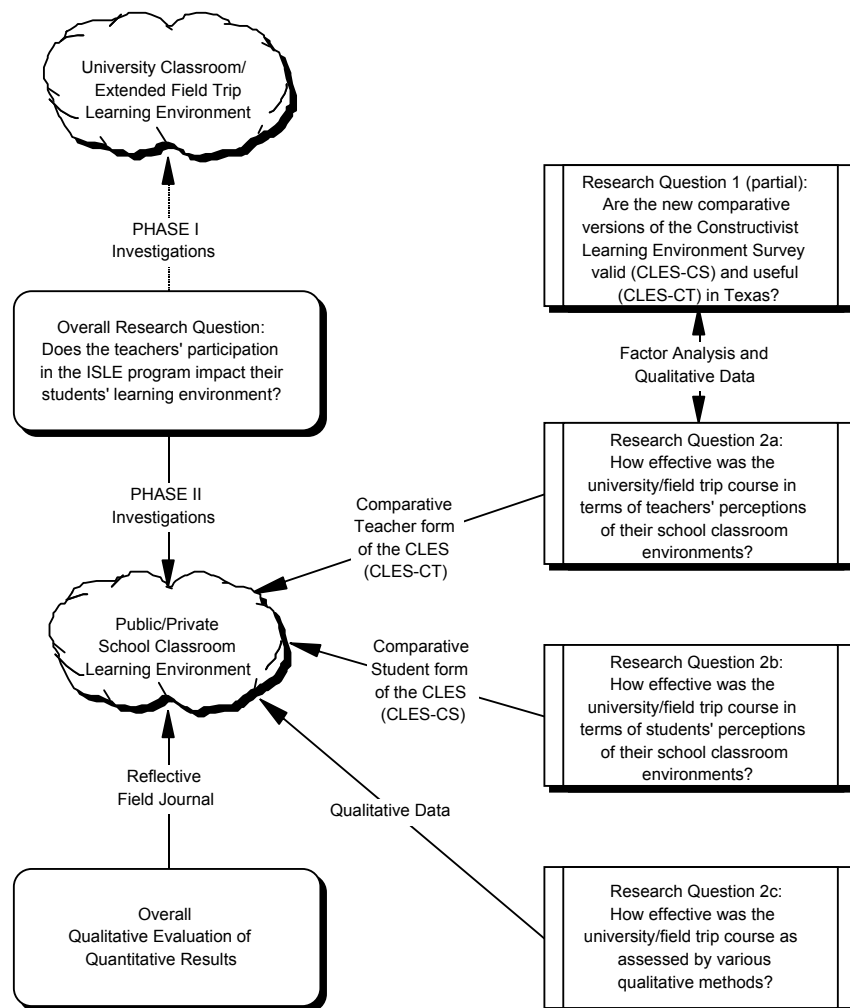


Figure 2. **Phase II Research Design: Examining the Public/Private School Classroom Learning Environment**

To partially answer Research Questions 1 and 2, the two comparative forms of the Constructivist Learning Environment Survey (CLES) were administered. The comparative teacher form of the Constructivist Learning Environment Survey (CLES-CT) was used to determine the participants' perceived effectiveness of the university classroom/extended field trip course in terms of teachers' perceptions of constructivist practice in their school classrooms BEFORE and AFTER participating in the ISLE program (Research Question 2a). These data were also used to qualitatively evaluate the usefulness of the CLES-CT in the north Texas area.

Also to answer Research Question 2b, the comparative student form of the Constructivist Learning Environment Survey (CLES-CS) was used to determine the effectiveness of the university classroom/extended field trip course in terms of school students' perceptions of the classes taught by ISLE participants (THIS) and classes

taught by other teachers who did not participate in the ISLE program (OTHER) in the same school. Also a comparison was made between the classroom environment perceptions of students in science classes taught by ISLE teachers and the perceptions of students taught by teachers who had attended other field trip programs (non-ISLE). These data were subjected to principal components factor analysis to validate the CLES-CS for use with secondary school students in the north Texas area, partially answering Research Question 1.

Additional quantitative data collected from observations, interviews, reflective field journals, and electronic mail messages, for example, were used in the interpretation and discussion of results (Research Question 2c).

1.4 Summary of ISLE Program and Thesis Overview

This study evaluated a new teaching model designed to use information technology to foster a constructivist approach to science education, addressing the ultimate challenge of learning: placing new content in personally-relevant contexts. Quantitative assessment through learning environment dimensions, attitude scales, and concept map analysis were supported by inferences based on qualitative data derived from reflective field journals, interviews, and observations. Specifically, Chapter 1 introduced the Integrated Science Learning Environment (ISLE) model and design of this research study, summarised in this section 1.4.

Section 1.1 described the rationale for developing a new model. The significance of the research study and the influence of the researcher's personal experience on the development and evaluation of the ISLE program were discussed. This study used a novel combination of methods from the fields of science education, psychosocial cognition, and information technology; it documents a new model for improving learning and understanding in the field of education, specifically science education; and, it makes a unique contribution to the field of learning environments by comprehensively assessing an integrated milieu that envelops three classically distinct learning environments. With the full benefit of several science education field trip experiences, the classroom preparation and laboratory research of the researcher's past experience came together in the field, making natural sense.

The general research question asks whether or not a teacher's participation in the Integrated Science Learning Environment (ISLE) program would lead to teachers' implementation of constructivist learning environments in their respective

students' school classrooms. As an introduction and for general reference purposes, section 1.2 stated the specific research questions investigated, described the organisation of the thesis, and defined the terminology used in this study.

Specifically, this study evaluated the ISLE program in terms of promoting a more constructivist school classroom learning environment as perceived by teachers and students, teachers' attitudes toward information technology, and teachers' conceptual development. Quantitative data from three new versions of the Constructivist Learning Environment Survey (CLES), the Teachers' Attitudes Toward Information Technology (TAT) questionnaire, and participant-generated concept maps were reported. These results were further interpreted with qualitative data derived from interviews, observations, and reflective field journals.

The research was conducted in two stages outlined in section 1.3. Phase I investigated the university classroom/extended field trip milieu. Phase II investigated the impact of the ISLE program on public/private school classroom learning environments. Representing 773 science students, the primary sample for this study involved 12 classroom teachers and one administrator from the Dallas-Fort Worth metroplex area in north Texas.

As briefly noted, development of the Integrated Science Learning Environment was complex. At this point, it is important to be aware of the comprehensive nature of the unifying scaffold that enabled the creation of an ISLE. The university/school classroom, extended field trip, and information technology learning environments are, in fact, separate entities with distinctive physical characteristics. Within the broad view of the ISLE program, however, they constitute a single, multi-faceted logistical framework. In order to merge the topically-related aspects, the definition of a new and unique (yet underlying) conceptual framework was necessitated. An holistic approach to teaching and learning required that the traditional logistical framework(s) be combined with this innovative conceptual framework to literally torque the model perspective. The resulting integrated framework is not dependent on physical location; rather, it dynamically maintains a relative position that is anchored to each individual participants' overall state.

To assist the reader in understanding the design of this model, the conceptual and logistical frameworks are described in separate chapters (3 and 4, respectively). In preparation, Chapter 2 describes the overall context of this study in terms of the educational environment in which the ISLE program was implemented.

Chapter 2

TODAY'S EDUCATIONAL ENVIRONMENT

The ISLE program encompasses an emergent model for developing an integrated learning environment to accomplish the goals set forth for today's science educators and their students. Combining an Internet-based virtual field trip product with an extended field trip to a natural area offered a unique framework to address the specific needs of multilevel inservice and preservice science teachers, and the increasingly diverse audience of learners they served.

In March 1998, it was reported that a new website was created every four seconds (Clarke, 1998). The 'information explosion' has resulted in the creation of massive amounts of bits of data reinforcing the misconception that science is simply a collection of facts and figures with little relevance to the everyday lives of individuals and societies (Gallagher, 1989; Humrich, 1988; Ledbetter, 1987; Tobin & Gallagher, 1987; Weiss, 1987). Building on the explosion imagery, the increase of information on the World Wide Web is consequently non-linear in nature. This poses an interesting challenge to classroom teachers, as well as teacher educators, on a global scale. Science teachers, in particular, teeter on the apex of this rapidly-advancing wave and must find effective ways to balance issues and manage change in the classroom.

This chapter, comprised of five main sections, presents an introduction to factors influencing the development and implementation of the ISLE model with respect to significant trends in scientific methodology and pedagogical practice that are pertinent to today's educational environment. The following section 2.1 describes the call for educational reform on a global scale. Section 2.2 highlights aspects of the study that are specifically related to issues in education in the United States. Especially pertinent to this north Texas study, section 2.3 specifically notes state level aspects of science education, including teacher preparation and certification, and curriculum research and development. Section 2.4 reviews the role of field trips in science education. And finally, section 2.5 provides a summary of this introduction to the research study investigating the ISLE program.

2.1 Educational Reform on a Global Scale

Recent technological advances have created an awareness of the global community and provide graphic examples of the impact of individuals and the inter-relatedness of systems and societies (Kosakowski, 1998). The impact on education has been tremendous, rapidly transforming the proverbial one-room schoolhouse into a global system without limitations (Ellmore, Olson, & Smith, 1993). As such, “the new emphasis on information processing has spawned some instructive and educationally relevant findings” (Gallagher, 1993, p. 19). As stated in a review of the Danish educational system, “... information technology is creating entirely new pedagogical possibilities” (Ministry of Education, 1997, Chapter 1, Information Technology, ¶ 2).

In response, the governing bodies of Australia, Canada, Israel, and the United States (Curriculum Council, 1998; Ministry of Education, 1999; Ministry of Education, 1992; National Research Council, 1996; respectively), for example, have issued the call for change on a worldwide scale (Gardiner, 1998; OECD, 1996; Ruppert, 1998; Steiner-Khamsi, 1999). “Three consecutive years of surveys in higher education showed the same thing: institutions ranked their greatest technological challenge as ‘assisting faculty to integrate information technology into instruction’” (Kerrey & Isakson, 2000, p. 40). Nevertheless, educational leaders are rising to the challenge of using information technology to restructure their educational systems to meet the demands of a world involved in an on-going technological revolution (Hurd, 2000; Jones, 1993; Marx, 2001; National Science Foundation, 2001; Seller, 2001; Trinidad, MacNish, Aldridge, Fraser, & Wood, 2001; Yager, 2000).

Fraser (1997), in his presidential address the National Association for Research in Science Teaching (NARST), highlighted the importance of the expansion, internationalisation and cross-nationalisation to this educational research organisation. “New technologies facilitate a shift from communication isolation and deprivation to communication access and exchange” (SEDL, 2000, ¶ 3). Also evidenced by the abundance of new publications, increased interest in both teaching and learning combined with the political and social attention to education on a global scale has supported similarly rapid and significant advances in learning environments research specifically (see Chapter 5). New approaches and methodologies are being developed in direct response to the effects of the information revolution (Britain & Liber, 1999; Christensen & Knezek, 1996; Fisher, Aldridge, Fraser, & Wood, 2001;

Fraser & Maor, 2000; Fraser & Tobin, 1991; Harwell, Gunter, Montgomery, Shelton, & West, 2001; Jegede, Fraser, & Fisher, 1995; Kessell, 1999; Knezek, Christensen, & Miyashita, 1998; Lavoie, 1997; Maor, 1997; Nix & Ledbetter, 2002; Nix, Ledbetter, & Fraser, 2001b; Novak, Mintzes, & Wandersee, 2000b; Orion, Dubowski, & Dodick, 2000; Pederson & Yerrick, 2000; Rakes, Flowers, Casey, & Santana, 1999; Stoddart, Abrams, Gaspar, & Canaday, 2000; Taylor & Maor, 2000; Teh & Fraser, 1995b; Zandvliet, 1999; Zandvliet & Fraser, 1999).

Clearly, education has been pulled into a new realm. Information technology in science education is quite real. Our job as citizens of this now global community is to place these tools and resources into the proper context and provide sufficient support to all learners, especially today's teachers. The possibilities are indeed endless. Tomorrow's educators must be involved in the development of a new model for science education. We will realise the potential of information technology in science education today by approaching the challenges just as our children will have to face the issues of tomorrow. We are all simply learning by doing.

Incorporating information technology in educational reform efforts has fostered a global learning community. Increasing collaboration among classroom teachers, science education professors, and graduate students is already helping individual elementary school teachers to change their science teaching practices (Briscoe & Peters, 1997). The same can be done to help teacher education programs address the needs of practising classroom teachers (Hammer & DiMauro, 1996; Hofstein & Mamlok, 2001; Los Alamos National Laboratory, 1999; Mehlinger & Powers, 2002; Winograd, 2001).

2.2 Education in the United States

Unfortunately, yet undeniably, the United States is in the midst of an educational crisis. It is painfully ironic that schools were instituted in response to the critical societal need for structure. Nearly 150 years later, that basis could be its demise; however, it is beyond the scope of this work to elaborate on the multitude of factors that are involved in a survey of the educational climate in the United States. The underlying issues are paramount to the development of solutions for the secondary and graduate school levels. As the purpose of this research is to effect positive change in the teaching of science, an understanding of the context of the

present situation is necessary to address the implications for the classroom-level learning environment.

The fact that all 70 professional development programs of the U.S. Department of Education are currently being re-aligned is a tell-tail sign. The goal is to promote ten principles of good practice, including “a focus on the teacher as central in school reform, and emphasis on both content and pedagogy, and an embodiment of good research and practice” (Office of Educational Technology, 1995, Issue 2, section C, ¶ 2). Bosco (1995) concisely presented the key aspects of the current status of public schools in a comprehensive report published by the U.S. Congress’ Office of Technology Assessment (pp. 25-55). According to this widely accepted document, the five basic factors to be considered with respect to educational reform are further condensed in Table 2.

Table 2. **Key Aspects Affecting the Current Status of U.S. Schools**

Factor	Description
Widespread Dissatisfaction	Building concerns about declining test scores, the skills to meet business and industry needs, and the prevalence of drugs and violence in American public schools have made educational reform a major political issue.
Federal, State, and Local Reform Efforts	State legislation of various types and thousands of local reform projects have been initiated, mostly modest in intent and scope.
Privatisation	Many districts have ‘contracted out’ services and programs to private corporations.
Constraints	State law and policy often block reform laws; college entrance requirements set curriculum; school climate and morale – including teacher and administrator resistance – is yet another barrier to change.
Technology Integration	The focus has been on how to fit technology into the existing fabric of life in schools; it can be used as a means for disrupting existing practices and for creating a new way of schooling.

Adapted from Bosco (1995, pp. 27-28)

Former President Clinton, in conjunction with the governors of the states, identified the importance of science and mathematics for the children in American schools in the Goals 2000: Educate America Act (U.S. Department of Education, 1996). Currently, the H.R.100: National Science Education Act, known as the Ehlers’ Bill, supports a focus on the advanced preparation of science and mathematics educators, making possible an emergence into global achievement in these vital areas (Ehlers, 2001). This Bill authorised National Science Foundation

(NSF) grants to public and private schools to hire Master Teachers to provide support and assistance to kindergarten through grade 8 (K-8) teachers, direct NSF to make grants for professional development in educational technology use and integration, and create a national scholarship to reward teacher participation in research. NSF's Division of Educational System Reform presently manages large-scale programs designed "to strengthen the science, mathematics and technology education infrastructure of states, urban centers, and rural areas" (National Science Foundation, 2001, ¶ 3).

The need for significant educational reform is evident in the vast number of documents consistently published in the United States (Hurd, 1994 cited in Kaspar, 1998), Australia, and other leading countries, in addition to those available online. Unfortunately, few offer concrete solutions for such issues as teacher preparation, transfer of meaningful learning, and effective use of teaching tools to affect sustained positive change within today's educational system. "If educational innovations are to succeed, they must take a more realistic view of the realities of classroom life than have some past curricular projects" (Geelan, 1997, p. 4). Geelan further identifies complexity and interrelatedness, teacher beliefs, and student expectations as the three essential and complementary areas to be addressed for successful reform. Educators must develop and support qualified individuals who will contribute to understanding and problem solving associated with educational issues. These leaders will then be able to make educationally sound decisions that will affect the students of our cities, states, nations, globe, and, ultimately, the future of us all.

2.3 Science Education in Texas

The north Texas region is home to 100 large and small school districts, several dozen private schools, three large community college systems, and over 450 technology companies, including Texas Instruments, Hewlett-Packard, Silicon Graphics Inc., Alcatel, Nortel, and many others. Each of these organisations has a vested interest in teacher preparation in terms of their jobs, families and community. The local demand for lead teachers and administrators with science backgrounds far exceeds the current supply. The national need for science teachers is also increasing. Additionally, business and industry seek instructors with science education backgrounds for managing corporate training and professional outreach programs.

Former Governor George Bush, now President, told the Texas Higher Education Coordinating Board in 1998 that his top priority for higher education in Texas was to improve the quality of education for the State's teachers. Successful graduate programs provide teachers with a strong, broad science background and an understanding of the myriad of issues facing science education supporting the Texas Higher Education Coordinating Board's (2000) four goals for closing the gaps in education. 1) To close the gaps in participation, we need to bring the benefits of effective programs in science education to people whose opportunities have been restricted. 2) To close the gaps in success, efforts need to focus on increasing graduates in the highest level of science education through programs designed with the help of partners from business, industry and other educational entities. 3) To close the gaps in excellence, we must be open to external advisors and continue to pursue all types of support for program initiatives. 4) To close the gaps in research, teachers must be given the opportunity to conduct studies that will improve the education for all children in Texas schools, leading to further closing the gaps in participation (which leads back to goal 1).

Texas needs scientifically skilled and educationally astute individuals to address the teacher shortage (particularly in mathematics and science), the lack of industry specialists, and the needs of citizens faced with decisions involving technical information. Given the chance to acquire increased skills and understanding, experienced teachers in school districts, community colleges, business and industry can be a key resource for tackling these problems and taking advantage of opportunities. Innovative and challenging programs will help bring teachers to these leadership roles and are justified for the following reasons:

- 1) the need to respond to the State's top priority for higher education in Texas, i.e., to improve the quality of education for our teachers and children
- 2) the needs of persons in science education research areas for more advanced study
- 3) the need for a more advanced preparation for personnel working in public/private schools and community colleges
- 4) the critical need to meet and address the science education issues raised at all levels of American society.

New legislation and state-of-the-art materials are a small part of the solution. Adequate attention must be given to the preparation and professional development of certified teachers. Nevertheless, professional development ranks low on local school district priorities. Based on the level of state funding, time allocated, and incentives for professional development, Texas was classified with weak state support (Lewis, 1998). In turn, and partially to blame, university teacher training programs are being targeted as being responsible for the low standards in public schools (Pipho, 2000). The chasm between reform initiatives and classroom teaching is magnified by one teacher's recent comment in a graduate level science education seminar course:

The administration delivers these big boxes of new curriculum to our rooms. Like little kids, we can hardly wait to open the fancy cases and have fun looking through the colourful, glossy manipulatives. But that's about it... Do they suppose we just know how to use it all because we're called teachers? Things always end up just sitting there, taking up valuable space.
(Paraphrased from Student X, 2001)

Clearly, it is unrealistic to assume that any teacher can teach any part of a general science course (Fraser & Tobin, 1992). As more and more Texas teachers retire – 40% of Dallas teachers were eligible for retirement in 2001 – there will be an increased need for new teachers. School districts around the state, feeling the impact of an aging workforce and the need to fill classrooms with qualified personnel, are setting up alternative certification programs. However, there are few, if any, administrators trained to manage the learning of these para-professionals. In addition to the physical shortage of teachers, the quality of teachers being produced clearly threatens the future of public education. Our schools need personnel with advanced science and education knowledge, plus timely management strategies, to keep the education of the students above the minimum levels of competence. Teachers with formal training in science education will help achieve the educational standards to which many districts aspire.

2.3.1 Teacher Preparation and Certification

Teacher education programs provide an appropriate starting point for dealing with the dilemma at hand. The introduction of Pestalozzi's 'Arschuung' philosophy of learning from direct concrete observation at Oswego Teacher College demonstrated significant positive change via teacher education. If thorough training

has direct relevance, it will be “a natural development for the materials to pass from the teacher’s hand into the student’s hands” (Rillero, 1993, p. 15). In an extensive study of how field trips impact on the educational experiences of teachers and students, Mullins (1998) develops the case that, “...teachers must be in a student’s position in order to make shifts in their teaching patterns. It seems imperative that teachers be removed from a teacher’s position of authority and responsibility and assume a student’s role in order to accomplish a pedagogical transition from authoritarian/director to learner/guide” (p. 109).

Teachers are typically avid, lifelong learners. Clearly, there must be more to improving education than simply providing good teaching tools and offering expert resources. “A variety of factors contribute to the effectiveness of a classroom teacher. One factor is a teacher’s belief about his or her own abilities to teach effectively. Ashton comments that ‘no other teacher characteristic has demonstrated such a consistent relationship to student achievement’, and that ‘a potentially powerful paradigm for teacher education can be developed on the basis of the construct of teacher efficacy’” (1984, p. 28 cited in Wilson, 1996, p. 53).

The overall shortage of teachers has brought about a number of alternative certification options. The issuance of emergency certificates to fill vacancies adds to the complexity of raising teacher quality. The Texas Legislature authorised alternative certification programs (ACPs) in 1985; “...the programs have produced more than 35,000 certified teachers for Texas schools. These new teachers come from all walks of life. Engineers, attorneys, accountants, scientists, social workers, and a great variety of other professional people have entered teaching through ACPs” (State Board for Educator Certification, 2001c, p. 1). In 1998, the first-time failure rate of would-be teachers on a Massachusetts certification examination was an alarming 44%. In response to a nationwide reaction, “...by the time the state board of education had finished making adjustments, the new cut-off score had 55% of education school graduates flunking the test” (Pipho, 2000, ¶ 3). That same year, Texas became the first state in the nation to rate preparation programs based on the quality of their graduates. The first-year pass rate for 1999-2000 in Texas was nearly 88% (State Board for Educator Certification, 2000). *But does passing the test ensure qualified teachers in the school classroom?*

Just as the secondary school agenda is based on graduation requirements, one can expect that curriculum and standards for teacher education programs directly

reflect certification requirements. Certification for science teaching in Texas public schools is required to take place at the undergraduate level. Currently, Texas requires that all science teachers have an undergraduate degree in a content area (science) prior to certification. This allows only 18 hours of professional development (teacher) training (State Board for Educator Certification, 2000; 2001b). Prior to 1987, degrees were conferred in education, where the bulk of hours were in pedagogy rather than science content. As such, the majority of inservice science teachers are professional educators first and content specialists second. Those with strong content backgrounds typically lack the expanded understanding of educational theory. Large sections of teaching responsibilities are missing either way. It is therefore important for both preservice and inservice teachers to synthesise the application of sound pedagogy to current science content.

There are four basic phases in the typical preparation of a teacher: general preparation, professional education, student teaching/internship, and the first year of teaching which is usually performed under contract. Unfortunately, as a National Science Foundation study concluded, “it is much more difficult to correct deficiencies, particularly in the academic backgrounds of teachers once they have been certified, than it is to require adequate preparation before certification” (Mechling, Stedman, & Donnellan, 1982, p. 9). Fortunately, change is already in process. Because of the variety of alternative certification paths to initial licensure, many districts are investigating performance portfolios for assessment.

For example, Indiana is one of several states planning a three-level, performance-based teacher certification process (Andersen, 2000). An initial provisional certificate will be granted on completion of an approved teacher education program and passing performance on a series of written content and pedagogy tests. After two years, the teacher must submit evidence that they “have successfully taught a variety of students and that they have a personal plan for continued professional development” (§ 8). New standard certificate renewal and continuing professional education requirements have just been approved in Texas (State Board for Educator Certification, 2001a). All classroom teachers must complete at least 150 clock hours of continuing professional education (CPE) within a five-year renewal period. Indicating a move toward the philosophy of lifelong learning for all, the six activity areas are defined as follows: 1) Content Area

Development, 2) Professional Development, 3) Independent Study, 4) Teaching/Presenting CPEs, 5) Mentor Education, and 6) Serving as an Assessor.

The models for teacher education, as well as those of higher education in general, are undergoing rapid and significant change in many respects. “While traditional courses will continue to be a major part of a university’s provision, the most likely growth area will be in ‘lifelong learning’ courses offered to industry or individuals. The virtual learning environments of today and their successors are likely to form key strategic aspects of teaching and learning in universities of the future” (Britain & Liber, 1999, section 4.2, ¶ 4). Inservice teachers are the link between teacher education and teaching. Perhaps it is time to look to their experience in today’s classrooms for ways to make science relevant for tomorrow’s leaders. This suggestion is supported by a recent study to determine the graduate education needs of science and mathematics teachers in North Carolina (Berenson & Dawkins, 1999).

These teachers envision that they will bring their professional knowledge and experience to a university classroom that will value what they know about teaching and learning. Additionally, these teachers hold the expectation that their professors will be able to mentor them in a collegial relationship within the real experiences of classroom teaching. (¶ 23)

The ISLE model builds on this existing foundation of unique experiences, adding to the teachers’ repertoire by developing new skills and knowledge in a personally and professionally relevant context.

2.3.2 Curriculum Research and Development

Information technology has already changed our world. As Bosco (1995) suggests, the essence of the issue is this: “If anything is possible, what should we make probable in schools” (p. 26). Educational researchers, acutely aware of the magnitude of this tenuous situation, are investing tremendous time and energy into plausible solutions. One essential condition for teacher preparation is that “...candidates must continually observe and participate in the effective modelling of technology use for both their own learning and the teaching of their students” (International Society for Technology in Education, 2000, p. 7).

As evidenced by numerous information technology strands at national research conventions, like the National Association for Research in Science Teaching

(NARST) and the Australian Association for Research in Education (AARE), work is being done and progress is being made with every study – successful or not. Focused task forces and conferences have dedicated resources to developing effective ways of incorporating new information technologies and techniques into science teaching. The 1996 Technology and Teacher Education Annual, proceedings of the Seventh International Conference of the Society for Information Technology and Teacher Education (SITE), presented over 250 research papers on topics such as diversity and international issues; social studies; reading, language arts, and literacy; mathematics; science; preservice teacher education; the educational computing course; graduate and inservice education; teacher development; concepts and procedures; new media; simulations; instructional design; telecommunications; research; theory; technology diffusion; special needs and young children. As the already rapid pace of the information revolution continues to increase, the currently monumental magnitude of research continues to grow exponentially.

Developments in science curriculum, instruction, and assessment reflect the higher expectations based on new goals (American Association for the Advancement of Science, 1994) and standards (National Research Council, 1996). Critical thinking and scientific inquiry (Ledbetter, 2000a) are necessary skills for both teachers and students to realise the potential of present reform movements. Particularly relevant to this study, teachers and researchers collaboratively researched courses developed on the premise of scientific modelling as part of a 12-year project in Wisconsin. MUSE (Modelling for Understanding in Science Education) employs strategies that “are geared to facilitate students’ learning, reasoning, application and linking of concepts” (National Center for Improving Student Learning and Achievement in Mathematics and Science, 2000, p. 1). To be effective, the program developers urge policymakers, teachers and school administrators to consider the critical factors summarised in Table 3.

Each of these issues, along with many others, must be considered for the development of a fully-integrated science learning environment. Regardless of the model, even the most excellent design does not guarantee successful implementation. The broadening perspectives of parents, teachers, administrators, employers, and policy-makers definitely influence and impact the realisation of such programs aimed at improving the educational horizons for our students.

Table 3. **Key Considerations for Teaching Based on Scientific Modelling**

Factor	Description
Policymakers	
Communication and Support	Teachers, administrators, parents and policymakers need to communicate about – and jointly support – the goals for student learning in science.
Classroom Environment	Students must function as a scientific community – collaboratively. Smaller classes provide teachers with more opportunities to engage with students and assess learning.
Professional Development	Teachers will require time to incorporate modelling strategies into classroom curricula. They will need experience in scientific modelling, as well as professional support, as they alter their pedagogical and assessment styles. They may also need to develop more sophisticated content knowledge.
Technology	Computer programs can assist instruction if they are relevant. Simulation programs can support learning by giving students a chance to generate data and test their predictions.
Standardised Tests	High-stakes or standardised tests might discourage teachers and schools from adopting the new model. Such tests often fail to adequately gauge students' grasp of both science content and scientific processes. They do not provide opportunities to demonstrate their understanding of modelling strategies.
Teachers and School Administrators	
Tasks	The teacher will need to provide examples and enable students to observe and collect their own data, look for patterns, develop models, discuss, judge, explore, communicate, and critique.
Instruction	The teacher will serve as 'co-inquirer' rather than information distributor, encourage active learning, group discussion and scientific argument, and be aware of individual student needs.
Assessment	The teacher will need to probe students' understanding, use assessment as a tool for developing instruction, employ various forms of authentic assessment, and make use of different formats.
Learning Environment	The teacher will need to assure the physical space is conducive to collaborative work and establish norms to create an active learning environment and reasoned argumentation.

Adapted from NCISLA (2000)

Building on this new and common vision focused on the basics of student-centred lifelong learning, science education field trips present extraordinary potential for a comprehensive solution.

2.4 Field Trips in Science Education

From Aristotle to Krepel, the historical significance of extended field trips in science education is well documented throughout the literature (Brady, 1972; Falk & Balling, 1979; Jelinek, 1998; Kaspar, 1998; Rillero, 1993; Rudmann, 1994). In

addition to these same studies, many more report equally numerous accounts of the educational value and personal benefits of field trips to natural settings (Jones, 1990; Lisowski, 1987; Orion & Hofstein, 1991; Orion, Hofstein, Tamir, & Giddings, 1997). “A survey of the literature yielded 167 statements from 70 sources attesting to the positive value of field trips” (Brady, 1972, p. 14).

Kaspar (1998) presents an extensive review of literature related to field trips (pp. 32-102), determining that: “An excess of research exists in regard to the value of field trips, or lack thereof ...” (p. 19) and “...most of the studies that were found pertained to the value of field trips... None of the studies reviewed revealed any work in regard to underlying psychological constructs that contribute to a teacher’s support of an outdoor field trip” (p. 6). He also concludes that, “Outdoor field trips have been considered to be extracurricular” (p. 17), presenting a separatist view of the implementation of scientific field studies. Mullins (1998) noted that, “teacher and student statements concerning learning on field trips were similar. According to both groups, the context of learning revolved around personal involvement and relationships. The overall combination for a meaningful learning experience included aspects of: 1) experiencing the environment, 2) forming relationships, and 3) learning new information. All three aspects worked synergistically to build students’/teachers’ experiences. The relationship aspect of field experiences was not noted by museum instructors” (p. 158).

The potential for using extended science-related field trips in a teacher education program is virtually unlimited, as is the multiplied impact of experiential understanding on classroom teaching. “Teachers with a background of outdoor education experiences are able to offer more meaningful learning experiences for the children. Through seeing, hearing, and doing in the outdoors, children are challenged to seek satisfactory solutions to perplexing problems. The student in the outdoors is guided and aided in his quest for answers because the teacher ‘has been there’, and can ‘tell it like it is’” (Chadron State College, 1972, p. 166).

Orion (1993) refined a model for developing and implementing field trips that promoted a process-oriented approach, conducted the event as early as possible as an integral part of the unit, and involved sufficient preparation. Hamm (1985), in his review of Perkes’s research states, “The teacher’s sensed adequacy to teach science emerged as a significant factor in the teacher’s commitment and confidence in teaching science...” This suggests, “teachers develop positive perceptions of their

ability to teach science by successful work in science courses” (pp. 38-39). Jelinek (1998) cites ‘a sense of relevance’ as one of the major obstacles to effective science education. Educational field trips can give teachers an opportunity to experience effective science teaching and develop an increased awareness of relevant issues and teaching methods. Ultimately, “such teacher variables as enthusiasm, enjoyment and motivation can influence student achievement” (Jelinek, 1998, p. 2).

Despite the proliferation of virtual field trips available on the World Wide Web, little has been published on the topic in the traditional sense. Two journal articles describing classroom technology projects (Barshinger & Ray, 1998; Hixson, 1996) and one book, a cross-referenced description of web sites (Cooper & Cooper 1997), directly approached the subject. Informal background information was occasionally discovered on pages within major web sites.

A nationwide project to build and link geography curricula using the Internet and World Wide Web provides a possible model for science education. The program proposal (Foote, 1995) raises issues of how information technology can be developed to benefit students and society and notes the changing role of the teacher as new opportunities are explored. One of their goals is to make use of the vast repository of materials already available on the Internet and World Wide Web. Dr Bruce Herbert of Texas A&M University has posted several presentations that discuss the design and effectiveness of using virtual field trips to improve delivery in earth science (Herbert, 1998). His initial assessment of the use of Web-based instructional materials in an introductory Physical Geology class shows positive improvement in the impact of science on students’ lives and their change in geologic interest. Chapter 3 and Chapter 4 of this thesis support his statement that, when the objectives are incorporated into the design phase, virtual field trips can support learning objectives.

2.5 Summary of Today’s Educational Environment

Pertinent to today’s educational environment, significant trends in scientific methodology and pedagogical practice influenced the design and implementation of the Integrated Science Learning Environment. The ISLE program encompasses an emergent model for developing an integrated learning environment to accomplish the goals set forth for today’s science educators and introduced in section 2.1.

Stressing the need for significant educational reform, Section 2.1 provided a survey of the educational climate in the United States to address the implications of

the present situation for the classroom-level learning environment. Section 2.2 assessed the national need for science teachers along with the myriad of issues facing science education. Innovative and challenging teacher education programs that directly address the changes brought about by the information revolution are needed to help bring experienced teachers into leadership roles in school districts, community colleges, business, and industry.

Specific to this study, section 2.3 describes the science education crisis in the state of Texas. The need for new teachers continues to increase, particularly in science. And section 2.4 documents the historical significance of extended field trips in science education, reporting that although the potential for using extended science-related field trips in a teacher education program is virtually unlimited, little work has addressed the psychological aspects of outdoor education and teacher efficacy in authentic learning environments.

In many respects, models for teacher education and for higher education, in general, are undergoing rapid and significant change. As teachers provide the link between university-based professional development programs and student-centred classroom learning, the ISLE program attempts to leverage first-hand experience in today's classrooms to make applications of information technology in the context of real-world science relevant for tomorrow's leaders.

Chapter 3 describes the conceptual framework of the ISLE model. Chapter 4 describes the logistical framework of the ISLE program.

Chapter 3

ISLE CONCEPTUAL FRAMEWORK

The challenge for developing a personally-relevant, context-sensitive, content-rich strategy for science education in today's information-driven society has been issued to professional educators around the world as noted in Chapter 2. To address this need, the ISLE model integrated critical aspects of the learning environment, teachers' attitudes, and teachers' conceptual development to broaden the context for enculturation of the constructivist paradigm in public/private school classrooms.

Although the ISLE program can be described logistically by distinct pre-trip, field trip, and post-trip activity stages (detailed later in Chapter 4), the theoretical underpinnings of the program must be described within the context of a holistic conceptual framework (detailed in this Chapter 3). The information technology, classroom, and field trip learning environments are individually reviewed in sections 3.1, 3.2, and 3.3, respectively. Section 3.4 describes the holistic implementation of the field-based ISLE program along with expectations for programs based on the ISLE model. And finally, section 3.5 summarises the conceptual framework presented in this chapter.

It is important to keep in mind that the pressure to 'teach to the test' is a major inhibiting factor in schools as evidenced by traditional assessment and evaluation (section 2.2). By creating a real-world environment, in which adult students personally experience learning through a constructivist approach, teachers are more likely to be able to provide the same type of learning environment for their respective classroom students. In response, the ISLE model applied information technology in the university setting to foster constructivist pedagogy by enabling teachers to create a product that they understand and know how to use in their individual school classrooms to promote inquiry and high-order thinking.

Equally important is the fact that the majority of specific studies on using field trips in science education (section 2.4) naturally focused on environmental, biological and geological content, providing a somewhat limited view of the overall experience and effect on participants. In contrast, the ISLE model promotes a

multidimensional approach. Figure 3 shows how the ISLE model used relevant information technology to merge the physical milieus by shifting the focus to the single element common to all learning environments: the classroom teacher.

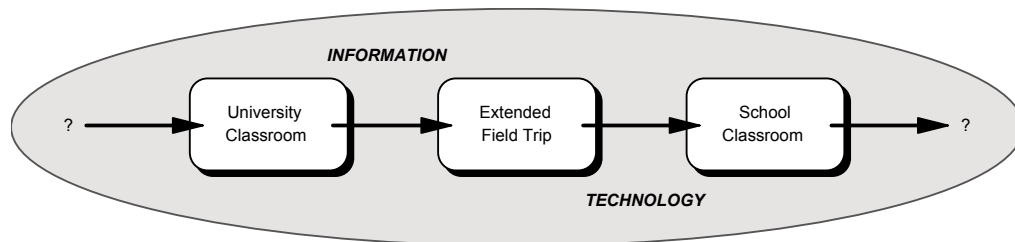


Figure 3. Integrated Learning Environment for Field-Based Programs

Based on the researcher's prior experience (refer back to section 1.1.2) and as evidenced by a review of past and current literature (expanded later in Chapter 6), the issues of information overload and non-linear processing, brought about by the information revolution, pervade each of these learning environments. The resulting effects of novelty can be detrimental not only to learning, but consequentially affect teaching as well. Grounded on these observations, three key aspects specific to the design of the integrated learning environment distinguish the ISLE model from traditional field-based teacher development programs.

- 1) The ISLE program modelled the integration of information technologies into the university classroom curriculum, as they might be implemented in the school classroom. By actually experiencing the appropriate and effective use of information technologies in educational practice, the teachers were able to appreciate the value of new tools and resources.
- 2) The ISLE program encompassed the field trip, as well as the university and public/private school classroom milieus. By focusing on the common element, the individual, the experience was internalised and thereby naturally transferred among the physical settings.
- 3) The ISLE program seamlessly presented information technology as a means to an end, not the end itself. By selecting and applying appropriate tools and resources, the benefits (rather than the implementation challenges) of such were maximised.

Integrating disciplines and personalities to produce a comprehensive picture broadened both the individual and group perspectives. This provided a unique depth and richness of understanding that was internalised by participants and, therefore, was more likely to be applied at various levels in real-world situations. In creating a singular group dynamic by requiring a collaborative project (virtual field trip) rather than promoting multiple individual efforts, the inhibiting effects of site novelty (newness), information overload (massiveness), and the three-day phenomenon (appropriateness) typically experienced on field trips were placed in context and therefore manageable and understandable. The coursework developed an integrated learning environment that extended across the intellectual, physical, and emotional boundaries of the university classroom, field trip, and school classroom learning environments to support and encourage implementation of new technologies and teaching strategies. However, as one teacher aptly described a field experience, “Nothing can prepare a person for the sight of the snow-covered volcano, Mt. Discover, in the distance” (Van Wey, 1995, p. 280).

This large-scale integration was achieved by applying a process approach to implementing the constructivist paradigm. The transfer of knowledge and understanding was reinforced by the multilevel design. For example, the Community Juggling activity (Nix, 2000b) was conducted in the first meeting to level the playing field by providing a common experience, unique to the assembled group. This experiential training tool served as a powerful physical and conceptual metaphor for merging educational and scientific theory and practice throughout the program.

As illustrated in Figure 4, the individuals in the circle represented the items on a concept map, the pages in a website, and the peers within a mentor network. The pathway of the object represented the links on a concept map, the hyperlinks in a website, and the collaboration within a mentor network. The continuous application of appropriate information technology established a personally relevant commonality among the learning environments. In the ISLE model, information technology facilitated content background and preliminary research in the university, data collection and recording in the field, and dissemination to and presentation in the classroom.

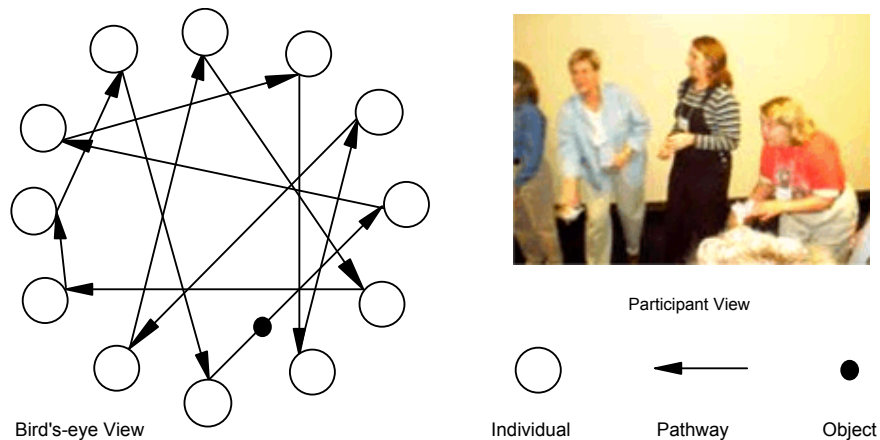


Figure 4. Community Juggling: Bird's-eye and Participant Views

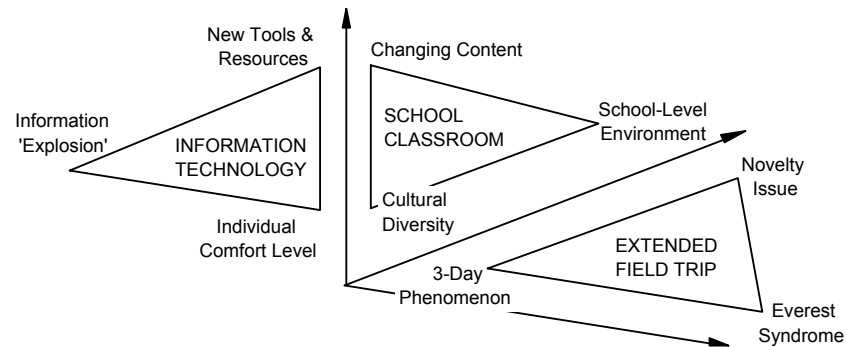
Figure 5 illustrates how the ISLE model developed an integrated (three-dimensional) learning environment by addressing the key issues of each separate learning environment at their common level. Figure 5.A shows how, in the traditional framework, there would be three separate and perpendicular planes in which activities would occur independently from the other learning environments. Each of these aspects is detailed in a later section 5.4.

In the ISLE model, the conceptual framework is shifted from an effective perspective (pertaining to physical aspects) to an affective perspective (pertaining to emotions or feelings). Specifically, the virtual field trip project changes the program focus from the physical environment (field trip, classroom or information technology) to the basic issue challenging learning in each milieu (appropriateness, massiveness or newness).

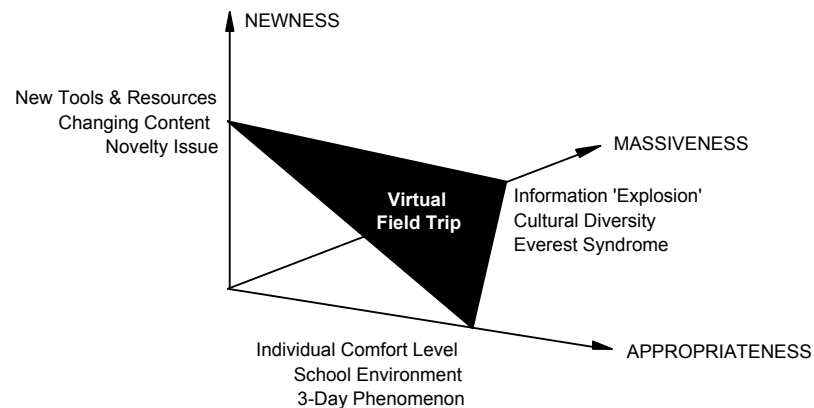
As illustrated in Figure 5.B, a single and integrated plane is constructed in which activities can occur contiguously throughout the three learning environments. The outcome is a tangible representation of the constructivist paradigm, enabled by a process approach to implementing information technology in science education.

The final product of the ISLE program (virtual field trip) was constructed by linking the elements common to the supporting learning environments (university classroom, field trip and information technology) at their basic levels:

- 1) newness
- 2) massiveness
- 3) appropriateness.



A. Effective Perspective



B. Affective Perspective

Figure 5. Merging of Perspectives through the ISLE Virtual Field Trip

As cautioned by Gray (2002), the ISLE model does not attempt to provide the emotional support needed for personal fulfilment, but does try to help teachers find ways of coping with stress to improve their levels of productivity. The ultimate goal of education is “to broaden the mind of a student” (Hoadley & Bell, 1996, ¶ 1). The first goal of science education is for students to “experience the richness and excitement of knowing about and understanding the natural world” (Yager, 1997, ¶ 15). Therefore, one of the goals of graduate-level science education programs must be to meet the specific needs and wants of today’s science teachers. Through a constructivist approach, the ISLE model was designed deliberately to help teachers to learn and apply science content within the context of their current level of understanding (Bowen & Roth, 2000).

The resulting virtual field trip, titled Global Environmental Change (Science/Mathematics Education Department, 2000), was made publicly available with no restrictions. Figure 6 shows a screen capture of the virtual field trip homepage. All visitors are invited to explore the teachers’ website exactly as are the

classroom students. The site completely represents the program, featuring the actual trip logistics, content-specific instructional materials, supporting online resources, pedagogical approaches and curriculum implementation, data collection protocols and field archives, and comprehensive resource images.

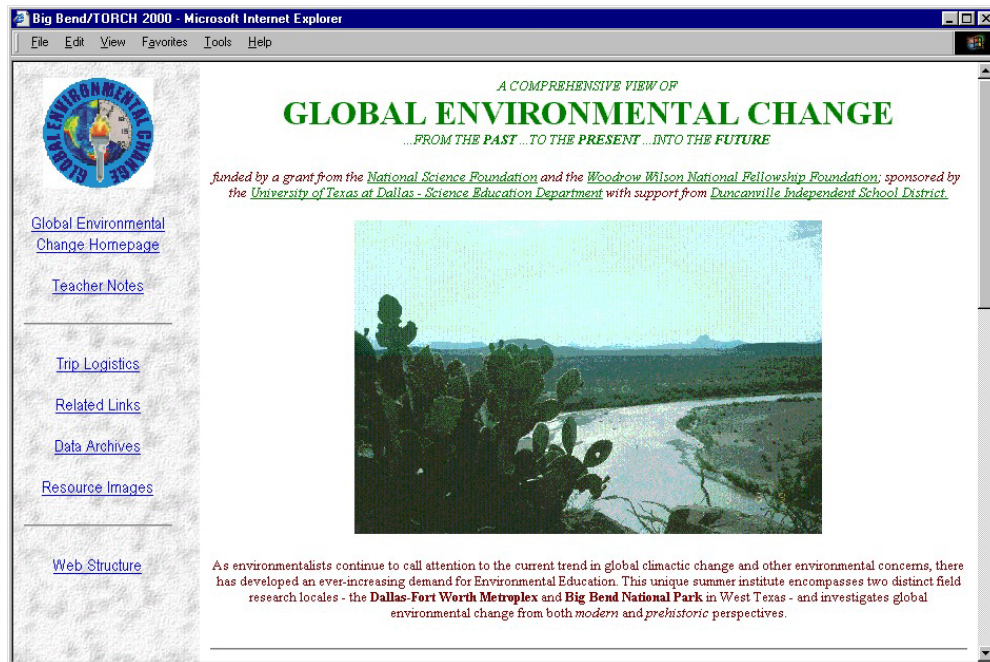


Figure 6. **Virtual Field Trip Homepage**

Through this unique format the ISLE program presents an innovative model for improving learning and understanding in the field of science education. A constructivist approach to the design and development of an inquiry-based Internet product merged theory and practice to create an integrated learning environment. Clearly defined interrelationships effectively and efficiently linked complex content within a germane context. The program structure empowers individuals to discover the same content through unique pathways at independent paces, thereby meeting the needs and modelling the methods of a diverse range of learning, teaching and evaluation styles.

Deliberate in design, each scale of the Constructivist Learning Environment Survey (Personal Relevance, Uncertainty of Science, Shared Control, Critical Voice, and Student Negotiation) was used to specifically address each aspect of the integrated learning environment (newness, massiveness, and appropriateness) in each of the traditionally separate learning environments (classroom, field trip, and information technology). To realise a shift in teaching practice, “As science

educators, we need to be able to support our personal efforts and teachers' efforts..." by "...trying to model such practices in our own classrooms" (Moscovici, 1999, ¶ 19).

As such, the ISLE model was carefully organised to promote a constructivist pedagogy within the university classroom and extended field trip segments. This complementary, multi-dimensional program design (Phase I) provided the essential foundation for individual internalisation and direct knowledge transfer into public/private school classrooms (Phase II) as detailed in the following sections.

3.1 Purpose of Information Technology in the ISLE Model

Implementation of information technology reinforced the conceptual design and therefore was evident in all stages of the program – *although never the focus in the classroom or field trip milieus*. Real-world applications of relevant tools and resources were covertly employed to join the university classroom and the field trip experience seamlessly. This was achieved by taking a process approach to applying information technology within the context of science education. Less than 10% of the ISLE implementation of information technology was allocated to instruction specific to using the application software. The focus was intentionally shifted from the details of hardware and software to finding ways to improve teaching and enhance learning through the most appropriate method(s). With respect to the actual implementation of information technology in the ISLE model, the relative time dedicated to application (73%) was much greater than the time spent on instruction (27%).

Figure 7 graphically illustrates the ways in which information technology was applied throughout the university and field experience. During the pre-trip segment, appropriate use of information technology was demonstrated through: modelling, as the teachers experienced the integration of information technology in the university classroom and on the local day trips; observing, as the teachers saw information technology applied for everyday operations at the university and local facilities on the day trips; and researching, as the teachers searched the World Wide Web for reference sites and other electronic resources.

During the field trip segment, appropriate use of information technology was evident in: training, as the teachers demonstrated the functionality of a range of tools and resources; sampling, as the teachers collected field data using various devices;

and analysing and interpreting information, as the teachers recorded and manipulated data with a variety of information technology resources.

During the post-trip segment, appropriate use of information technology was demonstrated through: facilitating, as the instructors helped the teachers support the presentation of content with applications of information technology; organising, as the teachers outlined their reports and verified their content with information technology resources; and building their pages, as the teachers used software to create their final project to be integrated into the final virtual field trip product.

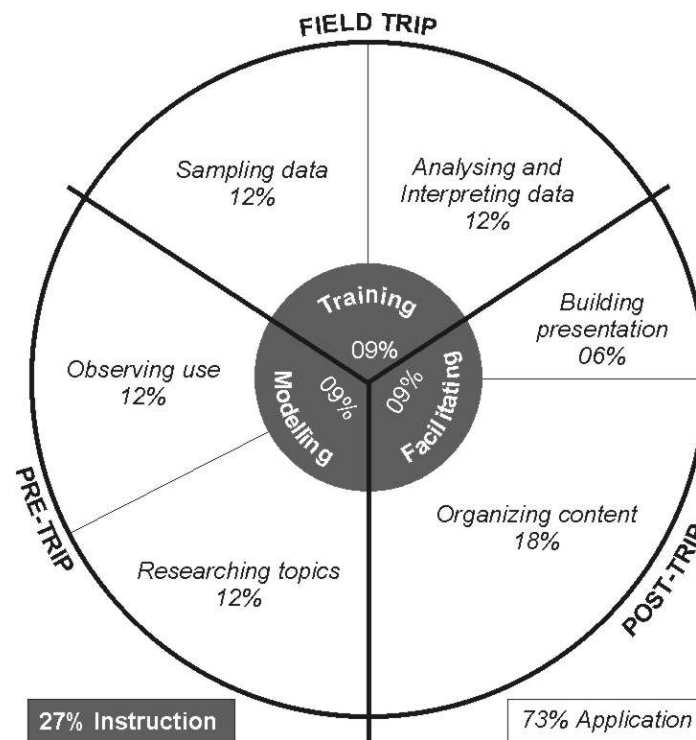


Figure 7. Implementation of Information Technology in the ISLE Model

Throughout the ISLE program, computers were used at the individual's discretion. For instance, through electronic mail, participants asked questions about logistics and content, turned in assignments and projects, and shared ideas with local experts, university instructors, and peers. They used the World Wide Web to research the field locales and study background information on topics related to the university coursework in various areas beyond their initial interest; they were directed to Internet resources (satellite images, virtual tours, and published classroom activities, for example) used in the teaching of the course itself; and they were coached about how to conduct a successful Internet search.

Through these types of focused exchanges, teachers were exposed to the non-linear nature of web-based resources and experienced the use of an enormous collection of information. They experienced multimedia in the form of an electronic presentation that reviewed the pre-trip coursework and expected field experience. This helped develop a 'bigger picture' from information presented in small, usable 'chunks'. Additional electronic resources, like topographic mapping CD-ROMs, were introduced in the classroom and made available in the field.

The teachers reported common use of computers for personal productivity, and so were generally comfortable using the available facilities to create and present their projects. It was important that as the field ecology instructor and information technology assistant validated the fact that all participants had access to the Internet at home, other sources of support, including access to the university computers, library and laboratories, were reiterated also. By not relying on computers in the classroom only, information technology became transparent in its usage.

To simulate the reality of the majority of the participants' school classrooms, there were no permanent computers in the ISLE classroom. Overheads, handouts and presentations incorporated information from the Internet. Teachers enquired as to how various web pages were saved for use on a local hard-drive that was brought into the classroom as needed. Benefits of the same process were evidenced again as the pre-trip web site was saved to a laptop computer for reference in the field. The university computer laboratory (30 stations) was used for the brainstorming and development of the initial (top-level) concept map and presentation of the pre-trip web site showing the context for their projects. After the trip, computers in the instructors' offices were used for individual and small-group work sessions to complete the final projects.

To simulate the reality of scientific fieldwork, a broad range of data sampling, recording, manipulation and storage devices and methods were demonstrated and discussed in the ISLE classroom, addressing the issue of newness. Links to vendor and supplier web sites were referenced for background and future use. Teacher-generated guidelines were reviewed and included with each sample kit. An electronic field log was generated to compile and archive the actual results recorded on separate grids also stored with the related equipment.

These same techniques were practised on the local day field trips, addressing the issue of massiveness. The participants worked in pairs to collect data via both

manual and digital methods for the same sample. As teams rotated through the procedures, each individual gained personal experience with the equipment and processes to be used on the extended field trip.

These trials allowed the teachers to ask questions about the instruments, compare results, and intelligently evaluate the advantages and disadvantages of each method. The pressure of ‘doing it right’ was relieved as the group worked together in places that could be easily revisited if necessary. By recording their data on the same form used by another pair during the previous session, a sense of responsibility and team, along with an awareness of data trends evident over the spread of sample sites was cultivated. They were encouraged to discuss differences and questioned each other to determine possible variables that influence data collection and interpretation.

Ultimately, on the extended field trip, participant teams were prepared to and comfortable with independently employing proper sampling methods and techniques, thereby, addressing the issue of appropriateness. Immediately realising their tangible contribution to the group data archive, they gained confidence and ownership in the overall project outcome through this single aspect of the design.

3.2 Context of the Classroom in the ISLE Model

To support and develop the integration established in the underlying information technology learning environment, the instructors modelled constructivist practises in the university classroom that were again applied during the actual field trip. Information technology was presented in an open framework to facilitate the teachers’ conceptual understanding and to demonstrate the practical implementation of relevant options. Information technology was not approached as a separate subject or as a specific tool or resource. Such first-hand experience allows for direct knowledge transfer (near- and far-term) to teaching and learning environments surrounding the actual field trip (Foxon, 1993). This further study of psychosocial aspects of the learning environment offers potentially valuable ideas and techniques for teacher education (Fraser, 1998a).

A process approach to constructivist practice created an open and flexible framework within which each participant was supported in processing all aspects of the concept. Coursework was carefully arranged to maintain a balance among the physical, intellectual and emotional elements of each lesson. In planning sessions, key points to be elucidated in each stage were defined. If the group processing did

not lead toward similar conclusions or began to follow an unrelated tangent, the leader refocused their reasoning through guided inquiry.

In essence, the instructors did the *teaching* and left the *learning* to the individual program participants. Instead of giving them rote answers, they were helped in finding and using a variety of means to discover viable solutions for themselves. Instead of lecturing (which would inevitably set the field ecology instructor and information technology assistant apart from the group), a context for experimentation and observation through hands-on activities, individual and team reflections, multi-faceted generalisations, and multilevel applications was developed.

Although each class was centred on a different topic (ecology, geology, technology, humankind, and the environment), the lesson structure followed a similar format for each. This critical design feature transformed the ‘facts’ gathered from an independent, subject-based division into an integrated, concept-based continuation. Understanding developed and the focus flowed from general observations to specific details and back into the context of the original – but now sharper – ‘big picture’. The sequence of experience, reflection, generalisation, and application (ERGA, described later in section 6.1.3) provided the scaffolding for each class, as well as the framework for each lesson within the class.

Figure 8 illustrates how the cyclical repetition within each segment illuminated the commonalities and inter-dependencies of each concept. Participants were repeatedly exposed to activities and instruction in a hierarchical fashion. Every group instruction could be outlined as a four-part macroscopic overview comprised of experience, reflection, generalisation, and application phases. Each segment of that overview enveloped a similarly repeated four-part microstructure comprised of more detailed experience, reflection, generalisation, and application phases. Further, each segment of the microunit was directly tied into each of the main topics of the course: ecology, geology, information technology, humankind, and the environment.

Note that within the conceptual framework, the ERGA sequence is represented by a vertical progression (↓ ↓ ↓ ↓), as opposed to the horizontal progression (→ → → →) for the logistical framework shown later in Table 6.

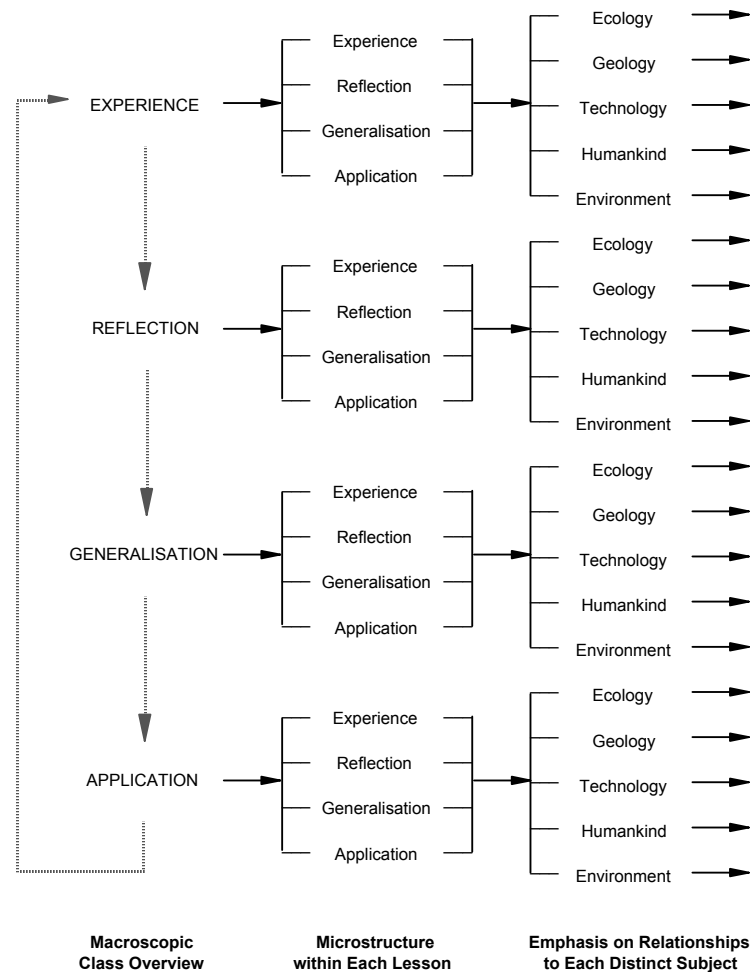


Figure 8. Conceptual Hierarchy of ISLE Classes and Day Trips

This cyclical hierarchy, or information ‘chunking’, was further accentuated through the virtual field trip project configuration. Simple in design, concept maps (described later in section 6.1.2) served as a catalyst for exploration, as well as evaluation. The ISLE model utilised concept mapping to help teachers to think about science in a different way, encouraging them to ask and answer the *why* and *how* of the *what* and *where*. Information technology was continually reiterated within the course project web interface through the navigation panel. Teacher notes, trip logistics, related links, data archives and resource images were consistently updated and made available as assumed features within the virtual field trip structure.

In the university classroom – as a group – the participants created a top-level, big picture concept map to represent the goal of their field studies and the structure of the web site, illustrating the main course topics: ecology, geology, information technology (implicit in the supporting materials), humankind, and the environment.

This provided a prescribed framework (context) in which to collaborate, along with a purpose and direction for focusing their individual reports. Figure 9 shows the actual top-level concept map which presents the final topics.

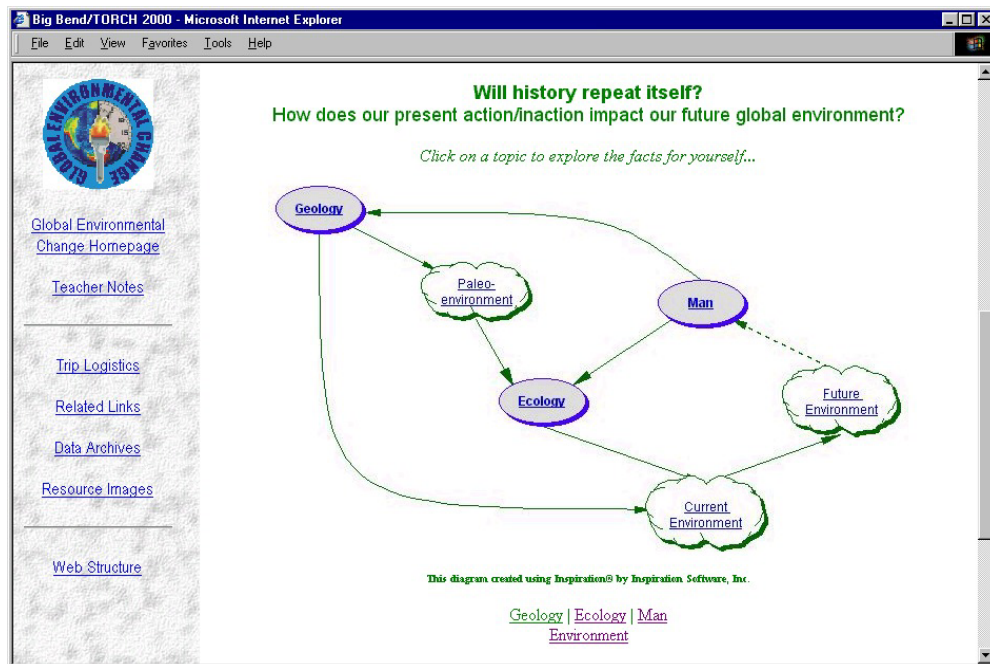


Figure 9. 'Big Picture' Concept Map (Group)

Before leaving the university, the participants generated a list of topics considered in the lessons and experimented with various ways to organise the concepts into associated threads. In this manner, they inadvertently described various pathways for discovering the same materials, a unique benefit of the non-linear nature of the web. Following that review, the instructors, as facilitating members of the group, helped each of the teachers to identify a related theme that s/he, for a multitude of reasons, found interesting.

Then, each teacher formulated and presented a specific research question to be investigated in the field. These questions constituted the main ideas for the topical concept maps, one each for ecology, geology, man and the environment. The information technology assistant (also the researcher) compiled the topics into second-level concept maps that were taken into the field to remind the participants of the specific areas of investigation and concretely reinforce the inter-relatedness of each subject within the whole project. Figure 10 shows an example of a second-level map, representing specific research questions.

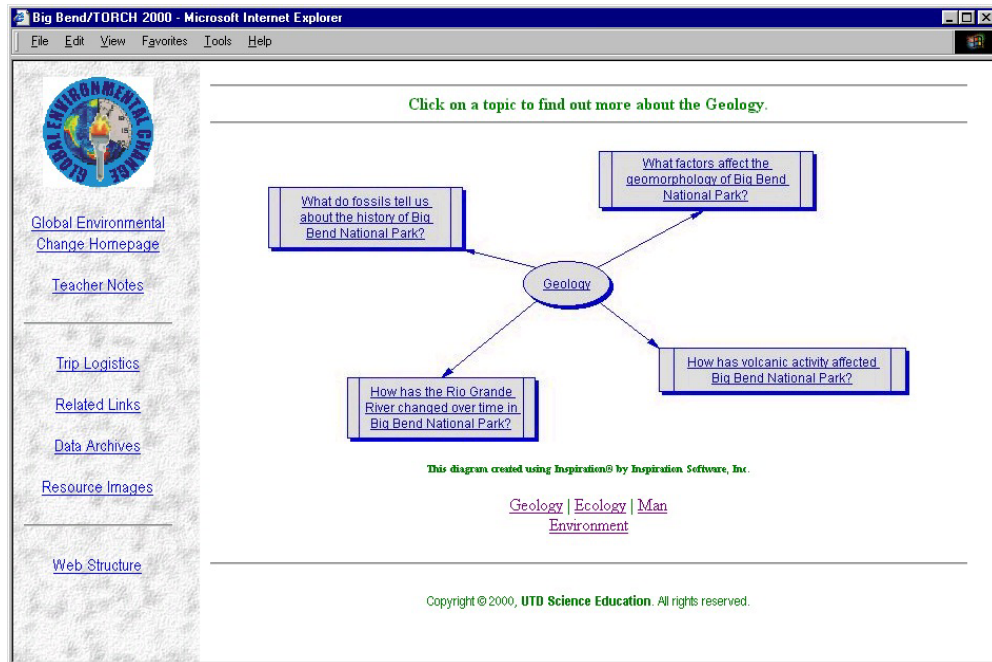


Figure 10. 'Topical' Concept Map (Compiled)

On the extended field trip, the painted walls and glass windows of the classroom were replaced with the majestic peaks and scenic vistas of the natural area. As the teachers recorded their own observations and articulated the intricacies of the relationships to the previously-defined key concepts, they developed their own topic-specific projects, presented as third-level content concept maps, completed with text, graphics, links to external sites and other resources. Figure 11 shows an example of a third-level concept map that includes supporting text, graphics and images.

After a few instances emphasized by the field ecology instructor and the information technology assistant, the teachers instinctively supported each other's work. When one noticed something not directly relevant to her/his focus area, s/he brought it to the attention of the person who was working on that specific feature.

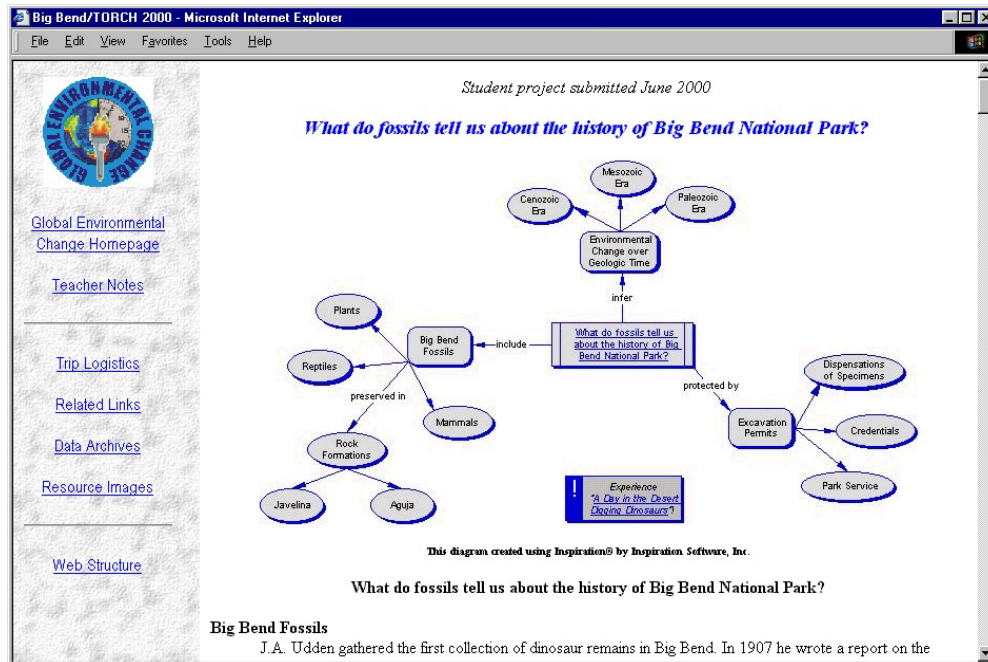


Figure 11. 'Content' Concept Map (Individual)

In the post-trip phase, the final web site was assembled by linking the individual field reports to the topical maps already linked to the top-level map. As part of the project requirement, teachers also included cross-links to other individual project pages. Understanding the virtual field trip design, they were assured that the detailed observations would be available to them. By design, the inhibiting effects of information overload and non-linear processing were minimised before leaving the university classroom and entering the actual field locale.

3.3 Role of the Field Trip in the ISLE Model

The extended field trip to a natural area provided an occasion for the participants to utilise their new skills and exercise their talents freely in a real-world setting. Elements of the physical environment significantly impact this learning environment – *and constitute a gamut of variables far beyond the researcher's and instructors' control*. Those same challenges afford a truly distinctive opportunity to model the critical techniques of a constructivist pedagogy. The field adds yet another dimension to the commonality of the group as the limitations of being human are not restricted to role. Teachers, instructors, local experts, and visitors meet on the most basic level. This simple realignment confers a new perspective on the 'big picture'.

Capitalising on the unique aspects of the field trip learning environment, the instructors' teaching role shifted toward that of a consultant, with a less noticeable, but equally important, responsibility for leadership. The pre-trip stage was essential to the ISLE design in that it removed much of the fact-based teaching required to learn in the field. As such, rather than revert to a content-centred approach, the instructors were able to maintain the principle student-centred focus. The decisions that the team members made in the field addressed the psychosocial needs of the individuals in addition to the general safety and physical comfort of the group. Also, the instructors thereby were empowered to utilise their skills and exercise their talents freely to further model good practice in the field.

For example, to address the issue of newness, the lead instructor informally introduced the teachers to each point of interest with a brief overview of what to expect, noting specific particulars such as what they needed to bring, how long they would be away from camp, and what features they were expected to explore. Just as in the classroom, the program design balanced individual, team and group activities to deepen the collaboration and strengthen the networks.

Because the typical three-day phenomenon (the period of adjustment typically required for individuals to feel comfortable as a part of the functional field trip group) was reduced to about three hours, the time for discussion and relevant exchange was dramatically increased. With a predefined purpose, the teachers were able to stay on-task and maximise the learning opportunities available for them. With a basis of understanding individual comfort levels and background interests, the instructors were able to tutor each individual and team effectively, thus supporting the learning spawned by the reawakening of natural curiosity and wonder. Explorations and expectations matched the present level of ability and acceptance. This in turn reduced the effects of the Everest syndrome (the tendency to feel the need to use technology, simply because it exists; includes overwhelming nature of massive amounts of information resources and tools available).

To address the issue of massiveness in a tangible way, the instructors made the same variety of types and scales of maps previewed in the coursework available in the field. These resources including electronic versions, on which the teachers located the sample and study sites as each was experienced. After visiting a locale, as the team re-grouped, a few minutes were focused on discussing what was seen, heard and felt along the way. This perpetuated the overall cycle of experience, reflection,

generalisation, and application that was initiated in the classroom activities (refer back to Figure 8). Participants were engaged physically, intellectually and emotionally in the process. Dedicating time and energy to thorough completion ensured that the site visit meaningfully contributed to the teachers' life experience with both knowledge and understanding and became much more than simply a memorable tour. Every facet of the entire adventure became a unique lesson that enriched the group professionally and personally.

The issue of appropriateness was addressed from the instructors' point of view through the reflective journal questions (see section 7.2.6). High-level questions were composed for each area to be visited to guide observation and stimulate reflection. The participants naturally exhibited the principles of constructivist pedagogy as they taught each other. Because the teachers knew that it was acceptable to learn in that way based on their recent classroom experience, they looked for and found the answers and support that they needed. The instructors did not have to dispense the facts or selectively indicate the nuances to the teachers; the teachers constructed the context and interpreted the implications for themselves.

Surprisingly, from the participants' point of view, the instructors practically personified appropriateness as they improvised events rather than attempted to follow a prescribed schedule in the ever-changing field environment. The teachers were actively involved in the daily planning. In one session, the options were put to vote. Everything is personally relevant in the real world. Throughout the trip, the instructors and local experts shared observations that indicated change over time based on their prior experience and research. This additional insight provided a continuity that expanded the perspective and intensified the relevance of the group's actual field trip.

3.4 Integrated Science Learning Environment (ISLE)

Conceptually, the program approach followed a logical development and directly addressed each scale of the learning environment assessment, the Constructivist Learning Environment Survey (CLES, described in section 5.1.6). For example, personal relevance was established, on the basis of existing knowledge and understanding, by formalising what feature interested each individual in the field locale. *What did they already know about the site?* The uncertainty of science was illustrated by the instructor's presentation of multiple theories and the participants'

discovery of conflicting interpretations of real-world data. *What do others know about it and how did they find out?*

Critical voice was promoted by classroom exercises and field investigations that exposed teachers to the opportunities and encouraged them to hypothesise about the possibilities for their research projects. *What do you want to know about it in this area?* Shared control was demonstrated as the participants learned more about scientific methodology and focused their individual topics within the collaborative group perspective. *What do you need to know and be able to do to find out about it?* Student negotiation was fostered through professional networks initiated and developed throughout the program. Participants discussed their ideas with scientific experts conducting timely research, informal science education specialists offering curriculum support, community leaders promoting local agendas and, most importantly, with each other as peers and colleagues with a shared goal and unique vision. *How will you find out what you want to know about it in this area?*

Key concepts were addressed from multiple perspectives to accommodate multiple learning styles and levels of understanding. As an example, consider the overt transfer of the Community Juggling activity (Nix, 2000a) across the traditionally separate learning environments. Table 4 summarises the activity in terms of how each component (objects, pathways, and individuals) was translated into each milieu (university classroom, extended field trip, and information technology).

Table 4. Examples of How the Community Juggling Activity was Used in Each of the Traditional Milieus in the ISLE Model

Component	Objects	Pathways	Individuals
University Classroom	Scientific disciplines and related fields of research (group map)	Relationships and dependencies among topics (compiled maps)	Focused research questions explored (individual maps)
Information Technology	Informational web sites and electronic media	Internal and external hyperlinks in media	Static and dynamic pages in media
	Collection and recording devices	Research methods and procedures	Published studies and proposed hypotheses
Extended Field Trip	Qualitative and quantitative data	Observation and communication	Colleagues within a research team

Similarly powerful physical and conceptual metaphors concerning the integration of educational and scientific theory and practice with information

technology were used throughout the program. The continuous application of appropriate information technology established a personally relevant commonality among the learning environments. Teachers are typically avid lifelong learners and their distinct perspective as teacher-students allows for virtually immediate transfer when provided with a clear, relevant and supportive environment.

3.4.1 *Holistic Implementation of Field-Based Program*

The Integrated Science Learning Environment was enabled by realising the constructivist paradigm (described in section 6.1.1). Conceptually, instead of scheduling separate technology-based classes, the instructors used information and technology in the context of learning about *what* the team investigated by emphasising *why* the processes and purposes mattered. Practically, assigning small-scale, independent research exercises from the program start ensured that the teachers were confident and comfortable with using the specific information technology.

Through the experiential cycle, as participants assumed an active role in acquiring and sharing background information relevant to the group project, they also gained experience in navigating and integrating non-linear resources into their teaching repertoire. Hence, the instructors also were able to help them to exercise discretion in selecting from a wide range of current information options throughout the program (technological literacy). Table 5 describes ways in which information technology was integrated into the ISLE program to address each aspect of the virtual field trip product in each of the traditionally separate learning environments.

Table 5. Examples of How Information Technology was Used to Develop Each Aspect of the ISLE Model in the Traditional Milieus

ISLE aspect	Examples of Information Technology Usage		
	Newness	Massiveness	Appropriateness
University Classroom	Detailed itinerary and suggested websites on virtual field trip website	General overview presentation; areas of focus and interest	Email participant introductions; email rules and expectations
Information Technology	Intranet and internet usage	Electronic presentation; web surfing	Electronic mail to/from trip participants
	Contribution to website/group project	Website design; availability of laptop	Mini-presentations; use of digital camera
Extended Field Trip	Focus on creativity; journal questions to address likes/dislikes	Focus on collaboration; journal questions to address information/organisation	Focus on communication; journal questions to address change issues

For example, rather than simply distributing printed sheets of trip-related information, the teachers were shown how to access the detailed itineraries and other resources through the course website. Sharing this common tool reduced the newness of both the Internet and the impending trip for both the teachers and their families and friends. By providing field access to the same laptop computers that were used throughout the classroom lessons, the teachers were relieved of having to bring or remember everything that had been assembled to date.

The organised, familiar structure of the developing website helped the participants to place new information acquired in the field into an appropriate context, thus reducing the negative effects of overload. A focus on maintaining individual and group communications throughout the extended field trip further assisted the participants in developing an appropriate perspective toward new and developing theories, as well as more comprehensive interpretations of the collected data with the benefit of their combined observations.

3.4.2 Expectations for Programs Based on the ISLE Model

Combining a variety of approaches to learning could lead to the successful development of a new, Integrated Science Learning Environment (ISLE). Extending continuously across the intellectual, physical, and emotional boundaries of the university, field trip, and class/school learning environments, the ISLE model was designed to support and encourage classroom teachers in the implementation of new technologies and teaching strategies. The purpose of this was to bring about personal growth through activities that place science-related content into perspective and apply the principles of collaborative problem solving in a real-world setting.

In creating a singular group dynamic by requiring an integrated project rather than promoting multiple individual efforts, the inhibiting effects of site novelty, information overload, and the three-day phenomenon typically experienced on field trips could be placed in context and therefore more manageable and understandable. Directing participants to concentrate on an aspect of the field experience that has particular significance to them should minimise the distractions and frustrations of sensory overload in the natural setting (Ledbetter, 1999a). With successful transfer, the same techniques used to deal with these physical, intellectual, and emotional issues in the field could be applied to integrating information technology in the classroom.

It was anticipated that effective applications of technology and modelling of inquiry-based teaching would add critical and creative thinking practices to each individual's teaching repertoire. A holistic approach could result in the internalisation of concepts and development of support networks and skills. Such a positive life experience could then serve as the foundation for implementation of new teaching techniques that would further influence lifelong learning.

The principles of constructivist teaching guided the design of the ISLE program, providing a common thread throughout both phases of the research. The Constructivist Learning Environment Survey (CLES) was used to provide comparative assessment and comprehensive evaluation of this multidimensional program. Through focused activities and strategic exercises, the ISLE model was designed to encourage individual communication, collaboration, and creativity to develop a sense of personal relevancy and ownership of a complex group product. Exposure to scientific processes and practice in real-world settings, as observed on day trips and performed on the extended field trip, was implemented to demonstrate the uncertainty of science and importance of inquiry and discovery in everyday life. Modelling constructivist teaching throughout the university/field trip course was intended to develop individual experience with and skills for recognising critical voice, managing shared control, and effectively utilising student negotiation to be transferred for similar application in the school classroom.

Responses to CLES were used to support the general research question of whether or not a teacher's participation in the ISLE program effected a change in their respective students' learning environment. If the university/field trip segment successfully modelled a constructivist approach, supported by the results of the adult form (CLES-A) administered immediately after the field trip, then the question of interest is whether or not the participants' teaching style changed, as assessed by the comparative student (CLES-CS) and comparative teacher (CLES-CT) forms administered just before the school holidays. This also indicates the degree of far-term transfer from the university/field trip experience into the actual classroom, the ultimate goal. The comparative form is appropriate in that the school-level environment has a tremendous impact on the implementation of science teaching.

The teacher concept maps were used to indicate, both quantitatively and qualitatively, the individual acceptance/understanding of non-linear processing as represented by the web-based project. By design, the ISLE program attempts to

change their thinking. Pretest and posttest analysis of the Teachers' Attitude Toward Information Technology (TAT) data were used to evaluate ISLE in terms of teachers' attitudes toward information technology. Additional qualitative tools were used to support the documentation of breakthroughs that might affect a significant change in the teachers' perceptions of the pieces of science taught in the university classroom and observed in the field and how they fit into the big picture. In theory, this change in viewpoint deepened their understanding of pedagogical concepts and personalised their knowledge of science content and practice – thereby internalising the information – and could result in both near- and far-term transfer that reaches into the school environment.

The specific research questions stated in section 1.2 were addressed separately, but the data was intermingled. In other words, the same data contribute to answering the general inquiry of whether or not the teachers' participation in the ISLE program would result in a more constructivist learning environment for their classroom students. For example, the construction of knowledge (the education portion) can be accessed visually through concept mapping, which also indicated the ability to process information in a non-linear fashion, i.e. create and use a web-based product (the science portion).

The conclusions of this work are of equal importance to three distinct audiences impacted by each main facet: 1) teaching style, of direct benefit to teachers, 2) integration of available information technology, of direct benefit to administrators; and 3) multidimensional assessment of constructivist programs, techniques of direct benefit to educational researchers.

3.5 Summary of ISLE Conceptual Framework

Chapter 3 presented the conceptual framework underlying development and implementation of the ISLE model with respect to the logistical framework of the ISLE program (discussed in the following Chapter 4). It described how the implementation of information technology reinforced the program design and therefore was evident in all stages of the program – *although never the focus*.

As such, the classroom and the field trip learning environments were joined seamlessly through the covert application of relevant tools and resources in real-world settings. By using information and technology in the context of learning and by emphasising process and purpose, the teachers' confidence and comfort with

using the technology was improved within the constructivist paradigm. It stands to reason that the creation of a truly Integrated Science Learning Environment could dissolve the psychosocial boundaries of the independent learning environments to support information technology and constructivist pedagogy.

Sections 3.1, 3.2, and 3.3 detailed the ISLE model in the context of the traditionally separate learning environments. With respect to the information technology milieu, less than 10% of the course implementation of information technology was allocated to instruction specific to using the required application software. With respect to the classroom milieu, a sequence of experience, reflection, generalisation and application provided a scaffold for each class, as well as the framework for each lesson within the class. Within this context, the extended field trip provided an occasion for the participants to utilise their new skills and exercise their talents freely in a real-world setting. Then, section 3.4 reviewed factors that influence the holistic implementation of field-based programs and suggested expectations for programs based in the ISLE model.

The ultimate success of the ISLE program is dependent on a design that appears simple at the surface, yet is supported by a complex theoretical framework, as described in this chapter. Through covertly indirect methods, the ISLE model overtly attempts to directly address two major issues that challenge effective fieldwork and offer the key to effective design and integration of web-based media into the classroom learning environment: information overload and non-linear processing. Comprehensive evaluation and assessment of critical cognitive and psychosocial aspects is the ultimate challenge in such a multidimensional environment.

Implementation, described in Chapter 4, poses yet another set of issues.

Chapter 4

ISLE LOGISTICAL FRAMEWORK

The ISLE program was marketed as a summer science education course designed to enable teachers to create materials for use in their respective school classrooms. It was unique in two ways. First, it encompassed two different localities for field research: the Dallas-Fort Worth metroplex in north Texas and Big Bend National Park in southwest Texas. Second, participants compared and contrasted global environmental change from two different perspectives: modern day and prehistoric time.

Complete logistical details – including a detailed itinerary with packing list and field trip menu; specific site information with location maps, related links, and real-time weather reports; course requirements listing lesson topics and references along with registration forms and project descriptions; and contact information for participants as well as family and friends – were made available to the participants through the developing program website. This information was archived for public review and unrestricted classroom use on the Global Environmental Change website, maintained and perpetuated by the university for students, teachers, and other lifelong learners.

During recruitment, it was emphasised repeatedly that teachers were expected to participate in several evening and weekend classes, as well the extended field trip to a natural area. It was reiterated that, during the extended field trip, they would be camping and hiking (up to two miles per excursion) across desert terrain. Food and transportation were provided, but participants were expected to bring their own camping gear and personal field equipment. The entire course (Phase I) spanned approximately two months, from May 4-June 27. The camping segment lasted a full week, from June 8-14. Participants were notified of acceptance to the ISLE program through an electronic mail message that introduced them to the developing virtual field trip website by requesting completion of preliminary release forms available online. All 12 teachers and one administrator completed the requirements for the Field Ecology coursework. As described by the instructor, the purpose of the Field Ecology course was:

...to familiarise students with ecological principles while allowing them to collect actual scientific data in the field. Pre-trip work includes lecture/discussion of ecological concepts and applications to the areas to be visited. Students also incorporate the latest related information from the Internet to enhance their understanding of the incursion of humans on wilderness areas. They are also required to become facile with one or more data collection tools prior to the trip. In the field, students are required to keep a detailed journal, including data from water quality tests, tree transects, weather data, and observational data. Students then interpret the information using statistical analyses, to present a detailed summary of the ecological structure of the area. These data are compared to data collected in previous years to determine man's impact on the environment. This information, along with trends from data provided by the World Wide Web, allows a global perspective on the issues facing National Parks and other natural areas.

Upon their return from the field, students are required to report their results in a form conducive to incorporation into the data section of the Science Education Program's web site. Students provide mathematical and written analyses of their data, an overview of the ecology of the area visited, explanation of use of their chosen data collection tool, and detailed information about the interaction of geology, ecology and man. This report also includes recommendations for stewardship of the wilderness areas. (Ledbetter, 2000b)

This practical description embodies the conceptual framework of the ISLE model (described in Chapter 3) by stressing the *how* and the *why* of the coursework as equally important as the *what* or *where* of the specific experiences. Additional details about activities, resources, and site locales are available on the virtual field trip web site. This Chapter 4 describes the logistical framework of the ISLE program. It identifies how information technology was used to support constructivist teaching in the university classroom and how constructivist practice was used to support meaningful learning in the field. The following sections, 4.1, 4.2, and 4.3, provide a thick description of the pre-trip coursework and local day trips, extended field trip, and post-trip coursework and follow-up activities that developed the Integrated Science Learning Environment.

4.1 Pre-Trip Coursework and Local Day Trips

Consistent with research findings (Abell & Roth, 1992; Birnbaum, Morris, & McDavid, 1990; Feazel & Aram, 1990; Kulke, Bowyer, & Spohn, 1992; McDermott, 1990; Pedersen & McCurdy, 1992; Rhoton, 1991; Vaidya, 1993; Young & Kellogg, 1993) concerning the advantages of integrating science content skills using real-life experiences and peer-directed hands-on cooperative learning activities to promote positive attitudes toward teaching science, the pre-trip coursework also aimed to promote positive attitudes toward the use of information technology in learning science. With the exception of the day trip to the water treatment plant, the field ecology instructor and the researcher, serving as the information technology assistant, facilitated all events.

Each class meeting incorporated an experiential training activity associated with a related aspect of information technology, the modelling of information technology in content-based instruction, and collaborative discussion requiring peer and mentor interaction, along with individual reflection and contribution to the group as a whole. Complementing the cyclical pattern described in section 3.2, Table 6 outlines each pre-trip lesson listing the starter experience, reflective topic, general activity, and pedagogical application. (The application stage is defined in terms of the five scales of the Constructivist Learning Environment Survey, detailed in section 5.1.6.)

Note that within the logistical framework, the ERGA sequence is represented by a horizontal progression (→→→→), as opposed to the vertical progression (↓↓↓↓) for the conceptual framework illustrated earlier in Figure 8.

Table 6. Implementation Outline for ISLE Pre-Trip Classes

Subject	Experience	Reflection	Generalisation	Application
Geology	Community Juggling	Paleo-environments	Dirt Cake	Uncertainty of Science
Environment	If I Had a Hammer	Data Collection Devices/Methods	Concept Mapping	Student Negotiation
Technology	Rope Tricks	Chunking Complex Topics	Furry or Fuzzy?	Critical Voice
Humankind	Who Was I?	Topical Inter-relationships	Map Overlay Comparison	Personal Relevance
Ecology	Balancing Acts	Ecology Field Methods	Oh Deer!	Shared Control

Throughout the university coursework, the virtual field trip web site was used to improve teaching efficiency and effectiveness by providing an ‘anytime, anywhere’ interface to specific information for review and reference. The teachers were active contributors from the start as assignments required them to conduct searches for appropriate web sites related to their personal and professional interests, access files and forms from the archives, and help build and use the water chemistry database in real time. (Water chemistry data were collected at all outdoor sites as described in section 4.1.2).

Outlined in Table 7, each local day trip built on aspects of real-world research, allowing the teachers to become comfortable about teaching each other and learning in an outdoor environment, through the implementation of constructivist pedagogy. As in Table 6, note that within the logistical framework the sequence is represented by a horizontal progression (→ → → →), as opposed to the vertical progression (↓ ↓ ↓ ↓) for the conceptual framework illustrated earlier in Figure 8.

Table 7. Implementation Outline for ISLE Local Day Trips

Site	Experience	Reflection	Generalisation	Application
Dallas Museum of Natural History	Fossil record of Texas dinosaurs	Reconstruction of excavated bones	Geologic research and field methods	Interpretation of historical artefacts
Parkhill Prairie	Plant identification and field sketches	Preservation of natural areas	Ecologic research and field methods	Significance of non-renewable resources
Heard Museum of Natural History	Tree identification and transect analysis	Co-existence of multiple members of a habitat	Environmental research and field methods	Impact of humankind on a local, closed system scale
Water Treatment Plant	Facility tour and water test	Comparison of results and techniques	Hydrologic research and recycling	General public awareness and global impact
Special seminar: Paleo-botany	Comparison and analysis of present and past leaf litter	Application of technology and statistics to current research	Integrated research and field methods and trends	Increased understanding through multi-disciplinary study

In terms of the project design, a sense of team was developed as the teachers practised various field methods, shared direct observations, and relied on the trip leaders, peers, and experts interested in their unique interpretation of the experience. In terms of classroom teaching methodology, the main goal of the day trips was to create an awareness of new and current sources of information and technology. The

instructors deliberately placed the teachers in situations in which they had to work together to make the most of the learning opportunities. As they worked together on their own accord, they were expected to ask questions in their own words from individually unique perspectives. This powerfully reinforced the transferability of conceptual knowledge from the university classroom, through various field locales, and back to what they knew from their school classroom and real-world experience.

At the close of every meeting, all of the activity descriptions, procedural details, related references, and presentation materials were made available through the virtual field trip web site. The teachers were encouraged to refer to the information for incorporation into their projects and to use the exercises in their own classes as appropriate. They were reminded to complete their journal entries or assignments and to refer to the online course outline for preparations for the following lesson. Individual and group electronic mail conversations were maintained throughout the program. The following chronological sections briefly describe the components used to implement the ISLE model in the pre-trip stage.

4.1.1 Geology-Based Class

(May 04, 2000 from 6-8 pm)

The Community Juggling activity (Nix, 2000a) was used as an ice-breaker to introduce participants to each other and, more importantly, to translate conceptual aspects of information technology into physically concrete entities. As described in section 2.3, information overload and non-linear processing are two key issues that challenge both teachers and learners in each of the traditional learning environments. In providing the critical foundation as the initial common experience required to position the virtual field trip product, this activity metaphorically became the group's ultimate frame of reference. It was referred to repeatedly in the context of each learning environment (refer back to specific metaphors detailed in Table 4).

For example, guided reflection, embedded within a discussion of paleo-environments that introduced new jargon and diverse terminology, placed the potentially overwhelming information in context and modelled logical progression through the material. After the lesson, the information technology assistant digitised the 35-millimeter slides used by the geology instructor to illustrate features of the main field locale and added them to the web site for the teachers' use, demonstrating the value of electronic media as well as the functional design of the virtual field trip.

With that basic understanding of geologic fieldwork, the Dirt Cake activity (Repine & Hemler, 1999) was used to generalise further the similar logic and organisation of stratigraphic investigations. The step-by-step progression required to unravel the hierarchical evidence within each 'strata' deliberately suggested the overall structure of the pages to be developed within the virtual field trip. Discovery of the multitude of variables inherent in each proposed theory paralleled the currently incompatible interpretations of the paleo-environment in the Big Bend region.

This application of alternative information processing thus supported the uncertainty of science. For follow-up, the teachers were required to locate and evaluate three new web sites addressing environmental issues relevant to the area to be added to the list of related links on the project web site. As they summarised their impressions, they realised how the opening Community Juggling activity, represented not only the form and function of the virtual field trip, but also that of the scientific method.

4.1.2 Environment-Based Class

(May 11, 2000 from 6-8 pm)

The If I Had a Hammer activity (Nix, 2000c) was used to focus the class on the appropriate selection and use of various tools and resources. It gave them the experience of trying to solve a problem with what they were given, then the opportunity to work together to find a better solution. As they collaborated on this specific task, they were exposed to the benefits of exchanging ideas, trying new methods, learning about other options, and focusing on their goal to make a decision. To transition from the activity to the course content and their school classrooms, the information technology assistant helped the teachers to expand their present definitions of educational technology to include a broad range of tools and techniques, not just the fact that there was or was not a computer nearby.

This led directly to reflection on the data collection devices and methods presented and practised on the campus grounds. Both manual and digital readings were recorded for each dataset (Site Description, Wind & Sound, Temperature, Relative Humidity, Dissolved Oxygen, Water Chemistry 1, and Water Chemistry 2). For example, both a glass ball thermometer and digital thermometer probe were used to take the various temperature readings. Both a titration kit and electronic meter were used to take dual readings of the dissolved oxygen. Extensive discussions

concerning the relative benefits and comparing general concerns about each procedure ensued among the sampling teams. The GPS (global positioning system) provided a way to tie sample sites directly to the digital and paper maps.

Participants signed their names and dated each sample site in a table on the reverse side of the sheet, allowing more room for field notes beside the actual data and a quick reference format for verifying performance of each technique as participants cycled through the protocols. More importantly, this up-to-date, non-intrusive resource served as a list of peer ‘experts’ who could be queried conveniently if new teams needed assistance in the field. Figure 12 shows an example of the field data log for dissolved oxygen. These forms were produced by printing the electronic spreadsheet files on coloured, heavy-weight paper. This format also provided another example of information organisation and management decisions made specifically in support of the virtual field trip product.

Site #	Titration Kit (ppm)	Electronic Meter (ppm)	Notes
01	10.0	9.64	No salt refractometer; estimated salinity at 2.
02	8.8	6.79	
03	7.6	5.35	
04	6.4	6.43	
05	6.0	6.63	
06	3.4	1.72	Titration done 2 times and ppm were same. Probe was acting up.
07	0.8		Probe not functioning properly.
08	6.4		Probe not functioning properly.

Figure 12. **Sample Field Data Log Sheet**

Through the use of concept maps (drawn by hand on a whiteboard), the information technology assistant revealed how the data archive related to each part of the overall project to generalise the participants’ understanding of the importance of data collection, manipulation, and presentation. This demonstration of how the archived field log database functioned within the project site paralleled the eventual incorporation of their contributions. Inferences were also made to the combination of qualitative and quantitative data to formulate a complete assessment.

That there were many more than one way in which to put the pieces together enabled the teachers to apply the principles of teamwork to reach acceptable guidelines and postulate reasonable conclusions meaningfully. Talking about their choices and sharing our experiences with options supported student negotiation and showed the value of multiple perspectives. The field ecology instructor reinforced their commitment to work with *them* to develop *their* web page by utilising the range of tools and resources *they* selected to best define and represent *their* work.

4.1.3 *Local Day Trip to Dallas Museum of Natural History*

(May 13, 2000 from 11 am-4 pm)

After enjoying a picnic lunch and collecting data from water sampled at the lagoon on the park grounds, the director of the Dallas Museum of Natural History led the group on a tour of their permanent exhibit featuring Texas dinosaurs and their habitats. The experience exposed the teachers to a well-documented and impressively displayed fossil record of Texas dinosaurs, from the perspective of the learner, that integrated aspects of each of the course subjects and university classes.

As one of the principal scientific researchers involved with the Big Bend excavations conducted through UTD's Science Education program, Dr Louis Jacobs was able to provide first-hand insight in the reconstruction of excavated bones. A 'behind the scenes' visit to the working laboratory offered a chance for the teachers to ask detailed questions that reflected information explained in the geology class. Computer-generated animations based on reconstructed models illustrated just one benefit of information technology in scientific research. X-ray capabilities enabled the creation of a three-dimensional image of a soft-bodied pre-historic lizard preserved in amber. These procedures were generalised in terms of other ongoing geologic research efforts and field methods, and further applied to the identification, cataloguing, and interpretation of historical artefacts.

4.1.4 *Paleo-Botany Seminar (Optional Class)*

(May 18, 2000 from 6-8 pm)

Unexpectedly and by coincidence, a special seminar on paleo-botany was offered as part of the program. Dr Bonnie Jacobs, head of the Environmental Science program at a nearby university, presented a brief overview of her research in Tanzania, Africa. (This optional class meeting was videotaped by the information

technology assistant so that those who were unable to attend could review the session.) Through an original, hands-on activity, the teachers identified and compared present and past leaf litter in the classroom just as Dr Jacobs does in the field and laboratory.

This experience helped the teachers to comprehend the complexity and detailed nature of her pioneering investigations into climate reconstruction based on fossil leaf evidence. In the pursuant discussion, Dr Jacobs reflected on specific examples of how information technology advanced her work by enabling the rapid identification of literally thousands of collected leaf shapes. These data were further subjected to complex statistical analyses and correlated with existing visual and data archives. Computer modelling processed the millions of variables needed to predict past climates based on fossil and isotope records reported from around the world reasonably.

Married to Dr Louis Jacobs (see section 4.1.3), she shared a keen understanding of the general trends in traditionally separate areas of research and therefore convincingly stressed the benefits of integrated research and cross-disciplinary field methods. This application of multiple perspectives demonstrated her increased understanding gained through multidisciplinary study. Both institutions added cross-linked references to each respective web site to support this collaborative integration of research. As members prepared for the ISLE field experience, new friends and peers excitedly followed this colleague's expedition through updates posted to her similarly developing web site.

4.1.5 Local Day Trip to Parkhill Prairie

(May 20, 2000 from 8 am-12 pm)

Identifying native plants, grasses, and insects in the field was a new experience for many participants. The trip leaders offered instruction in using the plant identification keys and enhancing field sketches with pertinent information. As the teachers collected water sample data from a man-made pond, they reflected on the benefits of and challenge to preserving such natural areas.

The value of information technology incorporated into digital photography and imaging capabilities was appreciated as team members collected visual data to add to the image resources archived on the virtual field trip web site. The cumulative effects of individual acts were generalised in the context of related ecologic research

and field methods. The critical impact of non-renewable resources was realised as environmental aspects were individually applied to each teacher's respective area of interest over a picnic lunch.

4.1.6 Local Day Trip to Heard Natural Science Museum

(May 20, 2000 from 12-4 pm)

To prepare participants for the required tree identification and transect analysis to be conducted during the extended field trip, the Trees, Trees and More Trees activity (Fifer & Ledbetter, 2000b) was performed during an afternoon session. This experience familiarised the teachers with specific terminology and measurements, as well as key concepts required for proper data analysis and interpretation. Calculators and spreadsheets were identified as helpful, if not critical, research tools.

The cooperation and collaboration necessary to complete the field work provided an opportunity for them to reflect on the similar dependency and co-existence of multiple members of a forest habitat. These activities and observations were further generalised to encompass large-scale environmental research and field methods. The noticeable impact of humankind on this local, closed system scale was readily applied within the context of the research team's virtual field trip project. They were told how their data would be archived and used for long-term studies in both locales.

4.1.7 Local Day Trip to Dallas Water Treatment Plant

(June 01, 2000 from 12-4 pm)

As the field ecology instructor and information technology assistant both attended a conference on research in science teaching, the Science/Mathematics Education Department's assistant facilitated the data collection and tour of the Water Treatment Plant on a major tributary that flows through the city of Dallas. This first-hand experience required signature of a release form acknowledging that the teachers were aware of the presence of two chemicals (chlorine and sulfur dioxide) which are extremely hazardous should accidental release occur at the site.

The group's sampling activity took on powerful significance in light of this potential danger to each individual and the surrounding community. Technicians guided the teachers' reflections as they compared their on-site results and sampling

techniques with those used by the Trinity River Authority of Texas. The training coordinator, John Bennett, generally discussed the importance of hydrologic research and recycling of water resources. To help the teachers apply this content in their classrooms, he provided links to related online curriculum activities created to promote general public awareness of and emphasise the global impact of mechanical and biological processing.

After the comprehensive facilities tour, pre-packaged sets of educational kits developed by the Texas Department of Transportation were distributed for the teachers' immediate use and future reference. The university assistant reviewed the contents and stressed the importance of addressing indirectly related issues noted in the Planning a Highway kit (endangered species habitat, hazardous waste disposal, historic structures and water quality concerns) on a continual basis. The instructors later reiterated the fact that all of these materials were freely supplied for classroom use, reinforcing the cooperation and support of the scientific research community through public/private education and lifelong learning opportunities.

4.1.8 Technology-Based Class

(June 05, 2000 from 9-12 pm)

The Rope Trick activity (Fifer & Ledbetter, 1994b) was used to stimulate creative problem solving. This engaging experience literally forced the teachers to exercise their unique resourcefulness in experimentation and observation. Paired with rope 'hand-cuffs', the teachers tried various approaches to 'straighten out' their interactions. As they worked with their partner and watched other pairs do the same, they discovered several different approaches to resolving their common dilemma.

The implications for constructivist pedagogy were clearly illuminated as the instructors reflected on how explorers can become entangled by the non-linear nature of the web. Both teachers and instructors listed ways to take full advantage of this unusual characteristic through the virtual field trip design. By enabling multiple pathways for discovering the same content, information technology could be used to meet the learning styles and interests of today's diverse population. This benefit was discretely emphasised in an introduction to concept mapping (see Appendix II).

Building on the common experience of a previous session, the visual attributes of multimedia were used to model development of a concept map similar to the contributions expected for the web site. Diagrams generated with Inspiration®

software were embedded in a PowerPoint® presentation on how to ‘chunk’ complex topics. As the teachers viewed the slides in detail at individual workstations in the computer laboratory, the team discussed strategies for breaking information related to their topics into stand-alone units that seamlessly tied into a big picture. The challenge was to minimise overload and maximise the advantages of non-linear processing by segmenting their contributions into manageable bits that complemented the whole.

On returning to the classroom, the teachers practised and improved their general observation skills by performing the Furry or Fuzzy? activity (Fifer & Ledbetter, 2000a). The instructors helped them to translate the differentiators which they visually recognised by verbalising statements that precisely described the detailed attributes and distinguished between the actual and inferred characteristics.

By providing an opportunity for focused discussion, the instructors helped them learn effectively to give and successfully to receive constructive criticism. The teachers experimented with ways to speak up for themselves and also to hear what others were saying in a group setting. This tangibly reiterated the value of each individual’s perspective as new attributes and characteristic were noted, offering deeper insight. Throughout each of the lessons, effective ways to apply their critical voice in their field investigations and project contributions were modelled and, in so doing, showed the teachers how to recognise and acknowledge the same in their unique students throughout their teaching practice.

4.1.9 *Humankind-Based Class*

(June 06, 2000 from 9-12 pm)

The Who Was I? activity (Fifer & Ledbetter, 1994a) provided an enjoyable way for participants to recall the critical attributes of certain organisms found in the fossil record. By asking ‘yes’ or ‘no’ questions to determine what role they were assigned, they gained first-hand experience with inquiry-based learning by formulating specific questions to narrow the field of possible scenarios. In the process, they also individually identified with aspects of the paleo-environment, thus developing a sense of connection to the past, in the present, with implications for the future concerning extinct and endangered species.

This environmental simulation led into a reflective discussion of how specific attributes of the paleo-environment affect the present-day ecology, geology and

economic and recreational development by humankind. These principles were then related to the potential impact on the future environment.

The general trends that echo the inter-relationships of the main projects topics (ecology, geology and humankind) were demonstrated with various electronic map resources made available on the virtual field trip web site. Same-scale overhead transparencies of Geologic, Tectonic, Population Estimate, Shaded Relief, Vegetation Types, Texas River Basins, Rivers and Natural Areas, Water Usage, Precipitation Maps, and a Satellite Image of Texas were compared and contrasted to show the trends that related each topic to the other. See Figure 13 for an example of the visual impression of one such comparison.

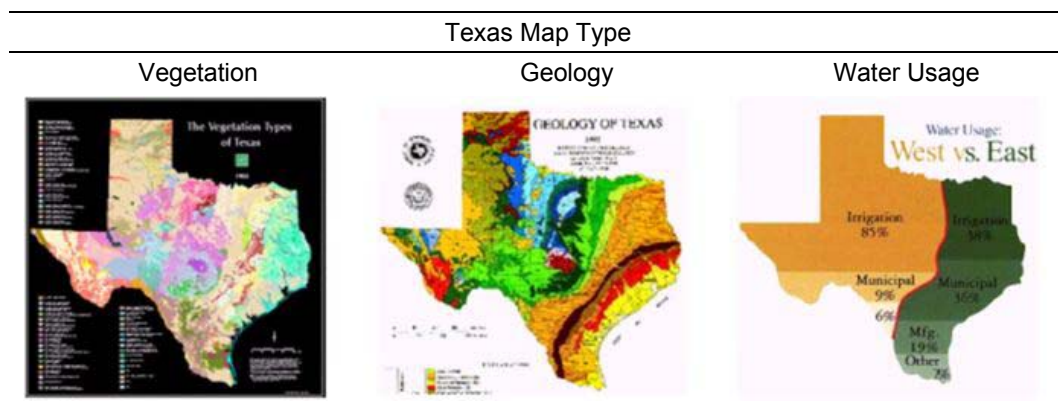


Figure 13. Selected Texas Map Comparison

Overlaying the transparencies in various combinations highlighted the similarities. Notice how the vegetation zones match the geologic outcrops and influence the water usage dividing line in Figure 13.

By directly showing the physical connections among the geology, ecology and humankind, a sense of personal relevance was internalised by each teacher as the intellectual and emotional connections developed. *They* were one of the many individuals impacting *that* local environment by using *that* water, building homes on *that* substrate, and co-inhabiting *that* biome! As they realised how each aspect affected the whole, they were able to apply the concepts and principles of systems science fully.

First-hand knowledge of their unique role in the ‘big picture’ took on new meaning with this increased personal awareness and professional understanding. The information technology assistant explained how this powerful exercise was

simplified by the appropriate application of information technology in acquiring the images and re-sizing each to an equal scale for direct comparison.

4.1.10 Ecology-Based Class

(June 07, 2000 from 9-12 pm)

The Balancing Acts activity (Fifer & Ledbetter, 1997) was used to introduce the concept of ecosystems. This intellectually challenging experience physically demonstrated the delicate balance of components. After many attempts to complete the activity in a multitude of creative ways, participants eventually shared their ideas with each other to help everyone master the task. A review of ecology field methods related the physical parts of the activity back to key concepts directly related to the course. For example, the balancing of chemicals opened discussion on homeostasis that led into the balancing of rocks on the roadway which tied into physics.

Eventually, the balance of information presented on a web page moved the discussion toward guided reflection on the importance of communication, collaboration, and creativity among science educators (Nix & Ledbetter, 2000b). Rather than actually presenting this content in the computer laboratory, the information technology assistant intentionally forced the teachers to conceptualise the points by simply talking about the specific details in the same classroom setting. Each participant was given a paper copy of the notes at the conclusion of the discussion and reminded that the same was available on the virtual field trip web site.

Through the Oh Deer! activity (Council for Environmental Education, 2000), participants generalised this ecological knowledge to principles affecting habitat components. Global issues – such as food, water and shelter essentials; factors that influence carrying capacity; and the natural limitations and fluctuations within – populations reinforced the concepts of systems and change. The teachers were reminded of how they had addressed these same issues in previous discussions concerning technology and teaching by reviewing the ISLE definition of virtual field trip (an inter-related collection of images, supporting text and/or other media, delivered electronically via the World Wide Web, in a format that can be professionally presented to relate the essence of a visit to a time or place) and relating the components of field work, web design and visual organisation to a diagram of the Community Juggling activity (see previous Figure 4).

On returning to the computer laboratory, the team applied the basics of shared control by brainstorming concepts and content items related to the actual field trip as a group. The information technology assistant, also the researcher, simply listed terms (based on the physical locale: prairie, university campus, lagoon, river, and speculation about Big Bend) that were spontaneously called out by the teachers on a wall-sized chart. Each participant developed a main idea (a single term or brief phrase) to define their developing area of focus and shared their intentions with the group. Then, individually at their workstations, the teachers were assisted in developing an initial concept map to represent what they expected to discover and document through their specific field investigations. They were directed to sketch the diagrams by hand on paper or to use their choice of application software (i.e., Inspiration®, PowerPoint®, or Word®), to design, print, and save their work to disk.

This preliminary project design phase helped to maintain the perspective developed in the university classroom and facilitated the transfer of knowledge and understanding into the field. The tentative project topics were tabulated, potential crossovers were suggested, and a complete listing was distributed to each participant. For example, ‘pollution policy’ complemented the ‘effects of pollution’; ‘human habitation’ complemented ‘human impact on the environment’; ‘field trip management’ complemented ‘visiting nature’; ‘regional tectonics’ complemented ‘geomorphology’; ‘fossil record’ complemented ‘geologic processes’; and ‘forest distribution’ and ‘wildflower diversity’ complemented ‘environmental cycles’.

4.2 Extended Field Trip

Physically removing participants from their everyday lives affects each person emotionally and intellectually in unique and often unexpected ways. As such, to facilitate effectively and manage efficiently the extended field trip component, the roles of instructor and assistant shifted in response. The teaching had been accomplished in the classroom; now it was time to let the learning transpire. As noted by Pohl (1999), “fieldwork on a collaborative basis is very much a real world experience and develops the level of interaction that students are expected to have when confronted within the social and academic mores of the real world” (p. 43).

Throughout the trip, participants helped each other to revise their inquiries, make observations, and gather data. An open format encouraged continuous discussion of their work with instructors, field experts, and peers throughout the field

experience. There was ample opportunity for one-on-one interaction as we hiked to study sites, as the teams collected their data, and as literally living together allowed time for spontaneous and informal discussion. As in the classroom, activities and procedures were strategically assigned to ensure continued group interaction. We worked together to conduct the tree identification, and data collection and analysis for the transect; we engaged in diverse conversations while riding to and from sites in the van; and we shared particularly memorable exchanges while performing the basic duties and responsibilities of making and breaking camp.

The following sections describe the key components of the ISLE program design used to implement the overall cycle of experience (section 4.2.1), reflection (section 4.2.2), generalisation (section 4.2.3) and application (section 4.2.4) during the extended field trip stage. By the time the group entered the field locale, they had re-discovered, to varying degrees, their individual strengths and abilities that sparked a sense of wonder and inherent curiosity about the natural world in which they realised their significance. Because we had established and were focused on maintaining the integrated science learning environment, particulars of the field trip are tightly interwoven.

4.2.1 Experience Stage of the Experiential Training Cycle

The adventure began at 6:20 am on June 8, 2000, as two 15-passenger vans departed from the university parking lot for a 960-kilometer drive to the wide, open spaces of West Texas. Our goal was to explore the geology, ecology and impact of man in the largest national park in Texas: Big Bend.

Big Bend park preserves unique and nationally significant natural phenomena: it contains the outstanding section of Chihuahuan Desert wilderness in the United States, with plants and animals occurring nowhere else. It is a mixing zone where Rocky Mountain species from the north meet Mexican highland species from the south. And, biologic zones climb from wet, moist floodplains of the Rio Grande, through vast tracts of dry Chihuahuan Desert, upward to the cool, moist elevations of the Chisos Mountains where pine forests predominate. Historically the park is also rich and fascinating, emanating from colorful border towns, isolated ranches, mercury mining, and Indian lore. But it is the geology of Big Bend National Park that strikes the visitor in an overwhelming display of topography, odd

erosional forms, volcanic remnants, fossil beds, and sheer cliffs of clearly exposed stratigraphy. (Spearing, 1998, p. 292)

Perched on the eastern limit of the Chihuahuan Desert wilderness, Big Bend's 708,221 acres range in elevation from 548 to 2,388 meters, presenting a never-ending study in contrasts. Mountains dominate the landscape bringing blessed relief from the surrounding desert, defined as an area that receives less than 10 inches of rain per year. On this trip, however, Big Bend was surprisingly un-desert-like. Along with some of their first wilderness hikes and outdoor camping, this group also shared the rare experience of the torrential downpours that characterise rainstorms in that region. Soaked sleeping bags were aired nearly every morning beneath the most magnificent rainbows, while the ground exploded with colour as the diverse ecology took advantage of the unique geology.

4.2.1.1 From Dallas to Big Bend National Park

(June 08, 2000 - Day 1)

Between the university parking lot and our campsite in the Basin, we noticed several changes along Interstate Highway 20. Near Weatherford, the blackland prairie transformed into rolling hills which gradually grew into the cross-timbers biome about the time when we passed through Ranger. As the road turned southward near Abilene, we headed toward the high plains, dramatically dropping off into the petroleum basin that gave rise to the towns of Midland and Odessa. From then on, we travelled throughout the extensive desert ecosystem. It's a long straight road from Monahans to historic Fort Stockton and Marathon. Still light at 6 pm, 12 hours later, we finally paid our fees at Persimmon Gap, the northernmost of the two park entrances.

Contrary to popular belief, fieldwork is not a vacation – everyone works all the time. Setting up camp is always entertaining and the kitchen is always the first priority! After amazingly tasty taco salad, corn chips, and salsa, the group quietly faded into all sorts of tents as neatly arranged as the pages of an REI [Recreational Equipment, Inc.] catalogue. Everyone was eager for a good night's sleep as soon as all the zipping stopped. And then came the announcing rumble, and the calming pitter patter, and then – uh oh – the rush of floods of sheets of rain, followed by rain, thunder and lightening, rain, thunder and lightening, and more rain.

4.2.1.2 Santa Elena Canyon and Lost Mine Trail

(June 09, 2000 - Day 2)

Everyone smiled as the sun breached the Basin rim. Hot coffee from a vintage pot warmed and awakened the soggy survivors as they rung out gear in anticipation of our first day in the field. Filled with folks ready for their first hike, both vans (now alike without the trailer) headed for Santa Elena Canyon, our first sample site. Along the way, an infuriated tarantula – stopping traffic as it crossed the road – ferociously showed its intensely red mouth when hordes of curious teachers circled to take its picture.

We stopped several more times along the Maxwell Scenic Drive to note various features typical of Big Bend. At the juncture of two major mountain ranges, a fascinating geologic history supports a unique ecologic setting. Remnants of an explosive volcanic period engage one's imagination with names like Burro Mesa, Goat Mountain and Mule Ears Peaks. Erosion, by wind and water, is the active agent today. Over unfathomable geologic time, the Rio Grande cuts through 3,000 feet of uplifted limestone.

At the end of the road, each of the teachers added a two-gallon zip bag with a data-collection device and field log to his/her pack and headed down the trail to the Rio Grande. Unfortunately, the previous night's deluge caused the river to swell and the National Park Service to close access to the canyon. We did manage to slip and slide down the banks of Terlingua Creek, a nearby tributary, to add readings to our growing database. Even though we didn't hike the canyon, we did enjoy ice cream at the Castolon Historic District – an active trading and farming community in the early and mid-1900s.

At the opposite extreme, our afternoon hike took us up into the cool mountains. The Lost Mine Trail is a scenic route that leads to great views of the Big Bend Basin. For the sport coaches and cheerleader sponsors, it was a nice run up the hill; for others, it proved to be an arduous scramble up the mountain as the air became even thinner. Unexpected to the idea of a desert, hikers enjoy beautiful specimens of the red-barked Texas madrone, desert olive, catclaw acacia, drooping juniper, alligator juniper, and Emory oak intermixed with lechugilla, ocotillo, sotol, cholla, strawberry cactus, and red, orange, and yellow prickly pear blossoms literally covered with butterflies and bees. On occasion, we've been lucky enough to catch a

glimpse of a peregrine falcon nesting at this higher elevation. This time, we shared the trail with a friendly chaparral. The evening found everyone chatting and comparing notes on the day's adventures.

4.2.1.3 Cattail Falls and Hot Springs

(June 10, 2000 - Day 3)

The sun energised us bright and early. Somewhat acclimated to the unique terrain, the teachers prepared to explore a lesser-known area of the park, Cattail Falls. Their goal for the morning was to understand another example of an ecological setting and to test the chemistry of the back-up water supply for the park. One of the few areas that has running water all year, it is lush with large trees, waist-high fern, and brilliantly-coloured wildflowers, including mountain columbine.

Rattlesnakes seem to like this trail particularly too, so everyone was keenly observant! Intrigued with the amazing variety of plants and subtleties within the rocks, no-one expected to encounter the animal that we awakened – a black bear. This magnificent, furry friend was resting in a tree as the string of science educators filed by. Good sense overcame ardent curiosity on both parts: the bear rambled on down the draw and we continued upward as a well-bonded group. That burst of excitement got us up and over a hill, then back into the mountain, leaving the desert seemingly far away at its base. Well worth the effort, the teachers recorded their observations and rested in the soft, green, cool box canyon nearly 300 feet directly below our campground in the uplifted Basin area.

After lunch, we compared that cool, quiet oasis to an entirely different clime, the Hot Springs. Years ago this area was developed as a resort where people came to find 'the cure' in the waters of natural hot springs. The park is restoring the old buildings that are adorned with frescos depicting a colourful past. As we strolled along the bamboo-shrouded trail, ancient pictographs added a mysterious dimension to the limestone cliffs that parallel the Rio Grande. Our air, soil, and water temperature readings were high, but we weren't surprised for a change; the desert and hot springs are supposed to be hot!

Dusty, dirty, tired, and hot now, we were absolutely ecstatic at the thought of a real shower at Rio Grande Village. The solar showers at camp were nice, but \$0.75 was a small price to pay for cold water, or hot water – it didn't matter as long as there was plenty of it. Between shifts, those who were clean enjoyed iced drinks,

popsicles and other cold delights. Back at camp, dinner tasted even better and our view of the sunset through the Window (a geologic formation) was priceless.

4.2.1.4 Dinosaurs Bones and Colorado Canyon

(June 11, 2000 - Day 4)

The special day most participants had come along to experience finally arrived: the visit to the dinosaur site in the Tornillo Flats badlands. For several years, the geology instructor, Dr Homer Montgomery has taken teachers to excavate an alamosaurus in Big Bend. Two miles into the desert through dirt, dust and every kind of plant that stings or sticks, teachers marched to an ancient ‘burial’ ground. Actual excavation was not underway that week, but our teachers were not disappointed. In this particular area, the desert pavement is littered with fossil remains – but you have to know what to look for. We had toured the exhibit and bone preparation laboratory at Dallas Museum of Natural History to gain a perspective on what we saw in the field. The enthused team discovered many telltale fragments exposed on the surface.

Federal law prohibits anyone from collecting or digging anything in a national park without a permit – and they aren’t kidding. The first offence brings a hefty fine and mandatory jail sentence. So, photographic field methods is one of several courses the university offers for graduate credit on such trips. The camera shutters pounded like machine gun fire as teachers collected all the photographic evidence that they could to document pieces of a story about the vivid interpretations presented by the fossilised environment.

After lots of cold water and a quick lunch, we took off for Colorado Canyon. Here the land rises in wondrous peaks above the green ribbon of water – the Rio Grande River. From the top of the volcanic cliff, you may see river rafters floating silently through the sunlit canyon. Massive outpourings of basalt formed the thick deposits of now-frozen flows. We also stopped at a fabulous bookstore in adjacent Big Bend Ranch State Park. Teachers in bookstores are like kids in candy shops. Every book is appealing and has a special allure, whether it’s reading for fun or something to use with their students once they get home.

A rather civilised evening in Terlingua, of national chilli (a thick and spicy meat soup) cook-off fame, was a special treat for all. This history-rich hamlet attracts tourists and desert rats alike to browse gift shops and wander through a most interesting cemetery until tables are ready at the Starlight Dinner Theater. Cooled by

oscillating fans and two-foot thick walls, the Starlight is a place to soak up local culture and enjoy a terrific meal. If your timing is right, self-styled Willie Nelsons (a country singing legend) entertain whoever might be willing to listen to country songs – some you’ve heard before and some you never will hear again.

4.2.1.5 Tree Transect and The Basin

(June 12, 2000 - Day 5)

Well-rested and completely immersed in the flora and fauna of the Big Bend region, the teachers were now ready to collect another type of data in a wooded area just above the Chisos Basin Lodge. A tree transect is a traditional exercise used by ecologists to analyse a forest structurally without having to identify, measure and count every single tree. Teams of teachers crawled everywhere on the mountainside – through brush and brambles, across creek beds and rock ledges – with measuring tapes, tree identification guides, scientific field journals, and cameras. Unfortunately, the prickly desert plants that thrived in such close association with the pines and oaks surprised some scouts.

For the past 10 years, UTD’s Master of Arts in Teaching (MAT) teachers have been studying this site. The data reveal slow change in the area. Once a fully-vested forest, the sturdy Ponderosa pine still guards the entrance to the research area, but more and more desert plants, like creosote and prickly pear, are becoming apparent. The creek bed is more often a dry ravine, and the denser shrubs of the understory indicate thinning of the large trees. Only time will tell if this is a permanent change or simply another iteration of an ageless cycle of growth and re-growth. Naturally, being in such close proximity to the lodge, the group was also encouraged to sample the famous Chisos burgers (ground beef sandwiches) – available only at the park restaurant. After exploring another gift shop, the afternoon was spent in rest and reflection, two commodities hard to come by on a field trip.

Catching up on writing assignments is fine, but a greenhorn’s visit just isn’t complete without taking a hike to ‘the Window’, a wonderful outlook onto the desert floor. But the trail is deceptive, winding down from the Basin, through open areas that you’d swear are part of the desert. Shady areas ahead beckon you onward, promising – and delivering – lush areas of oaks and sweet smelling shrubs. Farther in, the breeze coming from the desert through the Window picks up, and it’s cool in the shadows of gigantic rocks. Small streams often run through the area, cooling

hikers even more and adding a gentle symphony to the backdrop of birds and insects. At the Window itself, the rock is polished smooth from years of water washing through this primary drainage for the Basin. Experienced hikers enjoy their time here, hydrating while imagining the scenery eons ago, because the return passage is all up hill. That short, gentle descent becomes a rough, endless ramp to the blazing sun. Back at camp, a filling dinner followed by hand-made sopapillas (a Mexican puff pastry) drenched in local honey took care of any calories lost on the day's hikes.

4.2.1.6 Boquillas Canyon and Heading Home

(June 13, 2000 - Day 6)

The group had voted to get up early and make up the postponed hike through Santa Elena Canyon; but, again, Mother Nature, no longer surprisingly, had a different idea for our final day in Big Bend. In alternating fog, drizzle, and pouring rain, peppered with brief teasers of sunlight, we decided that it wasn't worth the risk of getting caught on the wrong side of the river should flash floods take over the trail again. So, we went on to another equally amazing venue, without any river crossings! Boquillas Canyon proved to be an excellent choice for the day as we caught a rare glimpse of a wild horse and an endangered Texas Horned Toad. Previously common across most of Texas, horned toads are actually lizards that love to eat ants. Housing developments and fire ants have reduced their range to the western fringe of the state. Signs of an earlier civilisation are evident along the riverbanks in the form of holes used by Indians to grind their corn.

Magnificent sand dunes rest against the looming limestone walls, providing both intellectual and physical challenge. The strong and brave are welcome to dig their way to the top of the dune and mark a serpentine path as they shriek pure energy on their run/roll down the hill! The power of the Rio Grande River is undeniable as you imagine the force required to move such oversized boulders and the flow level necessary to dump such enormous deposits. Incredibly smooth gouges in the canyon walls tell of powerful aeolian erosion as the wind-born particles literally sandblast the rock. Picture-perfect faults catch the eye of even novice observers as they subconsciously trace horizontal beds across the geologically dissociated layer cake.

That evening, we celebrated a successful trip with a totally-Texan steak dinner, chased by sautéed bananas topped with vanilla ice cream. Because of the

unpredictable performance of the week's weather, the trip leaders decided to strike camp early and spend our last night up at the lodge. A second round of real showers and electric lighting enabled to teachers to discuss their journal entries and collaborate on assignments and final project design. Of course, because we'd gambled on loading the vans and an uneventful sleep indoors, the huge night sky was filled with incessantly sparkling stars. Nevertheless, a refreshing breeze still cooled our bodies and cleared our minds to make room for awesome memories of an incredible experience in one of nature's most magnificent museums: Big Bend National Park.

4.2.2 Reflection Stage of the Experiential Training Cycle

As described in section 4.2.1 and typical of extended field trips to natural areas, the ISLE program's field experience was rich in both content and context. The often overwhelming effects of sensory overload make it difficult for participants to manage such huge masses of detailed information and to develop a coherent, meaningful perspective. Two key components of the ISLE model, the reflective field journal and ISLE field office, guided the construction of knowledge and demonstrated the appropriate use of information technology in the outdoor learning environment, respectively.

The Reflective Field Journal (see section 7.2.6) was employed to facilitate the teachers' processing on an individual basis. A series of questions (six per site locale) was designed to scaffold the participants' thoughts within observed interactions as opposed to reiterating discrete data points. The teachers were encouraged to complete the questions during or immediately following the actual experience to support the impending stages of generalisation (section 4.2.3) and application (section 4.2.4). Table 8 provides a sample question for each basic purpose represented within each set.

This required component, immediately collected on return to the university, forced the teachers to think about how the main topics (ecology, geology, and humankind) were dependently interrelated on a daily basis. New understanding was added to existing knowledge as the teachers were reminded to make time to reflect on the day's adventures and to record their responses and comments within a personally-relevant context and on an individual basis.

Table 8. Purpose and Sample of Reflective Field Journal Questions

Purpose	Sample Question
To focus, to recall, and to apply ecological content	On your drive from Dallas into the park, you passed through several different biomes. What were they and how could you tell them apart? Give specific examples.
To make sense of observations; to provide context for quantitative data collection	Do the plants in the desert form any sort of observable pattern? Explain.
To make connections among ecology, geology, and humankind	What is the major type of erosion in these areas? How is this related to the flora?
To evaluate the 'big picture'; to make justifiable decisions	Would you support the regulation of numbers of tourists in National Parks? Explain your position.
To make conceptual leap from knowledge to understanding; data analysis and interpretation	A column of water cannot be lifted by air pressure higher than 34 feet. How does water get to the top of trees greater than 34 feet tall?
To realise personal relevance; to set up transfer to their students	You've travelled back in time 200 years to visit your favorite part of Big Bend. Who would you bring? Why?

The teachers, also, were required to collect specific data (i.e., water chemistry) and to perform various analyses (i.e., tree transect) while in the field. A make-shift laboratory (within walking distance of the campsite) was made available throughout the extended field trip, for use at the teachers' discretion, to encourage the integration of information technology into their everyday practice. The field ecology instructor and information technology assistant were present to monitor progress and to direct work on the teachers' request.

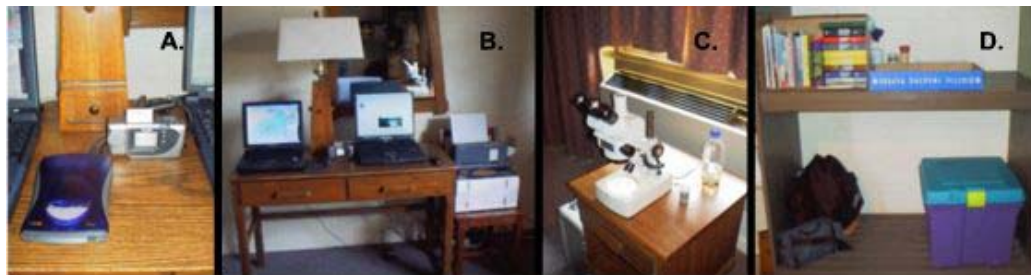


Figure 14. ISLE 'Field Office'

Specifically, Figure 14A shows external 100MB zip drive (for file storage and backup) and digital camera. Figure 14B shows two laptops complete with resource software and local instance of current Global Environmental Change website. A portable colour printer enabled daily updates to project development charts and field data logs. Figure 14C shows the binocular microscope used for detailed analysis of samples. Figure 14D shows the reference library and field gear,

including the crate of sampling kits made available for maintenance, repair, and practice sessions. This ‘formal’ set up was not explicitly incorporated on previous field trips offered by UTD’s Science/Mathematics Education Department.

Physically, the park lodge room provided power, accessibility, and a clean, non-distracting environment. The point of the field assignments was not to make it difficult to learn or survive, but to allow learning to occur naturally. Development of a local ‘field office’ enabled immediate use of information technology tools (electronic devices) to support, rather than to drive, the teachers’ learning. In addition, it consolidated resources, fostered teamwork, and allowed focused consultation in a comfortable and appropriate setting.

4.2.3 Generalisation Stage of the Experiential Training Cycle

Several critical features of the virtual field trip design helped to reinforce the multidisciplinary aspects of each field experience (refer to Chapter 3). The project design provided a tangible, yet flexible, framework for the teachers’ observations. The virtual field trip illuminated the links between the ecology, geology, and humankind through the online sampling data logs, digital image archive, and content-level concept maps created by the participants’ throughout the actual field trip.

Daily updates to the paper and electronic forms of the field data log sheets and spreadsheets showed trends that supported or refuted the hypotheses discussed in the course of the day – and caused the teachers to refine or redesign their individual thoughts. For example, because the air and water quality data recorded unexpected improvement in the local conditions, the teachers speculated on the effects of the recent rains. This information was incorporated into one teacher’s project that investigated the effects of pollution on the ecology, geology and inhabitants of the area. Many such ideas sprang from the exchanges initiated by questions in the reflective field journals; other related and new ideas were based on previous and on-going independent research.

Perhaps the greatest impact of the program was manifested in the digital image archive. Throughout the local day trips and extended field trip, the teachers increasingly realised the unbounded potential of this custom tool and practical resource for teaching and learning. They were excited about ways in which they were discovering to actually use the visual imagery within their respective classrooms to engage and excite their students with real-world examples they experienced.

Although most teachers carried their own 35-millimeter film cameras, any inhibitions of asking to borrow the digital camera or calling the information technology assistant over to snap an electronic picture were quickly dispersed on review of the first day's online photograph gallery. The ability to download and manipulate full-colour images, only moments after the experience, exhibited the value of information technology as the essence of the actual scene was recreated and made globally available through the image archive. The teachers gained a sense of confidence that the images were preserved and offered the means to create much more than a simple slide show about what they did over the summer. Because they noticed different features within each frame, the pictures also helped them to realise how the ecology was in fact a part of the geology and indeed impacted humankind (and vice-versa).

Ultimately, as the teachers developed their individual projects, they began to see how their unique contributions fit together. As they helped each other document observations, collect and analyse data, and interpret general trends, they accepted the critical fact that they *needed* to work together to acquire the necessary information and assimilate the multifaceted observations obtainable in the field. This coherence was inherently fostered by the ISLE model. Imperative links, overtly presented as the website contribution evaluation rubric (see section 7.2.5), were deliberately built into the program requirements, in contrast to just hoping that the teachers would *want* to work as a team. Specifically, the team was split into two sub-groups to double the size of forest area covered in the tree transect activity. To complete the assignment in the given amount of time (a day), they had to delegate roles and share data. As one student stated in her journal, "I can't imagine doing a transect without help. There are so many parts to the whole. Working as a team helps expedite the process, keep measurements accurate, and share knowledge during the process. It also allows people to work in their area of strength".

The teachers' different perspectives provided a new and broader context for integrating their respective disciplines, personal interests, and professional skills. Allowing time for and encouraging the continuation of individual discussions enabled the teachers to discover the benefits of interdisciplinary communication and collaboration as peer mentoring. Both the information technology assistant and field ecology instructor noticed a renewed spark of enthusiasm in each individuals' eye as they ingeniously realised how their topic tied into another as they identified links to

other resources (including their evolving content concept maps or existing project web pages).

The ultimate reward was when they made the effort to explain this relation to their colleagues. In the course of one hike for example, a science teacher eagerly explained the geologic principle of original horizontality to a history teacher, just as he teaches his classroom students. On the return passage, the history teacher literally jumped up and ran to the science teacher to share her enlightenment. The way he had approached the geologic principle was ‘exactly’ how she explained archaeological excavations to her students! They were equally thrilled with this new-found insight that linked geology and history – conceptually and logistically.

4.2.4 Application Stage of the Experiential Training Cycle

As evidenced by the immediately preceding example of the interactions between the history and science teachers, the unprecedented inclusion of non-science majors within the ISLE program created an interesting mix of personalities and backgrounds. The teachers took care of each other, as both professionals and people. It was good for each to realise that it was not just their own students who have trouble with some of the concepts and facts of their particular discipline. Because the challenge of teaching could no longer be attributed to differences in age or experience alone, each teacher worked to find creative and effective ways to explain aspects within their field of expertise to the others. This enhanced their ability to work with various approaches and increased their sensitivity to considering different learning styles on a more sophisticated level than can be gained through reading a text on curriculum and instruction. It promoted a rich interchange of ideas and constructive criticism with regard to pedagogical style.

To further increase the teachers’ familiarity with and understanding of applications of constructivist practice in science education, the information technology assistant and field ecology instructor directly related the field experience to each scale of the Constructivist Learning Environment Survey (CLES), described in section 5.1.6. For example, personal relevance was emphasised not only in the reflective field journal questions, but also throughout the actual investigations conducted at each site locale. By letting (and strongly suggesting that) people work together, they reinforced their viewpoints by openly discussing issues and developing problem-solving techniques. Taken for granted more often than expected, the

uncertainty of science was supported as the instructors and teachers suggested alternative options. They were encouraged to promote their own theories and reposition prior expectations. When one student lamented that she "...can't do pollution; it's the best visibility in over 10 years", others who had explored links to her topic from within their own, helped her see that the lack of pollution was as significant as the ironically hoped for presence of it!

Shared control was modelled in various forms throughout the program. The incorporation of optional activities and allowing the individuals to make their own choices as to where and when to work on what with who fostered a sense of personal responsibility for managing one's own learning. In addition, the teachers were often present as the field trip leaders and participants negotiated situations and cooperated professionally with the park managers and other local experts. Each teachers' critical voice was exercised clearly during the tree transect activity as team organisation and delegation of tasks was required. After a brief panic, each sub-group managed to appropriately assign roles to get the job done in an efficient manner. The open design of the program and sheer awesomeness of the natural environment honoured a passionate diversity of individual expression.

Aided by confidential information provided in the Field Experience Questionnaire (see Appendix III.1), the instructors were particularly sensitive to individual needs. For instance, after one student exhibited signs of over-heating, the trip leader mandated that she remain in camp with the field photography instructor to recover the following day. As they reorganised the 'kitchen', the opportunity was taken to discuss time management issues and personal demands that added undue emotional stress by examining her classroom efforts. As such student negotiation was acknowledged and encouraged by the trip leaders and the teachers themselves.

As the developed team intrinsically valued a safe and supportive environment, they were aware of individual circumstances and noticed acute performance variances. On several occasions, a more physically able teacher would covertly slow down or overtly sit down to help a fellow participant maintain a reasonable pace, often forfeiting a view from the final destination. The following journal entry described one of many such examples of selfless concern exercised on the team member's own accord: "The hike is quite deceptive, it doesn't seem far when told where the site was, but it is far. We finally found the hill and saw a variety of bone fragments, a ripple mark, alamosaurus femur and pterodactyl bone. I stopped

with Mary in the shade and waited for the rest to come from the larger femur. It was too damn hot to continue”.

4.3 Post-Trip Coursework and Follow-up Activities

Post-trip coursework and follow-up activities centred on emphasising the degree of personal power that the teachers exercised over their learning process and on exploring how they facilitated engaging their own with other’s learning in the pre-trip (section 4.1) and extended field trip (section 4.2) phases. By actually creating the virtual field trip, “the process of knowledge construction and meaning making from a visual and auditory perspective can be more fully explored... By creating their own environments [virtual], students can develop their own set of objects, relationships, and behaviours that are meaningful to them, and that can be shared...” (Osberg, Winn, Rose, Hollander, Hoffman, Human Interface Technology Laboratory, Char, & University of Washington, 1997, ¶ 9). The following components were essential to implementing the ISLE model in the post-trip stage.

4.3.1 Summary and Review Meeting

(June 20, 2000 from 10am-noon)

The first group meeting after the extended field trip was explicitly scheduled to ensure that the teachers had all of the information they needed to complete assignments. However, few content questions were asked during the ‘class’. Surprisingly, the time was spent reminiscing about their shared adventure! The teachers were happy to see each other and wanted to ‘catch up’ on what had transpired over the week with their friends and families. Many had already processed their pictures and shared their photograph albums. The majority of teachers had already exchanged electronic mail addresses and phone numbers in pre-trip sessions. After dismissal, several teams regrouped to finalise their tree transect calculations and determine the dominant species of plants in the Basin this year.

Rather than requiring the teachers to work in the university computer laboratory, the ISLE ‘field office’ (section 4.2.2) was replicated in the Science/Mathematics Education Department office area. Additional computer workstations and production tools, like a flatbed scanner and Internet access, were added to the resource options. This allowed the teachers to access the same tools and resources they had used in the field at their convenience. The teachers’ schedules

were flexible and varied as the summer break period typically spans through July. The close proximity to the field ecology instructor and information technology assistant, who were onsite from 9 am to 5 pm at a minimum, encouraged spontaneous consultation as questions were encountered. The teachers independently worked to develop their projects throughout the following two weeks.

4.3.2 Project Production Class

(June 27, 2000 from 9am-5pm)

A second meeting was explicitly scheduled to help the teachers finalise production of their electronic projects as described in the field ecology syllabus:

The end product required by the Woodrow Wilson Foundation and, as an extension, by the professors on this trip is a web site. Your job will be to contribute to that artefact. Each person will collect information for a specific page. As a group, we will design and 'build' the site. Your page will link to many other pages, therefore you must know how geology, ecology, and man are intertwined in your subject area(s) to make your piece fit. Don't panic! You will have lots of help with this before, during, and after the trip. Your journal and field notes will be invaluable.

The session format was intentionally open to accommodate individual needs. Recall that Inspiration® software had been used to create the top-level concept map (refer back to Figure 9) and other diagrams shown as examples throughout the program. Several teachers who had sketched their content-level concept maps on paper or with other software tools, used this time to learn the application by re-creating their individual concept maps (refer back to Figure 11). Many reported that they had access to the Inspiration® program through their school districts, but had not received training or had not been motivated to explore the potential of the software on their own. Others asked for help in using the scanner so they could add supporting graphics (i.e., *E. coli* Test Grid images) to their project pages. Nearly one-third of the teachers needed assistance to incorporate these files, or those made available through the resource image archive, into their text-based documents.

The teachers were required to deliver their final projects in electronic form to the information technology assistant (also the researcher). This provided an opportunity to review the content and intent of the project. In a few cases, linked image files were omitted from the diskette. A few participants were not sure of how

to indicate links to other project pages as the virtual field trip could not be compiled and published until the projects were received. Overall the teachers were pleased with their work and exhibited a sense of pride on turning over the files.

On acceptance, it was reiterated that the teachers' names would be displayed on the public web site to recognise their unique contribution and to reinforce individual ownership of the group project. The information technology assistant uploaded the content pages and linked each to the 'big picture' map by developing second-level concept maps (refer back to Figure 10) for each main topic.

4.3.3 Final Gathering and Further Optional Contact

(July 6, 2000 from 6-10pm)

The Global Environmental Change virtual field trip was officially released during the final gathering of the 2000 team. In keeping with a long-standing tradition of the Science/Mathematics Education Department, a casual dinner party was hosted at an instructor's home. Friends and family of program participants were welcomed also. Each guest brought her/his specialty dish to share in pot-luck fashion. The information technology assistant presented a humorous collection of captioned images that were not available on the public site! Each participant was invited to bring their best slides (maximum limit of 10) to show. Requested reprints were coordinated by the university assistant.

Unique to the ISLE experience, a composite photograph of the field team was given to each participant along with a wooden frame. Like a class yearbook, people signed their names around the virtual field trip and university logos on the mattes. The intent was to provide a reminder of the program that the teachers were encouraged to display in their classrooms. The teachers appeared to enjoy the individual exchange prompted by the activity.

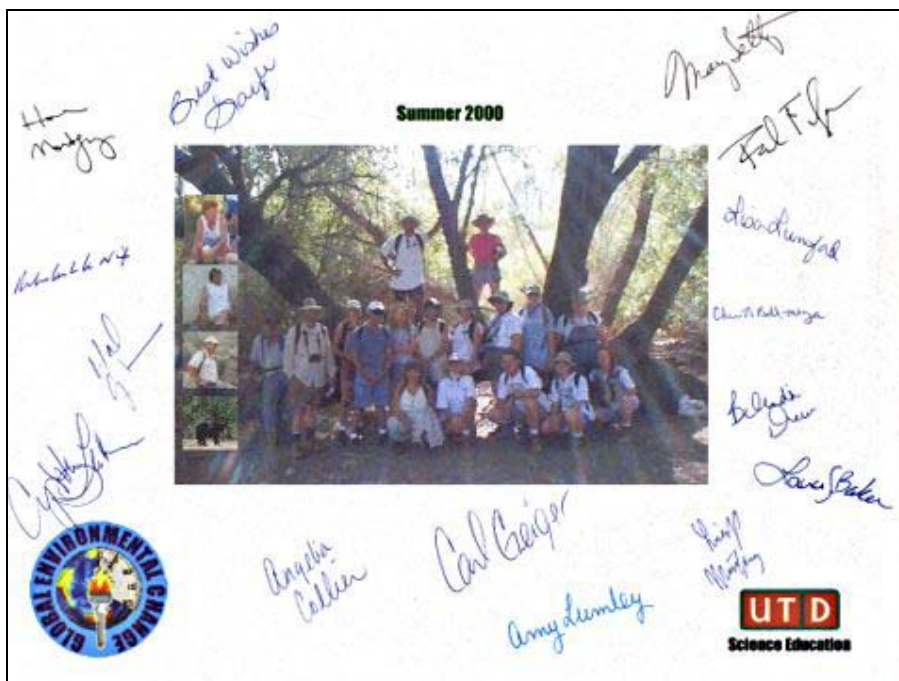


Figure 15. **Group Photograph with Logos and Participant Signatures**

Intermittent contact was maintained with the teachers after the program had officially ended. For example, the field ecology instructor and information technology assistant published a feature article about the actual and virtual field trip for a local news magazine (Nix & Ledbetter, 2000a). A link to the online version was added to the resource list on the web site. An electronic mail announcement was sent to participants to inform them of the story and to invite them to pick up paper copies made available at the university.

The field ecology instructor submitted the virtual field trip web site to an environmental education resource web site (<http://eelink.net/>). The link was featured in the Environmental Education-Related Education Sites, State – Texas and Teacher Education categories. (The teachers' virtual field trip was also accessible through the National Science Foundation's website and Dr Jacobs' environmental expedition website.) New links were usually added to the related links page. The teachers were notified by electronic mail each time the web site was modified notably.

Perhaps of more interest, the information technology assistant also took care to keep the teachers updated on the ensuing dinosaur bone excavation performed at the Big Bend dig site by paleontologists, including the university instructor who took them into the field. It was unexpectedly fortunate that this story became even bigger news as the local press picked up the story in November, 2000, four months after the

ISLE extended field trip. The controversial excavation engaged park officials, museum officials, university researchers and community members in stating their varied positions concerning the environmental impact of the collection of a large dinosaur fossil. After deliberations and multiple delays due to funding, equipment availability and park security, the fossils were excavated and curated according to National Park Service standards, preserving the important paleontological resources for the public benefit at the Dallas Museum of Natural History. Bell Helicopter's corporate assistance in completing the air lift was an historic event that captured the interest of many diverse audiences throughout the university and across the nation.

Needless to say, the teachers were encouraged, in electronic mail updates, to capitalise on the episode by raising issues in their respective school classrooms pertaining to the main topics of the virtual field trip: ecology, geology, and the impact of humankind, along with technology and the environment. Further contact was initiated by the field ecology instructor and information technology assistant as the Phase II research was conducted to assess the impact of the ISLE program in the science teachers' public/private school classrooms.

4.4 Summary of ISLE Logistical Framework

Chapter 4 presented the logistical framework implemented in the ISLE program with respect to the underlying conceptual framework of the ISLE model (discussed in the preceding Chapter 3). It described how information technology was used to reinforce the program design and therefore was evident in all stages of the program – *although never the focus*.

Sections 4.1, 4.2, and 4.3 detailed the ISLE program in the context of the physically separate learning environments. The pre-trip coursework aimed to promote positive attitudes toward the use of information technology in learning science in the university classroom and on local day trips. Throughout the extended field trip, an open format encouraged continuous discussion, as participants helped each other to revise their inquiries, make observations, and gather data. The post-trip coursework and follow-up activities emphasised the degree of personal power that the teachers exercised over their learning process and on exploring how they facilitated engaging their own with other's learning.

Ultimately, throughout the ISLE program, this logistical framework demonstrated how information technology supported constructivist teaching in the

university classroom learning environment and how constructivist practice supported meaningful learning in the field learning environment. Both the individual and group perspectives were broadened by the integration of disciplines and personalities to produce a comprehensive picture. A unique depth and richness of understanding was internalised by participants and, therefore, was more likely to be applied at various levels in real-world situations, particularly transferable to public/private school classroom learning environments.

Chapter 5 and Chapter 6 further document the concepts and methods strategically incorporated into the ISLE model.

Chapter 5

LEARNING ENVIRONMENTS RESEARCH

Although there is limited research literature specifically focused on the field trip environment, the published work on individualised environments, laboratory environments, and constructivist environments provides a starting point for this study of an Integrated Science Learning Environment (ISLE). Identified as a significant outcome of this work in section 1.1.1, the ISLE model addresses multiple influences from the fields of science education, psychosocial cognition, and information technology that are relevant to classroom teaching from the fundamental aspect of the learning environment. This chapter describes the past research that provided insight into how one might monitor, describe, and evaluate a learning environment and investigate the overall effectiveness of a comprehensive program, like ISLE.

As briefly outlined in earlier sections (2.1 and 2.2), increased interest in both teaching and learning, combined with the political and social attention to education on a global scale, have supported similarly rapid and significant advances in learning environments research. New approaches and methodologies are being developed in direct response to the information revolution. The abundance of new publications, particularly on-line journals, attests to the high level of recognition of the field of educational research. For example, a collection of 103 titles – from Argentina, Australia, Brazil, Canada, Italy, Japan, Mexico, Portugal, Spain, United Kingdom, and United States – that was developed by the Communications Among Researchers Special Interest Group (SIG) of the American Educational Research Association (AERA) includes “only links to electronic journals that are scholarly, peer-reviewed, full text and accessible without cost” (American Educational Research Association, 2002, ¶ 1). In 1984, the AERA established a SIG on the Study of Learning Environments. Continued growth of the burgeoning field over the past three decades and the success of the SIG over the past 17 years have led to the publication of *Learning Environments Research: An International Journal (LER)*.

Three key distinctions are important when considering learning environments research. The first is whether the study examines the school-level or the classroom-level environment. Based on earlier work on the organisational climate in business

contexts, the school-level environment involves psychosocial aspects of the climate of whole schools (Fraser & Rentoul, 1982). School-level environment work is distinguished from classroom-level environment research in that it tends to be associated with the field of educational administration and to involve the climate of higher education institutions. “Although the focus of past research in science education has been primarily upon classroom-level environment, it would be desirable to break away from the existing tradition of independence of the two fields of school and classroom environment and for their to be a confluence of the two areas” (Fraser, 1998b, p. 529).

A second distinction in learning environment research has to do with whether the ‘class’ or ‘personal’ form of an instrument is used. This important clarification is consistent with Stern, Stein, and Bloom’s (1956) terms of ‘private beta press’ (the idiosyncratic view that each person has of the environment) and ‘consensual beta press’ (the shared view that members of a group hold of the environment). Many students perceive the class as a whole differently from their perceptions of their personal role within the classroom (Fraser, Fisher, & McRobbie, 1996). “...Because the individual student is only part of the class, interactions with an individual student (Personal form) are less frequent than the interactions with the class as a whole (Class form)” (Fraser, 1998b, p. 539).

A third and subtle, yet important, variation has to do with whether the focus is on the actual (experienced classroom environment) or preferred (ideal classroom environment) environment. Most instruments have both options. Although the wording is similar for actual and preferred forms, the instructions for answering each are slightly different. For example, changing ‘there *is*...’ to ‘there *would be*...’ clearly changes the focus of the statement from what actually happens in the classroom to what the student prefers would happen in the ideal environment.

Research and evaluation in science education continue to rely heavily on the assessment of academic achievement and other valued learning outcomes. However, such results do not yield a complete picture of the educational process. Therefore, to fully understand the implications of educational reform, it is critical to investigate the determinants and effects of all aspects of the classroom- and school-level learning environments. The following section 5.1 describes historically important and contemporary instruments for the assessment and evaluation of learning environments. Extensive detail is included about the Constructivist Learning

Environment Survey as it was the instrument selected to assess the university and public/private school classrooms evaluated in this study. Various applications of learning environments research are reviewed in section 5.2. Section 5.4 delineates the scope of this study by describing the traditional approach to the learning environments (classroom, field trip, and information technology) encompassed by the ISLE model. The implications of the past and present studies in the field of learning environments research are summarised with respect to evaluation of the ISLE model in section 5.3. Finally, section 5.5 interweaves key aspects of this broad review of learning environments research into the context of this particular study of the Integrated Science Learning Environment.

5.1 Assessment and Evaluation of Learning Environments

In the relatively short record of learning environments research, a useful range of instruments has been developed for a variety of classroom contexts, such as individualised classrooms (Fraser, 1990), constructivist classrooms (Taylor, Dawson & Fraser, 1995a) and computer-assisted instructional settings (Teh & Fraser, 1995b), and for the primary school level (Fraser & O'Brien, 1985) and for higher education (Fraser & Treagust, 1986). Fraser (1998a) summarised the more prominent instruments for assessing the classroom environment, as briefly described in the following sections.

Table 9 lists the name of each scale in nine instruments, the educational level for which each instrument is suited, the number of items contained in each scale, and the classification of each scale according to Moos's (1974) scheme for classifying human environments. Relationship dimensions identify the nature and intensity of personal relationships within the environment and assess the extent to which people are involved in the environment and support and help each other. Personal development dimensions assess basic directions along which personal growth and self-enhancement tend to occur. System maintenance and change dimensions involve the extent to which the environment is orderly, clear in expectations, maintains control, and is responsive to change.

Table 9. Overview of Scales in Nine Classroom Environment Instruments

Level	Items per Scale	Scales Classified According to Moos's Scheme		
		Relationship Dimensions	Personal Development Dimensions	System Maintenance and Change Dimensions
Learning Environment Inventory (LEI)				
Secondary	7	Cohesiveness Friction Favouritism Cliqueness Satisfaction Apathy	Speed Difficulty Competitiveness	Diversity Formality Material Environment Goal direction Disorganisation Democracy
Classroom Environment Scale (CES)				
Secondary	10	Involvement Affiliation Teacher Support	Task Orientation Competition	Order and Organization Rule Clarity Teacher Control Innovation
Individualised Classroom Environment Questionnaire (ICEQ)				
Secondary	10	Personalisation Participation	Independence Investigation	Differentiation
My Class Inventory (MCI)				
Elementary	6-9	Cohesiveness Friction Satisfaction	Difficulty Competitiveness	
Questionnaire on Teacher Interaction (QTI)				
Secondary/ Primary	8- 10	Helpful/friendly Understanding Dissatisfied Admonishing		Leadership Student Responsibility and Freedom Uncertain Strict
What Is Happening In This Classroom (WIHIC)				
Secondary	8	Student Cohesiveness Teacher Support Involvement	Investigation Task Orientation Cooperation	Equity
College and University Classroom Environment Inventory (CUCEI)				
Higher Education	7	Personalisation Involvement Student Cohesiveness Satisfaction	Task Orientation	Innovation Individualisation
Science Laboratory Environment Inventory (SLEI)				
Upper Secondary/ Higher Education	7	Student Cohesiveness	Open-Endedness Integration	Rule Clarity Material Environment
Constructivist Learning Environment Survey (CLES)				
Secondary	7	Personal Relevance Uncertainty	Critical Voice Shared Control	Student Negotiation

Adapted from Fraser (1998a, p. 10)

5.1.1 *Learning Environment Inventory (LEI); Classroom Environment Scale (CES); Individualised Classroom Environment Questionnaire (ICEQ); and My Class Inventory (MCI)*

In the late 1960s, the Learning Environment Inventory (LEI) was initially developed and validated in conjunction with evaluation and research related to Harvard Project Physics (Fraser, Anderson, & Walberg, 1982). The Classroom Environment Scale (CES; Fisher & Fraser, 1983b; Moos, 1979; Moos & Trickett, 1987) emerged from a comprehensive program of research involving perceptual measures of human environments including psychiatric hospitals, prisons, university residences, and work environments (Moos, 1974). The first instrument not focused on teacher-centred instruction was the Individualised Classroom Environment Questionnaire (ICEQ; Fraser, 1990). It assessed dimensions that distinguish individualised classrooms from conventional classrooms.

The My Class Inventory (MCI) is a simplified form of the LEI for use with 8-12 year old children (Fisher & Fraser, 1981; Fraser, Anderson, & Walberg, 1982; Fraser & O'Brien, 1985). Four important modifications were made: to minimise fatigue, the MCI contains only five of the LEI's original 15 scales; readability was enhanced by simplifying the item wording; the LEI's four-point response format was reduced to a Yes-No (two-point) response format; and the student responses were marked on the questionnaire itself rather than a separate response sheet to avoid transfer errors. Fraser and O'Brien (1985) have developed an even shorter version since, further reducing the total number of items from 38 to 25.

5.1.2 *Questionnaire on Teacher Interaction (QTI)*

The Questionnaire on Teacher Interaction (QTI) is based theoretically on Leary's two-dimensional circumplex, originated in the Netherlands and focuses exclusively on teacher-student interaction (Wubbels & Brekelmans, 1998; Wubbels, Creton, & Hermans, 1993). The QTI has been cross-validated and comparative work has been completed at various grade levels in the United States (Wubbels & Levy, 1993), Australia (Fisher, Henderson, & Fraser, 1995), Singapore (Goh & Fraser, 1996), and Brunei (Riah, Fraser, & Rickards, 1997). Goh and Fraser (1996) also developed and validated a shorter 48-item version.

5.1.3 *What Is Happening In This Classroom (WIHIC)*

The What Is Happening In This Classroom (WIHIC) was developed by Fraser, Fisher, and McRobbie (1996) to bring parsimony to the field of learning environments by combining the most salient scales from existing questionnaires with new dimensions of contemporary relevance (e.g. equity and constructivism) to assess the classroom learning environment. Three scales of this instrument – student cohesiveness, cooperation, and equity – are particularly relevant to the science learning environment. Student cohesiveness examines the extent to which students know, help, and are supportive of one another. Cooperation refers to the extent to which students cooperate rather than compete with one another on learning tasks. And equity assesses the extent to which students are treated equally by the teacher (in terms of gender, for example).

Originally a 90-item, nine-scale instrument, the final form consists of seven, eight-item scales. Fraser and Chionh (2000), successfully used this version with 2310 high school students in Singapore. Aldridge, Fraser, and Huang (1999) administered English and Mandarin versions of the WIHIC to 1081 grade 8 and 9 science students from 50 classes in 25 schools in Western Australia and 1879 grade 7-9 students in 50 classes in 25 schools in Taiwan, respectively. Their study is distinctive in that it drew on multiple research methods from different paradigms (to validate a learning environment questionnaire for use in two countries, to identify differences between classroom environments in two countries, and to identify factors that influenced learning environments in two different cultures) in order to gain a more in-depth understanding of the science classroom learning environment from different perspectives in Australia and Taiwan (Aldridge & Fraser, 2000).

Zandvliet and Fraser (1999) administered 5 scales of the WIHIC to assess the psychosocial environment of high school internet classrooms in Australia and Canada. Results of their study identified factors for inclusion in a new model of educational productivity (see section 5.2.4). The psychosocial environment directly influenced student satisfaction. Pickett and Fraser (2002) employed a version of the WIHIC for use with elementary school students to provide insight into the effects of a mentoring program for beginning teachers in the United States (see section 5.2.5).

5.1.4 College/University Classroom Environment Inventory (CUCEI)

As little work had focused on higher education classrooms specifically, the College and University Classroom Environment Inventory (CUCEI) was developed by Fraser and Treagust (1986). The final form consists of seven scales containing seven items each. Each item has four response options of Strongly Agree, Agree, Disagree, and Strongly Disagree.

The CUCEI was designed for use with smaller classes typically encountered at the post-secondary level. As was the case for this study, university coursework is often conducted in a seminar format that commonly involves a total sample ranging from five to 30 students.

5.1.5 Science Laboratory Environment Inventory (SLEI)

Within science-related disciplines, the learning environment of laboratory settings is especially important (Hofstein & Lunetta, 1982). As such, the Science Laboratory Environment Inventory (SLEI) was developed specifically to assess the environment of science laboratory classes at the senior high school or higher education levels (Fraser, Giddings, & McRobbie, 1995; Fraser & McRobbie, 1995).

Two scales of this instrument – open-endedness and integration – are particularly relevant to the science learning environment. Open-endedness pertains to the extent to which the laboratory activities emphasise an open-ended divergent approach to experimentation. In other words, is there a choice as to how things are done to explore problems for which the answer is not already known? Integration refers to the extent to which the laboratory activities are integrated with non-laboratory and theory classes. For instance, does what is being taught in the lecture support what is being tested in the laboratory?

The SLEI was field tested and validated simultaneously in six countries (United States, Canada, England, Israel, Australia and Nigeria) and cross-validated with 1594 Australian students in 92 classes (Fraser & McRobbie, 1995), in Australia with 489 senior high school biology students (Fisher, Henderson, & Fraser, 1997), and in Singapore with 1592 grade 10 chemistry students (Wong & Fraser, 1995). Pohl (1999) validated the Science Laboratory Environment Inventory (SLEI) for use with high school students in a field-based environmental setting.

Using the SLEI, Hofstein and Cohen (1996) identified differences between student perceptions in chemistry and biology laboratory environments. Hofstein

(2002) incorporated the SLEI in a study that assessed the outcomes of inquiry-based laboratory experiments in the context of high school chemistry in Israel. Relevant to this study, the results of his work supported the introduction of inquiry-type experiments in the way in which chemistry is taught, learned, and assessed, and attempts at improving teachers' professional development.

5.1.6 Constructivist Learning Environment Survey (CLES)

As dimensions of learning environment research have not been used primarily in an integrated program evaluation (Fraser, 1998a), this thesis makes a unique contribution to the field of learning environments research by evaluating an integrated milieu that envelops three classically-distinct learning environments. Evaluation of the Integrated Science Learning Environment (ISLE) was based primarily on quantitative data derived from three new versions of the Constructivist Learning Environment Survey (CLES). These results were combined with data from an attitude questionnaire and participant-generated concept maps that were further interpreted with qualitative data derived from interviews, observations, and reflective field journals (refer to section 1.2 for specific details).

In response to the need to assess innovative classroom environments, like ISLE, the Constructivist Learning Environment Survey (CLES) was developed with a psychological view of learning that focused on students as co-constructors of their own knowledge (Taylor & Fraser, 1991; Taylor, Dawson, & Fraser, 1995b; Taylor, Fraser, & Fisher, 1997). As described in Aldridge, Fraser, Taylor, and Chen (2000), the CLES was originally developed to measure students' perceptions of the extent to which constructivist approaches are present in classrooms. A new version of the CLES was developed by Taylor (1996) to improve the theoretical framework of the survey from the perspective of critical constructivism. The conceptual strength and psychometric structure of the questionnaire were rigorously tested using quantitative and qualitative methods (Taylor, Dawson, & Fraser, 1995a, 1995b; Taylor, Fraser, & White, 1994). The resulting version was thereby enhanced with the omission of negative and conceptually-complex items. In addition, the CLES is unique in that items of the same scale are grouped together under a simple scale name to provide a contextual cue for respondents.

The 30-item questionnaire includes six items with a five-point frequency response scale (Almost Always, Often, Sometimes, Seldom, and Almost Never).

Table 10 presents a summary of the five scales of the Constructivist Learning Environment Survey which are: 1) Personal Relevance, the extent to which teachers relate science to students' out-of-school experiences; 2) Student Negotiation, the extent to which opportunities exist for students to explain and justify to other students their newly-developing ideas and to listen and reflect on the viability of other students' ideas; 3) Shared Control, the extent to which students are invited to share with the teacher control of the learning environment, including the articulation of their own learning goals, design and management of their learning activities, and determining and applying assessment criteria; 4) Critical Voice, the extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods, and to express concerns about any impediments to their learning; and 5) Uncertainty of Science, the extent to which opportunities are provided for students to experience scientific knowledge as arising from theory dependent inquiry, involving human experience and values, evolving and non-foundational, and culturally and socially determined.

Table 10. Description of Scales and Sample Items for the Constructivist Learning Environment Survey (CLES)

Scale Name	Scale Description	Sample Item
Personal Relevance	Relevance of learning to students' lives	I learn about the world outside of school.
Uncertainty of Science	Provisional status of scientific knowledge	I learn that science has changed over time.
Critical Voice	Legitimacy of expressing a critical opinion	It's OK for me to ask the teacher 'why do I have to learn this?'
Shared Control	Participation in planning, conducting and assessing of learning	I help the teacher to plan what I'm going to learn.
Student Negotiation	Involvement with other students in assessing viability of new ideas	I ask other students to explain their thoughts.

Administration of the CLES to 1081 high school science students in Australia provided support for its internal consistency reliability and factor structure (Aldridge, Fraser, Taylor, & Chen, 2000). Principal components factor analysis followed by varimax rotation confirmed the *a priori* structure of the instrument. Nearly all items had a loading of at least 0.4 on their *a priori* scale and no other scale. Based on the student actual form and using the individual as the unit of analysis, Table 11

summarises the internal consistency reliability (alpha coefficient), discriminant validity (using the mean correlation of a scale with other scales in the same instrument as a convenient index), and the ability of a scale to differentiate between the perceptions of students in different classrooms (significance level and η^2 statistic from ANOVAs) of the CLES for the Australian sample.

Table 11. Reliability and Validity of the Constructivist Learning Environment Survey (CLES) in Past Research

Scale	Alpha Reliability	Mean Correlation with Other Scales	ANOVA Results (η^2)
Personal Relevance	0.88	0.43	0.16**
Uncertainty of Science	0.76	0.44	0.14**
Critical Voice	0.85	0.31	0.14**
Shared Control	0.91	0.41	0.17**
Student Negotiation	0.89	0.40	0.14**

N = 1081, ** $p < 0.01$ Adapted from Fraser (1998a, p. 19)

Additional studies that influenced the design of this study further validated the CLES in a variety of research settings. For example, Cannon (1996) modified the CLES to create teacher and student versions to evaluate university courses in America. With respect to the impact of information technology, Fisher and Churach (1998) combined the use of the CLES with Internet usage at the college level. Beck, Czerniak, and Lumpe (2000) further established the internal consistency reliability of the CLES in an exploratory study of teachers' beliefs regarding the implementation of constructivism in their classrooms based on Ajzen's theory of planned behaviour. Harwell, Gunter, Montgomery, Shelton, and West (2001) investigated a collaborative action research endeavour between a regional university and a local school by using the CLES to monitor alignment of classroom learning activities with a constructivist viewpoint while integrating technology into the curriculum. And, Simpson (2001) used the CLES in a study that examined the measurement of learner characteristics (multiple intelligence, learning style, and learner ability), learner perceptions of the classroom (Constructivist Learning Environment Survey and views about teaching and learning), and learner constructs.

Of specific interest with respect to this study, Dryden and Fraser (1998) used the CLES to assess the impact of a large-scale Urban Systemic Initiative (USI) aimed at changing high school science instruction toward a more constructivist approach.

Unfortunately, the data reflected the state and district focus on increasing examination scores through professional development training with the direct delivery of program-specific information (i.e. content) rather than pedagogy in a general sense (i.e. context). However, the CLES was cross-validated with a large sample of approximately 1,600 students in 120 grade 9-12 science classes in the Dallas metropolitan area. It is not only notable that this work was conducted in the north Texas area, but also that it validated use of the CLES with high school students in the same locale in which my study was conducted. Also relevant is the fact that the CLES was used to evaluate the constructivist-oriented reform of science education, as was the purpose of this study.

Kim, Fisher, and Fraser (1999) used the CLES to investigate science curriculum reform efforts in Korea. In addition to validating a Korean-language version of the CLES, their data provided significant statistical relationships between classroom environment and student attitudes. These results suggest that favourable student attitudes could be promoted in classes where students perceive more personal relevance, share control with their teachers, and negotiate their learning. It is important to note that these classroom environment factors represent three of the five scales of the CLES used to develop the Integrated Science Learning Environment examined in my study.

Also as part of a longitudinal study conducted in Minnesota, Johnson and McClure (2002) investigated use of the CLES to provide insights into the classroom learning environments of beginning science teachers. The CLES was administered to 290 upper elementary, middle, and high school inservice and preservice science teachers. Although this study had not been published when the ISLE model was developed, both the results and design are significant with respect to the ISLE program evaluation. Exploratory factor analysis and internal consistency reliability, as well as examination of each item and of participants' questions and comments about them, led to a shortened, revised version of the CLES. The five original scales were retained, but the number of items in each scale was reduced from six to four and the negatively-worded item was eliminated. This second-generation, 20-item questionnaire was named the CLES2(20).

5.1.7 *New Approaches to Instrument Development and Use*

Other studies that influenced the ISLE model have drawn on scales and items in existing questionnaires to develop modified instruments that better suit particular research purposes and contexts. For example, Orion, Hofstein, Tamir, and Giddings (1997) developed the Science Outdoor Learning Environment Inventory (SOLEI) to specifically study the science outdoor learning environment. Enhanced with innovative modifications and additions, select examples of other developments demonstrate the flexibility of these basic learning environment instruments.

In evaluations of computer-assisted learning, Maor and Fraser (1996) developed a five-scale classroom environment instrument (assessing Investigation, Open-Endedness, Organisation, Material Environment, and Satisfaction) based on the LEI, ICEQ, and SLEI. Teh and Fraser (1994, 1995b) developed a four-scale instrument to assess Gender Equity, Investigation, Innovation, and Resource Adequacy. Fraser and Maor (2000) also developed and used the Constructivist Multimedia Learning Environment Survey (CMLES) to measure teacher and student perceptions of the learning environment when students use online multimedia programs and teachers use constructivism as a referent for their teaching.

To monitor various distance education environments, Jegede, Fraser, and Fisher (1995) developed the Distance and Open Learning Environment Scale (DOLES) for use among university students studying by distance education. Taylor and Maor (2000) developed the Constructivist On-Line Learning Environment Survey (COLLES) to monitor and compare students' preferred online learning environments to their actual experience.

5.2 Applications of Classroom Environment Research

The broad range of learning environment approaches illustrates the applicability of classroom environment research to today's diverse educational issues. This section briefly describes 12 major lines of past classroom environment research reviewed and organised by Fraser (1998a, pp. 17-28) as:

- 1) associations between student outcomes and environment
- 2) evaluation of educational innovations
- 3) differences between student and teacher perceptions of actual and preferred environment
- 4) do students achieve better in their preferred environment?

- 5) teachers' attempts to improve classroom environments
- 6) school psychology
- 7) transition from primary to high school
- 8) cross-national studies
- 9) combining quantitative and qualitative methods
- 10) investigating links between educational environments
- 11) teacher education
- 12) teacher assessment.

Several studies that directly influenced the design of the ISLE model and the methodology used to evaluate the ISLE program are discussed in greater depth.

5.2.1 Associations Between Student Outcomes and Environment and Evaluation of Educational Innovations

The strongest tradition in classroom environment research has involved investigation of associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classrooms. For example, studies by Fraser and McRobbie (1995), Fisher, Henderson, and Fraser (1997), McRobbie and Fraser (1993), Teh and Fraser (1995a), and Wong and Fraser (1996) revealed consistent associations between student outcomes and the nature of the classroom learning environment.

As demonstrated by Dryden and Fraser (1996), Fraser (1979), Khoo and Fraser (1997), Maor and Fraser (1996), and Teh and Fraser (1994), classroom environment instruments can be used as a source of process criteria in the evaluation of educational innovations. Recent applications of learning environment research used in program evaluation were presented at sessions sponsored by the Special Interest Group on the Study of Learning Environments at the annual convention of the American Educational Research Association (AERA). For example, Spinner and Fraser (2002) administered the Constructivist Learning Environment Survey (CLES) and Individualised Classroom Environment Questionnaire (ICEQ) to quantify the classroom environment when using an interactive elementary mathematics program based on constructivist approaches. Lightburn and Fraser (2002) used the CLES, Science Laboratory Environment Inventory (SLEI), and What Is Happening In This Classroom (WIHIC) to assess the classroom environment and student outcomes when students are engaged in activities that integrate science process skills and use

of information technology tools. Raaflaub and Fraser (2002) administered the WIHIC to teachers and students to investigate the learning environment in Canadian mathematics and science classrooms in which laptop (notebook) computers were used. Zandvliet and Buker (2002) employed a version of the WIHIC and a Computerised Classroom Environment Checklist to evaluate Internet classrooms in British Columbia, Canada. Analysis of their classroom environment data revealed that student autonomy/ independence and task orientation were associated with satisfaction in learning.

Also in response to the integration of information technology in education, Aldridge, Fraser, Fisher, and Wood (2002) examined the integration of information communications technology (ICT) into the learning environment at an innovative senior college in Western Australia. A major contribution of this work was the development of a valid instrument for monitoring outcomes-focused and ICT-rich classroom learning environments. The new assessment drew on scales and items from widely-used general classroom environment questionnaires such as the WIHIC.

5.2.2 Differences Between Student and Teacher Perceptions of Actual and Preferred Environment; Student Achievement in Preferred Environments; and Teachers' Attempts to Improve Classroom Environments

Classroom environment instruments have been used also to investigate differences between students and teachers in their perceptions of the same actual classroom environment and differences between the actual environment and that preferred by students or teachers. Learning environments research conducted by Fisher and Fraser (1983a), Hofstein and Lazarowitz (1986), Kim, Fisher, and Fraser (1999), Moos (1974,1979), and Wubbels, Brekelmans, and Hooymayers (1991) document differences between student and teacher perceptions of actual and preferred environment. The results suggest that students preferred a more positive classroom environment than is actually present. Also, teachers perceive a more positive classroom environment than do their students in the same classrooms.

Along this line, Fraser and Fisher (1983a, 1983b) asked whether or not students achieve better in their preferred environment. Using both actual and preferred forms of educational environment instruments permitted exploration of students' achievement when there is a higher similarity between the actual classroom environment and that preferred by students. Analysis of results from the ICEQ

suggested that class achievement of certain outcomes might be enhanced by changing the actual classroom environment in ways which make it more congruent with that preferred by the class.

Feedback information based on student or teacher perceptions has been employed in a five-step procedure as a basis for reflection upon, discussion of, and systematic attempts to improve classroom environments at all levels in work by Fraser and Deer (1983), Thorp, Burden, and Fraser (1994), Fisher, Fraser, and Bassett, (1995), Woods and Fraser (1996), and Yarrow and Millwater (1995). Of particular interest to this study, Yarrow, Millwater, and Fraser (1997) investigated teachers' attempts to improve both teachers' university classroom environment and preservice teachers' school classroom environments during school-based field experiences. The discrepancies between perceptions of the actual environment and the preferred or perceived environment can provide a basis for growth and change (Sinclair, 2000; Yarrow, Millwater, & Fraser, 1997).

5.2.3 School Psychology; Transition from Primary to High School; and Cross-National Studies

Equally important, the field of psychosocial learning environment furnishes a number of ideas, techniques, and research findings that could be valuable in school psychology. Burden and Fraser (1993) demonstrated how learning environments research can provide an opportunity for school psychologists and teachers to become sensitised to subtle but important aspects of classroom life and to use discrepancies between students' perceptions of actual and preferred environment as a basis to guide improvements in classrooms.

There is also considerable interest in the effects on early adolescents of the transition from primary school to the larger, less personal environment of the junior high school at this time of life as shown in studies by Midgley, Eccles, and Feldlaufer (1991) and Ferguson and Fraser (1999). Hine and Fraser (2002) combined qualitative and quantitative methods (see next section 5.2.4) in a study of Australian students' transition from elementary to high school. The results showed that students' transition experiences largely reflected the school context and site-specific measures introduced to cater for students moving between different stages of middle schooling. Students expressed greatest satisfaction in classrooms with more affiliation, autonomy, and teacher support. The ISLE model incorporated similar

aspects of psychosocial factors to reinforce the transfer of knowledge by creating a more favourable environment to assist students in the transitions between settings.

Educational research which crosses national boundaries offers much promise for generating new insights as there usually is greater variation in variables of interest and the familiar educational practices, beliefs, and attitudes than can be exposed in one country. Cross-national studies by Aldridge and Fraser (2000), Aldridge, Fraser, and Huang (1999), Aldridge, Fraser, Taylor, and Chen (2000), Fraser (1997), and Lee and Fraser (2002) have investigated the cultural adaptability of various instrumentation within learning environments research. Pioneering studies in Indonesia have been aimed at using learning environment research at the tertiary level (Margianti, Fraser, & Aldridge, 2002; Soerjaningsih, Fraser, & Aldridge, 2002).

5.2.4 Combining Quantitative and Qualitative Methods and Investigating Links Between Educational Environments

Significant progress has been made towards the desirable goal of combining quantitative and qualitative methods with the same study in research on classroom learning environments. For example, Fraser and Tobin (1991) and Tobin and Fraser (1998) combined quantitative and qualitative methods in their studies to provide a more complete picture of the learning environment. As in the ISLE program evaluation, qualitative information, when combined with quantitative data, can provide richer insights into the learning environment.

Past studies have successfully combined qualitative and quantitative research methods in studying the classroom learning environment at different 'grain sizes' to show how individual students and the teacher could be investigated also at the class level, school level, or system level (Aldridge, Fraser, & Huang, 1999; Tobin & Fraser, 1998). This helps to clarify whether particular teachers or students are typical of larger groups (Fraser, 1999). Aldridge, Fraser, Fisher, and Wood (2002) combined qualitative and quantitative methods to provide insight into the perceptions of students about the learning environment created in an outcomes-based classroom with a rich information communications technology structure.

With respect to the present study, although most individual studies of educational environments in the past have tended to focus on a single environment, studies by Dorman, Fraser, and McRobbie (1997), Jegede, Fraser, and Fisher (1995), Marjoribanks (1991), and Moos (1991), for example, indicated that there is potential

in simultaneously considering the links between and joint influence of two or more environments. In particular, Zandvliet and Fraser (1999) jointly considered the physical and psychosocial learning environments in a single study while combining both qualitative and quantitative methods. Their research is also distinctive because of its holistic approach to the study of the technological classroom, a newly identified learning environment. Zandvliet and Buker (2002) evaluated two learning environments in Internet classrooms in Canada using a combination of case studies and questionnaires. Relating classroom environment data (from the WIHIC and a Computerised Classroom Environment Checklist) to physical measures (i.e. workspace and visual environments), these researchers identified statistically significant associations between the physical and psychosocial learning environments in technology-rich classrooms.

5.2.5 Teacher Education and Assessment

Although the field of psychosocial learning environment provides a number of potentially valuable ideas and techniques for inclusion in teacher education programs, little progress has been made in incorporating these ideas into teacher education. The ISLE model was designed specifically to meet preservice and inservice teachers' need for a comprehensive professional development program founded in both science (to provide current content) and education (to provide a relevant context).

Research by Fraser (1993) and Duschl and Waxman (1991) has addressed the applicability of learning environments research in teacher education. In addition, Pickett and Fraser (2002) examined the effectiveness of a mentoring program for beginning elementary school teachers in Miami, Florida. The WIHIC was used to measure over 600 students' perceptions of their classroom environments. The results suggested that the mentoring program had been successful in terms of promoting improved achievement, attitudes, and classroom environment. As suggested by past research, this study investigated links between teachers' conceptual development, teachers' attitude scores, and teachers' perceptions of the learning environment.

Mink and Fraser (2002) evaluated a new mathematics program for students in kindergarten through to grade 5 that was aimed at improving teaching and learning by integrating language arts, reading, and science. Similar to the ISLE program evaluation, the purpose of the study was to determine if the mathematics program

positively influenced the classroom environment, student attitudes, and student achievement on performance-based and criterion-referenced assessments in Florida. A series of five professional development workshops and subsequent requests for the teachers to use the strategies with their students helped to accomplish their goal. The data provided strong support for the effectiveness of the innovative program.

Following a related line of research, Ellett, Loup, and Chauvin (1989) investigated a teacher assessment system, the Louisiana STAR (System for Teaching and Learning Assessment and Review), which specifically includes learning environment dimensions among a set of four performance dimensions.

5.3 Implications and Applications of Learning Environments Research for Evaluation of the ISLE Program

As stated by Fraser (1998b), tremendous progress has been made in “conceptualising, assessing, and investigating the determinants and effects of social and psychological aspects of the learning environments of classrooms and schools” (p. 527). Qualitative methods and thorough documentation with the addition of quantitative data (Fraser & Tobin, 1991) have the potential to provide a comprehensive picture of the merits of an integrated learning environment for science education. However, a comprehensive evaluation must extend beyond the individual learning environments to broaden the research and application within the context of the changing needs and perceptions of students, teachers, administrators, citizens, and researchers over time.

As suggested by Cannon (1996), establishing a positive learning environment is paramount to the success of any educational program. New directions in educational research support the use of learning environments instruments in a range of studies, with different instruments and scales used in particular studies. For example, Fraser, Fisher, and McRobbie (1996) developed a new learning environment instrument which “incorporates scales that had been shown in previous studies to be significant predictors of outcomes (Fraser, 1994) and additional scales to accommodate recent developments and concerns in classroom learning” (¶ 15).

Combined with the recent trends in pedagogical approaches and assessment methods, as later detailed in section 6.1, an open framework for student-centred learning can be created, supported, and evaluated. A critical and commonly recognised theme throughout the literature is that teacher change, in both attitude and

practice, does take time (Beck, Czerniak, & Lumpe, 2000; Dougiamas, 1998; Hand & Treagust, 1994; Kerrey & Isakson, 2000; Kessell, 1997). Thus, a deliberately structured plan with an open format based on principles rather than specific content, that recognises teachers as individuals, was chosen for evaluation of the ISLE model.

From the learning environment instruments described in section 5.1, the Constructivist Learning Environment Survey was selected for use in this study because of its ability to characterise specific dimensions of the constructivist classroom. The five scales (Personal Relevance, Uncertainty of Science, Shared Control, Critical Voice, and Student Negotiation) enable a multilevel assessment that provides the basis of the overall research design. Supporting this unique aim, a contemporary study by Allen and Fraser (2002) showed that the same questionnaire could be used to assess young students' and their parents' perceptions of actual and preferred classroom learning environment along the six dimensions of the WIHIC.

In this study, three modified forms of the Constructivist Learning Environment Survey (further detailed in Chapter 7) were used to assess the perceived degree of constructivist teaching in the university by teachers and the school classrooms by both teachers and their students. The goal was to enable the classroom teachers to quantify the learning environment in terms of whether or not it changed with the deliberate attempt at reform as presented in the ISLE program through different views, as illustrated in Figure 16.

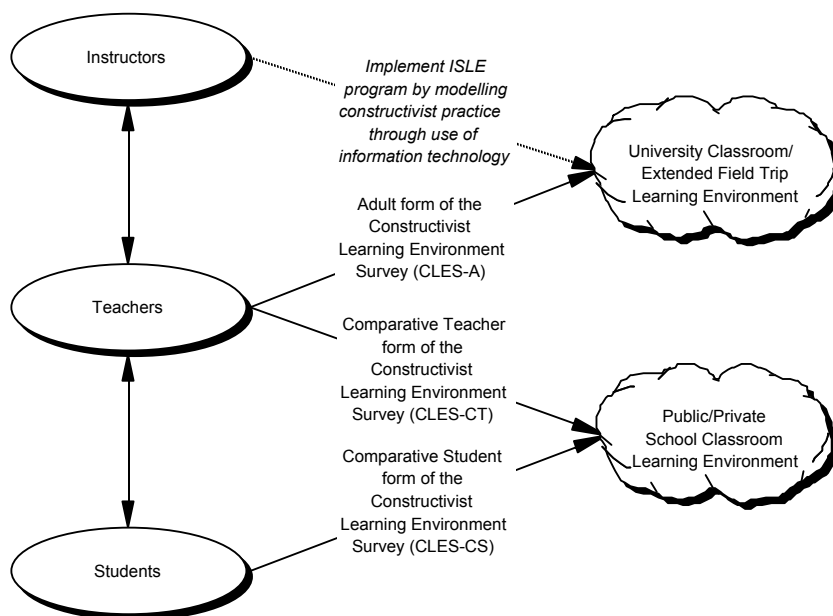


Figure 16. **Multilevel Assessment of ISLE Model Enabled by Three New Versions of the Constructivist Learning Environment Survey (CLES)**

Figure 16 shows how the different participants (university instructors, school teachers, and students) were able to evaluate two different learning environments (university/field trip and school classrooms) using three versions (adult, comparative teacher, and comparative student) of a single learning environment instrument (CLES). The adult form allowed the teachers to assess the degree of constructivist practice in the learning environment which they experienced as students in the university setting. Then, the comparative teacher form allowed the same teachers to assess the degree of constructivist practice in the learning environments which they created as teachers in the school setting. This evaluation was supported by their respective students' assessment of the degree of constructivist practice in the same school classroom learning environment.

Of primary theoretical importance, the five scales of this particular learning environment instrument (described in section 5.1.6) directly support the goals of educational reform effort in science described in the Adolescence and Young Adulthood/Science Standards (National Board for Professional Teaching Standards, 2001). Table 12 matches the scales of the Constructivist Learning Environment Survey to the Science Learning Environment Standard stated as the primary goals for educational reform in the United States.

Of primary methodological importance, as documented in section 5.1.6, the CLES provides a valid and reliable instrument for the assessment of how teachers' and students' perceptions of constructivist classroom learning environments (Fraser, 1998b; Taylor, Dawson, & Fraser, 1995b; Taylor, Fraser, & Fisher, 1997). The established validity of the CLES was important when selecting it to answer my overarching research question of whether or not a teacher's participation in the Integrated Science Learning Environment (ISLE) program would lead to the teachers' implementation of constructivist learning environments in their respective students' school classrooms (refer to section 1.2). Consideration was also given to the cultural adaptability of the instrument (Lee & Taylor, 2001) for potential use in future cross-national and longitudinal studies based on the ISLE model.

Table 12. **Constructivist Learning Environment Survey (CLES) Scales and Learning Environment Goals for Educational Reform in Science**

CLES Scale	Science Learning Environment Standard Statement
Personal Relevance	"Teachers help students learn about and internalize the values inherent in the practice of science by relying on those values to shape the ethos of the learning community."
Uncertainty of Science	"...they (the teachers) work diligently to establish a congenial and supportive learning environment where students feel safe to risk full participation, where unconventional theories are welcomed, and where students know that their conjectures and half-formed ideas will not be subject to ridicule."
Critical Voice	"...teachers recognize that the emotional response of some students to a lively, argumentative, inquiry-based classroom might never to venture an opinion or idea, thereby avoiding the risk of public failure."
Shared Control	"Accomplished science teachers deliberately foster settings in which students play active roles as science investigators in a mutually supportive learning community."
Student Negotiation	"They (the teachers) foster a sense of community by encouraging student interactions that show concern for others, by dealing constructively with socially inappropriate behavior, and by appreciating and using humor."

Quoted from 'Standard V: Learning Environments' (National Board for Professional Teaching Standards, 2001, p. 25)

As evidenced by its widespread implementation, the Constructivist Learning Environment Survey (CLES) is a valuable tool to assist researchers and teachers in assessing the degree to which a classroom's environment is consistent with a constructivist epistemology and to assist teachers in reflecting on their epistemological assumptions and reshaping their practice. Variations of the relatively short and highly appropriate instrument were made to make it suited to assessing both teachers' and students' viewpoints, as illustrated earlier in Figure 16.

5.4 Individual Learning Environments Encompassed by the ISLE Model

In order to effectively apply and interpret the results of learning environments research as demonstrated in section 5.2, it is critical to understand the specific context of the learning environment under investigation. The ISLE model encompasses three traditionally-separate learning environments: the classroom, field trip, and information technology. To delineate the scope of this particular study, a brief review of the traditional approaches to assessment and evaluation of each of the relevant milieus follows.

One emergent theme within learning environments research, as recognised in the National Educational Technology Standards for Teachers, is that students need to learn how to “apply strategies for solving problems and to use appropriate tools for learning, collaborating, and communicating” (International Society for Technology in Education (ISTE), 2000, p. 3). Table 13 compares traditional learning approaches to what the International Society for Technology in Education recommended establishing, through teacher preparation programs, for new learning environments.

Table 13. Comparison of Teaching Strategies for Traditional and New Learning Environments

Teaching Strategies	
Traditional Learning Environments	New Learning Environments
Teacher-centred instruction	→ Student-centred learning
Single-sense stimulation	→ Multisensory stimulation
Single-path progression	→ Multipath progression
Single media	→ Multimedia
Isolated work	→ Collaborative work
Information delivery	→ Information exchange
Passive learning	→ Active/exploratory/inquiry-based learning
Factual, knowledge-based learning	→ Critical thinking and informed decision making
Reactive response	→ Proactive/planned action
Isolated, artificial context	→ Authentic, real-world context

Adapted from ‘Establishing New Learning Environments’ (International Society for Technology in Education, 2000, p. 3)

Classroom environment research is typically conducted within the context of traditional epistemology underpinning the established classroom environment (Taylor, Fraser, & Fisher, 1997). In contrast to the design of the ISLE model, the classroom, field trip, and information technology learning environments are traditionally treated as separate milieus. Figure 17 shows how the traditionally separate learning environments develop a linear progression that temporarily bridges the gaps between the classic learning environments with short-term, perceived links. Information technology might or might not be evident in the classroom(s) and hardly ever is addressed directly during the field trip.

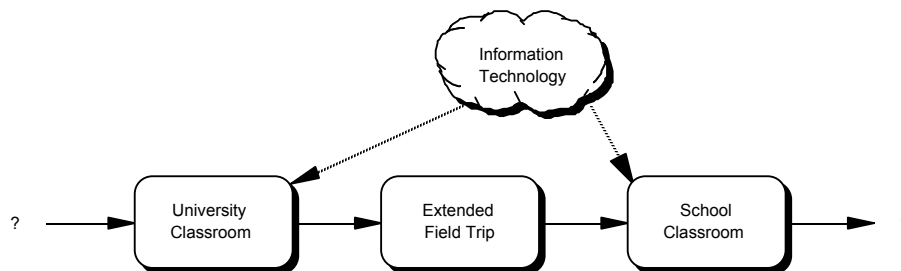


Figure 17. **Typical Learning Environments for Field-Based Programs**

As it turns out, although the physical environments of the classroom, field trip, and information technology learning environments are distinct, the issues facing students and teachers are similar. Table 14 shows how, as described in section 3.4 and illustrated in Figure 5, the integrated science learning environment realised the constructivist paradigm by addressing the specific aspects that impact teaching and learning in the separate learning environments at their most basic levels:

- 1) newness
- 2) massiveness
- 3) appropriateness.

Table 14. **Basic Aspects of the Integrated Science Learning Environment Related to Specific Issues in the Traditional Learning Environments**

Basic Aspect of Integrated Science Learning Environment	Specific Issue		
	University and School Classrooms	Extended Field Trip	Information Technology
Newness	Challenge of rapidly and continuously changing content	Novelty	Proliferation of new tools and resources
Massiveness	Diversity of students and tasks	Everest syndrome	Information overload and non-linear processing
Appropriateness	Influence of department- and school-level environments	Three-day, last-day, and 'me too' phenomena	Present comfort level of individuals

Providing the basis for variables that were addressed explicitly within the ISLE model as shown in Table 14, the following sections describe the commonly noted factors that typically impact each traditionally-separate milieu: the university and school classroom (section 5.4.1), extended field trip (section 5.4.2), and information technology (section 5.4.3).

5.4.1 Classroom Learning Environment

The recent revolution in teaching – technologically and otherwise – has had a tremendous impact on education. Based on an extensive review of literature, three key issues critical to the effectiveness of classroom teaching emerged:

- 1) the challenge of rapidly and continuously changing content
- 2) the diversity of students and tasks
- 3) the influence of both department- and school-level environments.

Science teachers, in particular, must find effective ways to balance issues and manage change in the classroom (Adams & Krockover, 1997; American Federation of Teachers, 1997; Batsche, 1993; Bently, Ebert, & Ebert, 2000; Duit, 1994; Fleming, 1996; Hand, Treagust, & Vance, 1997; Ledbetter, 1987, 1999b; Sinclair, Ledbetter & Fraser, 2001; Wulf, 1997; Yager, 1991). Harper and Hedberg (1997) make the point that tools change knowledge. This is a critical aspect of scientific research and, therefore, an important point to consider within the context of science education (Kuhn, 1970). Changes in the textbook industry (the inclusion of CD-ROMs, proprietary web sites, and other multimedia) reflect the degree and impact of rapidly and continuously changing content. Advances in communications challenge teachers to be aware of current events in a multitude of student interests. Today's teachers must find ways to effectively and efficiently select and use information technology to maintain a relevant, yet focused, classroom learning environment.

Cultural diversity has long been recognised in America and is increasingly evident in the composition of classes at all levels. Language, customs, backgrounds, and overall perceptions and attitudes add to the challenge of the teacher's task in addressing a widely varied class. For example, in a study on classroom environment in urban middle schools, students and teachers surprisingly highlighted the effects of student awareness of gangs and the inappropriate behaviour of teachers, thereby adding personal safety issues to the list of classroom concerns (Sinclair, 2000).

Not only are teachers encouraged to meet the needs of a changing world, they are still required to manage the issues of paperwork, parents and politics that confront them daily. Class size is another issue that is strongly challenged, but over which teachers and administrators have little control. For numerous reasons, "students in smaller classes learn more, and have better attitudes toward school and learning, than students in larger classes" (Glass, Cohen, Smith, & Filby, 1982, cited in Koballa & Montague, 1985, p. 7). The process of enculturation is strongly

influenced by both department- and school-level environments (Milne & Taylor, 2000) and must be taken into consideration to improve the long-term effectiveness of teacher education programs.

5.4.2 *Field Trip Learning Environment*

“Outdoor field trips have been researched from the standpoint of a unique learning environment” (Kaspar, 1998, p. 203). Field trips can be used to foster positive changes by creating a clearly defined and safe environment in which teachers are afforded the opportunity to risk and learn, thus bridging the gap between theory and practice in the classroom. Based on an extensive review of literature, three key issues critical to the effectiveness of extended field trips to natural areas emerged:

- 1) novelty
- 2) the three-day, last-day, and ‘me too’ phenomena
- 3) the Everest syndrome.

By far, the most commonly studied aspect of field trips is the novelty factor. Orion (1993) defined the ‘novelty space’ of an outdoor event in terms of three types of factors: cognitive, geographical, and psychological. Opinions vary as to the positive and/or negative impact of novelty (the newness of an environment) on learning (Barshinger & Ray, 1998; Falk & Balling, 1979; Mullins, 1998; Orion & Hofstein, 1991; Rudmann, 1994).

Kaspar (1998) views novelty as a positive feature of field trips, stating that, “although each learning environment was personal, each individual’s constructions were found to be mediated by the actions of others in the social setting and characteristics of the culture in which the learning was situated” (p. 100). The three-day phenomenon, describing the period of adjustment typically required for individuals to feel comfortable as a part of the functional field trip group, is inferred in several studies, but informally defined by Jones (1990). For this type of interpersonal novelty, participants need about three days to ‘detoxify’ from the influence of civilisation. A similar phenomenon noted at the end of a trip called the last-day phenomenon is characterised by rising inhibitions and withdrawal for personal protection against the separation from the group and re-entry into the respective daily roles. Jones (1990) also describes the ‘me too’ phenomenon that

relates to the tendency of participants to flock together (e.g., taking dozens of pictures from the secret position for winning composition).

The “Everest syndrome”, named by Maddux (cited in Gallo & Horton, 1994, p. 17), refers to the tendency of teachers to feel the need to use technology, specifically the Internet, in their classrooms simply because it exists. The researcher employs this term also to include the often overwhelming effect of massive amounts of information resources and technological tools made available through the World Wide Web (Belk, 1998; Brauch, Gerhold, & Patt, 1996). Sensory overload is a significant issue concerning adult educational field trips, as graphically expressed in one teacher’s query: “...how can you memorize a mountain?” (Jones, 1990, p. 97).

Typical evaluation instruments and assessment items for science-related field trips appropriately focus on content mastery, general cohesiveness of the group, and individual attitude change. Based on scales of the existing Science Laboratory Learning Environment Inventory (SLEI) developed and validated in Australia by Fraser, Giddings, and McRobbie (1995), Orion, Hofstein, Tamir, and Giddings (1997) developed and content-validated the Science Outdoor Learning Environment Inventory (SOLEI, described in section 5.1.7) for use in high schools in Israel.

Comprised of seven scales (Environment Interaction, Integration, Student Cohesiveness, Teacher Supportiveness, Open-Endedness, Preparation and Organisation, and Material Environment), the SLEI specifically investigates the actual environment in which outdoor science activities happen. Three different types of field trips (environmental project, industrial visit, and geology field trip) were conducted respectively in three different disciplines (biology, chemistry, and earth science). Many other new forms were customised or created by the individual researchers, including site- and audience-specific items. For example, the survey instrument used by Knapp (2000) referred to ‘Thompson Park’ and ‘how a tree transpires’. Lisowski (1987) specifically designed the Student Ecology Assessment (SEA) to investigate the influence of field instruction strategies on students’ understanding and retention of pre-determined concepts. Studies typically triangulated multiple data sources – including tests, journals, observations, and surveys – to provide an overall impression of the experience by effectively combining quantitative and qualitative data.

With respect to field trips, Lorsbach and Tobin (1995) suggested that “research on learning environments needed to utilize the referents of the culture that

underlie the sense-making processes of individuals” (cited in Kaspar, 1998, p. 101). A participant’s prior experience influences how learning can occur in any environment. If an educator does not perceive the outdoors as a viable teaching environment, s/he will be less likely to accept the pedagogical style experienced on an extended field trip as useful in the classroom. This realisation provided a major stimulus for developing the integrated learning environment fostered by the ISLE model. The psychosocial aspects of each individual influence the learning environment as much as the physical setting. Incorporating parts of Lisowski’s work in 1987, the Field Experience Questionnaire (Appendix III.1), was developed to partially address this issue.

Hamm (1985) presents an excellent review of educational evaluation models for use in program design, describing Scriven’s formative-summative model, Stake’s countenance model, Stufflebeam’s content-input-process-product model and Scriven’s goal-free model in which, “the removal of pre-specified goals is intended to remove the harmful effects of biasing or contaminating the evaluator’s objectivity. This allows the evaluator to gain a more holistic view of the program” (p. 6). To document a scientific field trip, Wilson (1996) employed a Science Teacher Efficacy Belief Inventory (STEBI), reactions to a Field Experience Evaluation Form (FEEF) and personal interview, using content analysis of the interview questions according to procedures described by Strauss and Corbin (1990, cited in Wilson, 1996). Sefein (1979) stated that, “an inherent problem of evaluation lies in the selection of criterion for judgment and decision making” (p. 25). He used an anonymous survey, achievement test, and semantic differential scale to evaluate a teacher training program in Middle Eastern studies. Bethel and Hord (1982) used: Stages of Concern Questionnaire (SoCQ) to determine teacher concerns about program; Environmental Education Questionnaire (EEQ) to measure teacher attitudes; and environmental science content instrument to assess gain in knowledge.

This section was intended to provide a general overview of the literature concerning the field trip learning environment in the context of science education. Select studies that uniquely influenced the development of the ISLE model are highlighted in the previous discussion. However, limited overall by the scope of this particular study, the review is not a comprehensive representation of this significant environment. Other pertinent works, for example, include Bowen and Roth (2000), Brady (1972), Chadron State College (1972), Cordiero, Kraus, and Binkowski

(1997), Cox-Peterson and McComas (2001), Gilmer (1997), Hammerman (1985), Harris (2001), Hofstein and Mamlok (2001), Jelinek (1998), Kempa and Orion (1996), Mackenzie and White (1981), Manzanal, Barreiro, and Jiménez (1999), Marlow and Stevens (1999), Nix (2000a, 2001a), Nodurft (1999), Orion (1994), Pohl (1999), Van Wey (1995), and Zielinski (1987).

5.4.3 Information Technology Learning Environment

“Academics are one of the best-connected communities worldwide, and the potential of the Web to this group is enormous” (Clarke, 1998, ¶ 3). Recent technological advances have created an awareness of the global community and provide graphic examples of the impact of individuals and the inter-relatedness of systems and societies (Kosakowski, 1998). Based on an extensive review of literature, three key issues are critical to the effectiveness of integrating information technology into education, emerged:

- 1) a proliferation of new tools and resources
- 2) information overload and non-linear processing
- 3) the present comfort level of individuals.

Kessell (1997) eloquently elaborated the dichotomous nature of information technology in education: simply having the infrastructure in place does not ensure its appropriate use. Education has and will continue to embrace advantageous tools/resources as technology evolves. The magnitude of today’s options for supporting teaching and learning with information technology is overwhelming and will result in a virtual revolution for teaching as indicated in section 2.1. However, the average person has a practical limitation on how fast information can be received and moved from short-term to long-term memory. This maximum is commonly referred to as ‘channel capacity’. Somewhere along every individual’s learning continuum, the opportunity for information overload arises. If not properly managed, “selective processing of some information and selective rejection of other information, cognitive shutdown, confusion, anxiety, and perhaps even depression” can result (Fournier, 1996, ¶ 14).

In addition, Internet technology has enabled complex information structures through immediate, multiple linkages. The nomenclature of the World Wide Web clearly supports this non-linear nature of information presentation and discovery. Learning at all levels is similarly complex. “The dynamic nature of learning makes it

difficult to capture on assessment instruments that limit the boundaries of knowledge and expression” (Brooks & Brooks, 1999, ¶ 5). Self-management, negotiation, collaboration, and reflection skills are required to maximise the benefit of most currently marketed self-regulated information technology (Harper & Hedberg, 1997). In addition, many teachers are not yet computer literate; adequate training in the basic computer skills is a time-consuming addition to their already long list of things that must be done.

Teachers are no longer limited to the resources within their physical reach. Integration of technology into educational reform has enabled a global learning community. Collaboration among classroom teachers, science education professors, and graduate students has already helped individual elementary school teachers to change their science teaching practices (Briscoe & Peters, 1997). Preliminary investigations suggest that information technology can help teacher education programs address the needs of practising classroom teachers by providing: specific, practical ideas and advice; a sympathetic and appreciative forum for discussion of ideas and experiences; general support for a progressive, active group of teachers exploring innovative methods; and continuity between preservice and inservice community and professional development (Hammer & DiMauro, 1996).

Information technology in teaching should be the means to an end, not the end itself. Appropriately integrated, information technology can support a more student-centred approach and offer significant benefits, including: an increased emphasis on individualised instruction; more time engaged in advising students; an increased interest in teaching and experimenting with emerging technology; multiple technology utilisation; increased productivity, planning and collaboration; revision of curriculum and instructional strategies; greater participation in restructuring efforts; business partnerships with schools to support technology; involvement of education with community agencies; and increased communication with parents (Cradler, 1994).

Efficient integration and effective implementation of information technology in the university/school classroom is largely dependent on the overall learning environment. As noted by Taylor and Maor (2000), professional educators must “be careful to ensure that technological determinism doesn’t overshadow sound educational judgement” (¶ 21). As stated in a study on higher-level cognitive learning, “teacher beliefs had a major impact on the way in which the curriculum was

implemented” (Fraser & Tobin, 1991, p. 275). It stands to reason, then, that teacher attitudes toward information technology will have a major impact on the way in which they learn – *and teach*. According to Christensen (1998), “the difference in classroom technique and the extent of technology utilization should have a positive impact on the teachers’ and students’ attitudes toward information technology. Because previous research has shown that positive attitudes are a precursor to effective utilization, verification of this outcome [that classroom technique and the extent of technology utilization have a positive impact on the teachers’ and students’ attitudes] could have a major impact on the way teachers are educated to use computers in the classroom” (¶ 8).

In addition to numerous other studies mentioned specifically throughout this thesis, work by Boethel and Dimock (1999), Cannon (1997), Christophel, Hardy, Johnson, Kramer, Neal, and Williams (1998), Glennan and Melmed (1996), Greenman (1998), Greeno (1993), Justice and Espinoza (1996), McCarley (1997), Nix (1998, 2001a, 2001b, 2002), Nix and Ledbetter (2000b), Pelliccione and Trinidad (2001), Roblyer and Edwards (2000), SEDL (1998, 1999), Thirunarayanan (1996), Van Horn (1997), Wezel and Chisholm (1996), and White (1999) contributed to the conceptual and logistical integration of information technology into the ISLE model.

5.5 Summary of Learning Environments Research

This chapter reviewed the present and past research that influenced the design and implementation of the Integrated Science Learning Environment (ISLE) model and program. Background on the growing field of learning environments research, including a summary of the assessment and evaluation of traditional learning environments and the applications of the resultant research was presented in sections 5.1 and 5.2, respectively. The implications and applications of learning environment research for evaluation of the ISLE program were specifically related to this study in section 5.3.

To enable assessment of the multi-dimensional aspects of an integrated learning environment, the Constructivist Learning Environment Survey (CLES) was selected as the basis of the overall research design. The CLES was developed in response to the need to assess innovative classroom environments. Providing an important view of learning from a psychological approach, it focuses on students as

co-constructors of their own knowledge. Theoretically, the five scales of this particular learning environment instrument directly support the goals of educational reform effort in science. Methodologically, the CLES provides a valid and reliable instrument for the assessment of how teachers' perceptions of a constructivist approach to teaching change with first-hand experience. Thus, the overarching research question concerning the impact of a teacher's participation in the ISLE program on their respective students' learning environment can be purposefully addressed.

The implications of existing learning environments research with respect to the Integrated Science Learning Environment were also discussed in section 5.4. To assess, evaluate, and apply learning environments research, it is necessary to understand the factors contributing to uniquely variable perceptions of the situation. A tangible representation of the constructivist paradigm was realised by addressing the specific issues faced in the university and school classroom (section 5.4.1), field trip (section 5.4.2), and information technology (section 5.4.3) learning environments as the basic aspects of the ISLE model: newness, massiveness, and appropriateness.

This comprehensive review learning environment research supported the creation of a fully-integrated virtual field trip, the final product of the ISLE program. In the ISLE model, as shown in Figure 5, 'newness' addresses the challenge of rapidly and continuously changing content in the classroom learning environment, the novelty of the extended field trip learning environment, and the proliferation of new tools and resources encountered in the information technology learning environment. 'Massiveness' addresses the challenge of a growing diversity of students and tasks in the classroom learning environment, the Everest syndrome of the extended field trip learning environment, and new issues of information overload and non-linear processing encountered in the information technology learning environment. And finally, 'appropriateness' addresses department- and school-level influences on the classroom learning environment, the three-day, last-day, and 'me too' phenomena of the extended field trip learning environment, and the present comfort level of individuals encountered in the information technology learning environment.

Chapter 6 reviews literature that specifically impacts the teachers' evolving role in today's classrooms.

Chapter 6

INFORMATION TECHNOLOGY REVIEW

As explained in Chapter 1, the goal of the ISLE program was to develop an integrated learning environment to accomplish the goals set forth for today's science educators in Chapter 2. By combining an Internet-based virtual field trip product with an extended field trip to a natural area, the ISLE model fostered a multi-faceted learning environment to make both content and pedagogy relevant for inservice and preservice science teachers across multiple grade levels, and the increasingly diverse audience of school students whom they serve. The purpose was to provide an opportunity for teachers to gain organised knowledge and learn new skills to make practical changes in education.

As supported by the two main sections that comprise this chapter, the introduction of information technology into the everyday lives of individuals and societies poses an interesting challenge to classroom teachers, as well as university instructors, on a global scale. To better help educators to find effective ways to balance issues and manage change in the classroom, a review of the literature relating to trends in curriculum and instruction was conducted. Subsequently, independent case studies pertaining to the critical needs of educators were conducted in support of the ISLE model. In section 6.1, changes in curriculum and instruction brought about by the integration of information technology into education are described in the context of learning environments. Section 6.2 presents precursory research that supports the feasibility, approach, implementation, and presentation of the final virtual field trip product. The chapter summary, section 6.3, interweaves key aspects of this broad review of related pedagogical literature.

6.1 Trends in Curriculum and Instruction

As introduced in section 2.1 and discussed in section 3.1, information technology has forced us to look at education in different ways. It has also provided new tools for building innovative learning environments. "The crux of the crisis for schools is the discordance between existent beliefs about schools and schooling and the conceptions of knowledge and learning engendered by developments in

information technology” (Bosco, 1995, p. 51). With respect to the rapid advances in information technology, “...basing curriculum content on mental processes, a relatively constant set of constructs, is more logical than focusing on technological products which are constantly changing” (Hill, 1997, ¶ 12). Similarly, with respect to the resultant dissemination of evolving scientific content, “teaching the process and dynamics of scientific activity may help students critically evaluate science” (Brem, 2000, p. 1).

Four things can happen when science (or any other subject) is taught; three of these are bad (Cosgrove & Osborne, 1985). First, the student can completely ignore the new information. Second, the student can learn the information for use in class, but ignore it elsewhere. Third, the student can use the knowledge to support a misconception. Fourth, the student can incorporate the knowledge accurately and efficiently into his/her understanding. The theory of cognitive flexibility, as summarised by a teacher-researcher (Pohl, 1999), “...implies that knowledge transfer and related skills are context dependent with the information coming from multiple perspectives. To transfer knowledge, it is vital that the constructs of knowledge are a result of schema processes that are constructivist and deductive. Learning must be constructed and not transmitted by the teacher” (p. 30).

An impressive body of research on teaching and learning lends insight and inspiration for the development of innovative curriculum and instruction. Joyce and Weil (1980) purport that three key theses on available models of teaching are that “there is a considerable array of alternative approaches to teaching...”, “methods make a difference in what is learned as well as how it is learned...” and “students are a powerful part of the learning environment, and students react differently to any given different teaching method” (p. 461). With proper design and implementation, information technology can powerfully support the creation of an integrated science learning environment – the role of the virtual field trip in the ISLE model.

The following section 6.1.1 describes the linkages between constructivism and cooperative learning enabled by the effective use of information technology in science education. Section 6.1.2 reviews ways to improve teaching based on knowledge representation and transfer. Approaching learning holistically facilitates the development of conceptual understanding and the transfer of knowledge to action within the respective teaching area as described in section 6.1.3. Section 6.1.4 explores the challenge of finding effective ways for utilising the potential of

information technology in science education. And finally, section 6.1.5 specifically relates these common themes in curriculum and instruction to the ISLE model.

6.1.1 Constructivism and Cooperative Learning

There is a link between the effective use of information technology in science education and the recently revived notion of constructivism. “Combine the boom in instructional technology and the trend of constructivism and you have a potent mixture”, according to McKenzie (2000, ¶ 4). He coined the term ‘techno-constructivist’ to describe professional educators who use technology in constructivist ways. One innovator, who was attempting to effect systemic change in the Montgomery County Public Schools, concluded that, “constructivism as a theory will be forced into play by emerging technologies because it is impossible for a teacher to use didactic methodology in a technology-rich classroom” (Matusевич, 1995, ¶ 38). In her experience, the non-linear nature of new information is one of the most positive aspects of recent advances. This interest has also increased investigation of cooperative learning options. Barr (1990) supports her classroom observations. “Interactive learning in this context means learning in which inquiry, feedback and ongoing collaboration play important roles” (p. 86, cited in Matusевич, 1995, ¶ 24).

Like field trips in science, constructivism is not a new idea in education. Since the turn of the century, numerous educational models, including those of Dewey, Piaget, Montessori, Bruner, and Vygotsky, have been based on constructivism. It is important to note, however, that there are many diverse interpretations of this commonly-used term. Von Glaserfeld (1993, 1995) developed radical constructivism. Tobin (1990) explored the collaborative and inter-subjective nature of learning as social constructivism. Taylor (1996) expanded the idea as critical constructivism which addresses the social and political forces that surround and shape education. Novak, Mintzes, and Wandersee (2000a) described three axioms of human constructivism. For the purposes of this study, in general, Shim’s definition of constructivism provides an appropriate context:

Most current constructivists would agree that the foundational components of learning in a constructivist perspective are based on the belief that:

- learning is an active, constructive process,
- learning is a social, usually collaborative, process, and
- knowledge is a contextualized, networking process involving the environment.

The teacher is thus a facilitator of thinking, shares control of learning, encourages student-to-student interaction, promotes discovery, and helps to fashion the contexts. (Shim, 1998, ¶ 33)

Viewing constructivism as a referent for science teaching has tremendous potential. Within such a framework, problem-solving is used as a learning strategy and cooperative learning is the primary teaching strategy. Research indicates that “as teachers made transitions from objectivist to constructivist oriented thoughts and behaviors their classroom practices changed radically” (Lorsbach & Tobin, 1997, ¶ 17). Constructivist learning is student-centred. It tends to be project-oriented, allowing students to learn through discovery and experience. When represented as a process rather than a collection of facts, traditional approaches to science teaching no longer make sense. Wooten (1999) reported that “students in a classroom where a constructivist approach to learning is used will exhibit greater improvement in their learning of science concepts than students in traditional classes” (p. 99). Reiterating this conclusion, Grau and Bartasis (1995) described three instructional perspectives that emerged from a study of constructivist learning environments: “instruction should be provided in relevant contexts”; “provide multiple perspectives of the information to be learned”; and “the primary values of constructivist learning are collaboration, personal autonomy, generativity, reflectivity, active engagement, personal relevance, and pluralism” (¶ 27).

Several other distinctive terms are often associated with the connotations of constructivism. Meaningful learning “occurs when the learner seeks to relate new concepts and propositions to relevant existing concepts and propositions in his/her cognitive structure” (Novak, Mintzes, & Wandersee, 2000a, p. 3). Discovery learning “emphasizes students’ personal experiences with information and materials as a foundation for conceptual development” (Bentley, Ebert, & Ebert, 2000, p. 180). Learning by inquiry “supports learning by suggesting that students design and carry out activities to answer their own questions” (Ledbetter, 2000a, ¶ 1). Natural learning is “learning in those instances when the process is not structured and regulated by

others but is woven into the life situation of the person” (Bosco, 1995, p. 46). As defined by Boud and Felletti (1991), problem-based learning is “an approach to structuring the curriculum which involves confronting students with problems from practice which provide a stimulus for learning” (p. 21 cited in Cordeiro, Kraus, & Binkowski, 1997, p. 6). Project-based science, through which students learn science by conducting science projects is “organized around a goal or driving question that motivates the students to explore data and make hypotheses” (Center for Learning Technologies in Urban Schools, 2001, ¶ 1).

Implementation of constructivist teaching has brought another change toward collaborative or cooperative learning. “Science and technology are themselves cooperative enterprises. Although Neil Armstrong was the first person to walk on the moon, tens of thousands of people in research, engineering and industry labored more than a decade to get him there” (BSCS, 1989, ¶ 1). Kempa and Orion (1996) reported that students’ reaction to team work in the specialised context of fieldwork was generally positive. Cooperative group teaching theory is built on the idea that learning together is more powerful than learning alone because of student-student interactions. It is not about learning to cooperate. Learning is a natural consequence when positive social interactions are combined with challenging science-related problems and issues.

Henton (1996) reported that students respond positively to their studies, the school, and each other, in proportion to the extent of effective collaboration in the classroom. “Mutual tutoring, a sense of shared progress and shared goals, and a feeling of teamwork are the natural outcomes of cooperative problem-solving, and these processes have been shown to produce substantial advances in learning” (Strommen, 2001, ¶ 9). A diversity of variables affects today’s schools and classrooms, adding to the complexity of education. Regardless, change is possible and can be successfully implemented. White (1998) reported similarities in the process of modifying educational practice as “new referents were linked with existing beliefs” (p. 124). Clearly, no single formula for managing the science classroom is always possible or even plausible. However, individual, cooperative, and competitive learning strategies can be effectively utilised within an overall context of supportive, team-based learning.

This brief overview hardly describes the tip of an enormous iceberg that has already changed the face of education. The question remains as to how professional

educators can support classroom teachers, school administrators, and policy-makers in realising this type of conceptual reform. “Lack of funding and no clear vision keep systemic change from occurring as rapidly as the evolution in technology” (Matusевич, 1995, ¶ 29). According to Duit (1994), “research has clearly shown that teachers are not usually ready to adopt constructivist teaching and learning approaches... without serious difficulties and distortions of the intentions of such approaches” (¶ 70).

In assessing teachers’ thoughts about changing to constructivist teaching/learning approaches in junior secondary science classrooms, Hand (1996) identified the change of the teacher’s role from manager to empowerer as one key issue. Flick (1998) suggested six techniques to help with the transition from a traditional to constructivist approach: “1) Teach skills and procedures for interacting in small groups. 2) Execute procedures for promoting interaction between existing student knowledge and new knowledge. 3) Execute explicit instructional methods for teaching specific knowledge, process skills, or scientific attitudes. 4) Execute methods for presenting content in the form of problems that stimulate selected aspects of inquiry. 5) Model or demonstrate inquiry so that students can copy the traits. 6) Execute skills needed for designing, implementing, or evaluating hands-on investigation” (p. 422). Ultimately, with respect to long-term professional development programs,

Courses should ensure that teachers are given opportunities to construct the knowledge that they need to teach both present and future science courses. Knowledge of the content and how to teach the content are both extremely important. Teachers will probably require specially designed courses of study which address both needs. (Fraser & Tobin, 1992, p. 80)

This was the rationale for developing the ISLE model and implementing the ISLE program described in this research study. Basing the virtual field trip project on an actual field experience provided the framework needed to support the teachers in developing more constructivist classroom learning environments, positive attitudes toward information technology, and to further their conceptual development in terms of content and pedagogy. The following sections describe how this was achieved.

6.1.2 *Knowledge Representation and Transfer*

Marlow and Stevens (1999) examined the impact of student participation in an authentic science inquiry on the changing attitudes of a group of science teachers toward inquiry-based science. “All teachers agreed that engaging students in authentic inquiry was highly desirable” but, unfortunately, for various reasons, “teachers had difficulty putting this view into practice” (¶ 13). Similar comments regarding the lack of knowledge transferred from the teachers’ experience to the classroom can be found throughout the literature. However, a classroom teacher’s uniquely distinct perspective as a former classroom student allows for practically immediate transfer of knowledge when provided with a clear, relevant, and supportive environment. Nevertheless, transfer is not easy. Thinking through ideas, discussing generalisations, and forming new constructs requires structured processing facilitated either by the student, an able peer, or the instructor.

The key to increasing transfer often lies in either the selection or design of appropriate learning activities or in the teaching methodology. This new application of learned knowledge can be transferred in three basic ways: 1) specific transfer, for which the learner takes the habits and associations acquired during a previous experience and applies them to a new experience to develop a new skill, 2) non-specific transfer, for which the learner generalises the common underlying principles received from a previous experience and employs them in a new learning situation, or 3) metaphoric transfer, for which the learner transfers the similar underlying principles between two seemingly distinct and unrelated environments. “Being guided by an image represents a potential explanation for teachers knowing intuitively how to act in certain situations” (Tobin, 1993, p. 26).

6.1.2.1 *Visualisation and Misconceptions*

Recent discoveries in multiple intelligence theory and modes of thinking provide insight into how to teach the competency and mastery skills needed to navigate successfully within this ever-changing society. People not only *learn*, but *remember* what they learn through visual imagery. According to Haber (1970), humans have an almost photographic visual memory and “...the capacity for remembering pictures may be unlimited” (p. 106). Interestingly, a program called Picture Thoughts “uses the abstract and personal nature of the visual arts to lead students to think conceptually when working with each other” (Hamilton, 1999, ¶ 1).

Fraser and Tobin (1992) suggested that "...the process of teacher change might be initiated by introducing a variety of metaphors, and reflecting on the efficacy of basing teaching and learning strategies on each of them" (p. 79).

Foxon (1993) described a process approach to the transfer of knowledge with respect to on-the-job application of skills and knowledge. Low motivation and lack of supervisor support are cited as the key factors that inhibit the transfer process in corporate training scenarios. Ledbetter (1999b) reported positive results from a process approach to science education using discrepant events, inquiry, and open-ended activities to model teaching strategies, stimulate discussion of content information, and enable teachers to construct their own knowledge in science courses for practising classroom teachers. Robertson (2001) used conceptual understanding to promote students' ability to solve transfer problems – unfamiliar problems that require previously encountered concepts for solution. Changing conceptual understanding is critical to correcting misconceptions. Scoring well on a written test certainly does not ensure complete understanding (Pendley, Bretz, & Novak, 1994). To apply established teaching models to the professional development of biology teachers, Kinchin (2000) made the analogy of conceptual ecology (which includes the learner's epistemological commitments, metaphors, analogies, beliefs, competing conceptions, and knowledge from outside the field) explicit through the use of concept mapping.

6.1.2.2 *Concept Mapping: An Introduction*

"Similar to an outline or flow chart, a concept map is a way of representing or organizing knowledge. However, a concept map goes beyond the typical outline in that concept maps show relationships between concepts, including bi-directional relationships" (University of Tennessee at Chattanooga, 2000, ¶ 1). Developed by Joseph D. Novak at Cornell University in the 1960s, the technique was based on Ausubel's theories stressing the importance of prior knowledge in learning new concepts. Other related ideas include semantic maps and mind maps, which contain only one main concept in contrast to concept maps, which can have several. This allows for variation in the actual structure that reflects individual understanding. According to Trochim (1999), the concept mapping process can take place in a single day or be spread across several weeks. In any case, he suggested progression through six distinct steps: preparation, generation, structuring, representation, interpretation,

and utilisation. The distinguishing feature is that key concepts and important terms (nodes) are related with labelled lines (links) that describe the relationships between them. Some techniques recognise the link between two concepts as a single item (proposition). Also, complex structures can indicate placement of specific concepts below more general concepts (hierarchy).

6.1.2.3 Applications of Concept Mapping

There are multiple applications and benefits of concept mapping. Zimmaro and Cawley (1998) suggested using concept mapping as: 1) an instructional tool to organise course content, prepare specific lessons, and present material to students; 2) a student learning tool to learn course material, integrate course content, and integrate material across different courses; and 3) a form of assessment to evaluate student learning and to give student and instructor feedback. Novak (1996) specifically used concept mapping, rooted in a constructivist epistemology, as a tool for improving science teaching and learning. “Although concept maps remain useful as a research tool to represent knowledge structures, we have also found them to be useful in a variety of applications, including facilitation of meaningful learning, design of instructional materials, identification of misconceptions or alternative conceptions, evaluation of learning, facilitation of cooperative learning, and encouragement of teachers and students to understand the constructed nature of knowledge” (p. 32). One of the most important aims of over 20 years of work on alternative conceptions and phenomena in the natural and technical environment is using concept maps to observe changes that occur during lessons (Dahncke, Behrendt, & Reiska, 2000).

Concept mapping (Novak & Gowin, 1984) represents a major breakthrough in teaching and learning by opening a window into the student’s mind, offering teachers a way to evaluate and assess conceptual understanding. Sinatra (2000) combined the use of concept mapping with text structure and teaching-style shift to help learners to think, read, and write more effectively. Bolte (1999) used concept maps, combined with written essays, as a viable tool for assessing student organisation of mathematical knowledge. Stoddart, Abrams, Gaspar, and Canaday (2000) assessed quantitative information about the quality of student understanding by using an open-ended concept map activity combined with a rubric. “Analysis of the patterns of concepts and links within a concept map may not only be used to

pinpoint existing understanding, but may also give an indication of a student's readiness to progress in a certain direction" (Kinchin, Hay, & Adams, 2000, p. 53). Appropriate for collaborative project-based learning, concept mapping is "a type of structured conceptualization which can be used by groups to develop a conceptual framework which can guide evaluation or planning" (Trochim, 1986, ¶ 1). Nix and Ledbetter (2002) proposed using student concept maps to simply and quickly direct changes in teacher instruction style. (Section 6.2.3 discusses the implications of this application within the ISLE program.)

6.1.2.4 Evaluation of Concept Maps

Not surprisingly, there are equally numerous methods for analysing and scoring concept maps. Techniques range from complex multivariate computations (Trochim, Cook, & Setze, 1994; Fisher, 2000) through subjectively defined point scales (University of Wisconsin – Madison, 2000) to an overall comparative rating scheme (Zimmaro & Cawley, 1998). Shavelson and Ruiz-Primo (2000) extensively investigated the psychometrics of assessing science understanding through alternative assessments, including concept mapping techniques. Their findings tentatively indicate that maps created with concepts provided by either the assessor or generated by the student "produce equivalent scores reflecting similar aspects of students' knowledge..."; sampling variability from one random sample of concepts "provide equivalent map scores (when the concept domain is carefully specified)"; concept maps can be "reliably scored, even when complex judgments such as proposition quality are required..."; the relationship between multiple-choice scores and concept-map scores suggest that "they measure overlapping and yet somewhat different aspects of declarative knowledge..."; and "the convergence score – the proportion of valid propositions in the student's map to the number of all possible propositions in the criterion map – is the most time-and-effort-efficient measure of the three score types" (p. 326).

The validity of links is dependent on the student's level of understanding. *Is such understanding compared to an expert, a textbook, or what students have experienced thus far?* The real issue for instruction is how the links change as the students' experiences increase and understandings deepen. "Students who learn meaningfully relate information from different sources in an attempt to integrate what they learn with the intention of imposing meaning" (Edmondson, 2000, p. 16).

Kinchin, Hay, and Adams (2000) attempted to bring concept mapping into the classroom by simplifying evaluation and approaching assessment qualitatively. The important part of concept mapping is determining if the writers have an understanding of the information or if they are simply repeating factoids. Viewed as a developmental progression, as knowledge is added changes that occur in the students' schemas will be evident in their revised maps.

Their classification is based on three patterns for structuring concept maps. If the student develops a spoke arrangement (central concept with individual items radiating outward), the knowledge can be added at any point, but might not connect any of the concepts together. In a chain arrangement (straight line formations suggesting a linear hierarchy), new knowledge can be added to the beginning or end, but adding it to the middle could throw off the hierarchy or not fit at all. And finally, additional knowledge can begin in the form of a spoke or a chain but, as understanding is increased, it will be incorporated into a net (employing cross-links between multiple concepts) through additional links. From a constructivist point of view, the student can begin by organising information in a chain or spoke, then convert the entire map to a net, showing that knowledge was, indeed, constructed.

Clearly, there are outstanding issues in determining the validity and reliability of concept mapping as a quantitative assessment measure; however, the value of concept mapping in representing conceptual change over time – in conjunction with other instruments – is promising. “The structure of a map is, therefore, unique to its author, reflecting his/her experiences, beliefs, and biases in addition to his/her understanding of a topic” (Kinchin, Hay, & Adams, 2000, p. 44). The way in which a concept map is constructed illustrates two essential properties of understanding: the representation and the organisation of ideas. In teaching complex topics, like science, the most important function of a concept map is to make the overall framework of the concept explicit. Concept maps provide a tangible way to help students complete fragmentary understanding and integrate multiple components for meaningful learning.

6.1.2.5 Implications of Concept Mapping for the Present Study

Concept mapping is a potentially effective approach for developing conceptual understanding to promote knowledge transfer – and combat the negative effects of novelty, information overload, and non-linear processing. Ritchie and

Volkl (2000) reported that students who created concept maps before engaging in manipulative experiments established a better mental network to support information encountered later. Novak and Symington suggested that concept maps provide an interface between the cognitive framework and textual information. Therefore, concept maps help students to move from a linear (text) structure to a hierarchical (psychological) structure and back again (1982, cited in Kinchin, 2000). Trochim (1999) identified an increase in group cohesiveness and morale as one of the major effects of the process of concept mapping. These benefits extend to the online educational environment as well. “Concept maps used as navigational tools provide an excellent and flexible instrument that each learner can personalize to her needs and skills” (Cicognani, 2000, ¶ 37).

Chapter 3 described concept maps in the context of the conceptual framework of the ISLE model. Concept maps provided the mechanism to create a singular group dynamic and produce a fully-integrated, collaborative project rather than promoting multiple individual efforts as typical of field trip experiences. The following section supports the adoption of the experiential learning cycle to implement this design.

6.1.3 A Holistic Approach to Teaching

Approaching learning holistically facilitates the development of conceptual understanding and the transfer of knowledge to action within the respective teaching area. Experience can be integrated into conceptual knowledge to encompass the entire individual, not just the intellectual aspect (Nix, Ledbetter, & Fraser, 2001a). “To teach someone any subject adequately, *the subject must be embedded in all the elements that give it meaning*. People must have a way to relate to the subject in terms of what is personally important” (Caine & Caine, 1994, p. 64). This premise is magnified in a natural setting, as John Muir simply noted:

When we try to pick out anything by itself we find it hitches to everything in the universe.

A variety of terms are used to describe the underlying principles of several pedagogical strategies that employ a holistic approach. Each offers insight into the development of new models for effective teaching within this evolving era of applied learning. For example, contextual learning approaches learning from the perspective of doing, thinking, speaking, and experiencing; it surmises the steps beyond hands-

on and minds-on (Gilmer, 1997). In proposing their model of situated cognition, Brown, Collins, and Duguid argued that meaningful learning will only take place if it is embedded in the social and physical context within which it will be used (1989, cited in Herrington & Oliver, 1997). An immersive environment “involves the whole student, engaging emotions and imagination, as well as intellect by providing a direct hands-on interactive experience to enhance learning” (Belk, 1998, p. i). Deep ecology is based on a change in worldview and describes a trend toward wholeness [connectedness] and more confidence in subject knowledge with “profound implications for the teaching of science” (Nodurft, 1999, ¶ 5).

Particularly relevant to the use of field trips is the idea that, according to Hammerman (1985), “...outdoor education is an approach toward achieving the goals and objectives of the curriculum, which involve: 1) an extension of the classroom to an outdoor laboratory; 2) a series of direct experiences, in any or all phases of the curriculum involving natural materials and living situations, which increase awareness of the environment and of life; 3) a program that involves students, teachers, and outdoor education resource people in planning and working together to develop an optimum teaching-learning climate” (p. 5). Wood and Gillis define adventure education as “a variety of training which involves high-risk activities... These types of educational programs are not strictly limited to thrill-seeking programs and may include educational programs involving camping. The programs are based upon the belief that educational programs should build up a person and make him discover his own power through personal experience” (1979, cited in Hamm, 1985, p. 50). The trend is clearly based on the general principles of constructivism, attempting to integrate multiple aspects of the individual forming a coherent view of the whole system through content knowledge and understanding.

Each of these approaches contributes to the broader definition of experiential training. “It should be emphasized, however, that the aim of this work is not to pose experiential learning theory as a third alternative to behavioral and cognitive learning theories, but rather to suggest through experiential learning theory a holistic integrative perspective on learning that combines experience, perception, cognition, and behavior” (Kolb, 1984, p. 21). Processing by way of experiential learning involves challenge and support (Henton, 1996; Luckner & Nadler, 1997; Rohnke, Tait, & Wall, 1997; Sakofs & Armstrong, 1996). It builds on physical activity that is

deliberately structured to affect an emotional response and intellectual awareness through a cyclical pattern of experience, reflection, generalisation, and application.

Figure 18 is a compilation of several similar illustrations that utilise various terminology. Within the Project Adventure program, Henton (1996) defines the stages as activity, reflecting, generalising and abstracting, and transfer. University Associates, Inc. (1990) label five stages as experiencing, publishing, processing, generalising, and applying. BSCS (1999) characterises their design with the five Es: engage, explore, explain, elaborate, and evaluate. Synthesised by the researcher, Figure 18 emphasises the critical processing phases between each stage of the ERGA sequence (experience, reflection, generalisation, and application; refer back to Figure 8 and Table 6). This distinction is paramount to the ISLE model in that it is used to relate the group's common experience to each individual's particular situation.

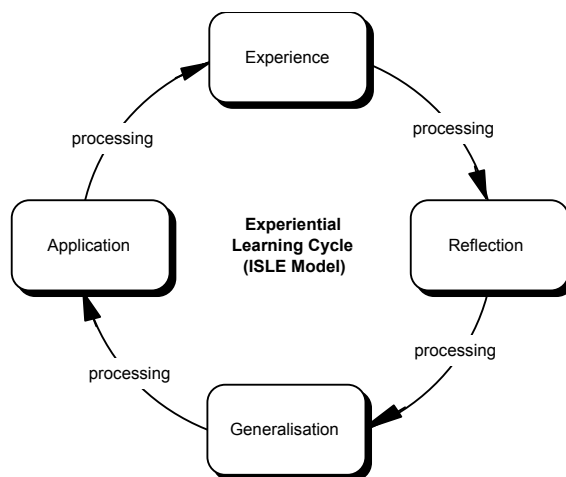


Figure 18. **The Experiential Learning Cycle (Revised for ISLE Model)**

Recall that in Figure 8, which described the conceptual hierarchy of the ISLE classes and day trips, the ERGA sequence was represented by a vertical progression (↓ ↓ ↓ ↓). In Table 6 and Table 7, which respectively described the logistical framework for ISLE pre-trip classes and local day trips, the ERGA sequence was represented by a horizontal progression (→ → → →). As each individual participant experienced the ISLE program, the conceptual (Chapter 3) and logistical (Chapter 4) frameworks were uniquely merged, and thereby, internalised in a personally-relevant, context-sensitive, content-rich strategy for science education.

Experiential learning is more than just doing. Summarised by Henton (1996), the stages of the experiential learning cycle build on the various learning styles that individuals bring to new situations. The experience or activity stage provides first-

hand experience with the material, engaging students in the topic by initiating as many connections as possible. By sharing unique perspectives, participants become involved in the discovery through multiple avenues based on personal interests and experiences. The reflection stage provides an opportunity to clarify facts and enable students to view their actions and the topic from different angles as they discuss their individual approach, strategy, organisation, and experimental design.

In the generalisation stage, students connect previous experiences with present ones by examining abstract concepts and making connections between ideas and experience. They identify basic principles that can be applied broadly by looking at the larger context. Then, in the application or transfer stage, a return to action helps students learn about the practical limits of their newly acquired knowledge, as well as broader applications, as they attempt to transfer what they have learned from one situation to another. Their questions become more sophisticated as understanding deepens with each attempt, leading to further exploration and discovery as the cycle continues to create an unlimited spiral.

What we discover becomes our own. Sadly, the sheer joy of discovery is one of the elements missing in many schools today. “The classroom, when extended into the outdoors, provides the setting in which students may enjoy the pure thrill of discovery, along with the plain, down-to-earth fun of learning. Learners are able to experience for themselves some of the same processes through which some of humankind’s most significant discoveries of science, aesthetics, and self have been made” (Hammerman, 1985, p. 30). Another educational advantage is that active excursion naturally results in markedly superior retention of content over other methods (Mackenzie & White, 1981).

With respect to experiential learning at science research sites as a context for teacher professional development, it is important to note that Cox-Petersen and McComas (2001) reported that “research-based, apprenticeship learning can be a valuable part of science teacher development. However, we cannot recommend that these are venues by which teachers might learn more about the nature of science of substantially change their attitude about scientists and their work” (p. 18). The program design must explicitly support and develop the desired outcomes if they are to be obtained and internalised by the participants.

Luckner and Nadler (1997) recognised that finding ways to establish active learning environments in the course of an academic school year can be a challenge.

They suggested using the experiential learning continuum to gauge the appropriate level of involvement and degree of real-life application. The stages increase along the following scale: 1) simulated experiences use slides, pictures, and films or role-playing; 2) spectator experiences use observation and identification of specific behaviour as the basis for subsequent discussion, 3) exploratory experiences use open-ended real-world activities and settings to develop an awareness of and personal questions about the subject, 4) analytical experiences require the application of theory in real situations where learning is accomplished through a systemic analysis of the setting or solving problems, and 5) generative experiences allow individuals to take part in the creation of products, processes, or relationships.

“The success of most field trips depends on leadership rather than location” (Zielinski, 1987, p. i). Because experiential learning can take place anywhere that there are interested people, Herbert (1981) encourages teachers to create such adventure on extended field trips, on short field trips, or within the classroom. Virtual field trips, based on actual field experience and enabled by information technology, provide yet another opportunity to incorporate a new form of experiential learning into teaching (Nix, 2001a).

6.1.4 Educational Technology

Few would question the claim that information technology offers numerous and valuable benefits to both society and education in general; however, the everyday application and classroom integration of the diverse array of tools and resources presently available is the subject of hot debate and frustrating confusion on a local level. The challenge of finding effective ways for utilising these emerging opportunities opens a new frontier for educational research and technological development. The potential of information technology in science education is enormous. The power of information technology in science education (and any other subject for that matter) must be realised through today’s teachers as their role is expanded to the vision of tomorrow’s educators (Wooten, 1999).

6.1.4.1 Information Technology in Science Education

Information technology significantly influences both the topics and tools of science education. In addition to the traditional textbook and standard curriculum (lesson plans, course materials), teachers can enhance lessons with a variety of

educational resources including visual media (videos, CD-ROMs), specialised manipulatives (games, toys), interactive software programs (computer-assisted instruction) and, most recently, the Internet (an open interconnection of networks that enables connected computers to communicate directly) (Encarta, 1996). The World Wide Web (WWW), which allows users to create and use point-and-click hypermedia presentations linked across the Internet to form a vast repository of information that can be browsed easily (Encarta, 1996), is revolutionising science education – blasting us through classroom walls on a real-time mission to Mars, bringing the excitement of undersea exploration to our desktops, and inviting all to experience a myriad of opportunities for personal growth and professional development. At the click of a button, time and space become irrelevant and we are limited only by our imagination.

As evidenced by the exhibits at the state-wide Conference for the Advancement of Science Teaching in late November 1998 (Lubbock, Texas), information technology indeed encompasses a significant portion of today's science education materials and strategies. Of course, the typical marketing propaganda displayed year after year was pervasive throughout the majority of 8x10-foot booths: free graphical posters to decorate bulletin boards, free buttons to pin on jackets, and bags, free samples of edible fundraiser treats, free game cards with a mailing address to order more mind-teasers, and piles and piles of free catalogues and flyers and booklets to carry home for filing and review. But the dominant features on the show floor were the 20x20-foot and 20x30-foot custom booths representing the major educational technology companies with multimedia presentation kiosks and fully-equipped interactive software demonstration centres.

After just one afternoon in the exhibit hall as a casual observer, I had collected two shopping bags of multimedia catalogues representing over 20 companies, acquired two videotapes and four software demo CD-ROMs, utilised a variety of computer-integrated probes and measurement devices, and participated in three 30-minute hands-on demonstrations of science-related information technology. Most vendors offered current details and additional examples on their corporate websites. What is disturbing about this picture is that I was able to experience all of those new tools and resources in such a short period of time because the other attendees were gathered at the jewellery stands, gift shops, and book displays. There is nothing wrong with people having a good time at a conference and purchasing

items to enhance their personal or professional resources. That single observation concerns me because, in a broader sense, it appears that the majority of today's teachers do not seem to perceive information technology as real or valid enough to merit voluntary, in-depth exploration.

6.1.4.2 Today's Teachers

The plain and simple fact that today's teachers were students in a totally different world has a tremendous impact on realising the potential of information technology in science education. Changes in evolving national, state, and district reforms to develop consistency and continuity across the curriculum will help advance the application and integration of new teaching tools and resources. But, to bring teachers, technology, students, and learning together, we must encourage and implement a new model of education suitable for tomorrow's classrooms. Dramatic changes have occurred rapidly in all areas since the introduction of the personal computer (PC) in 1981, the year I graduated from high school. At a rural learning centre, my five-year old niece is already taking a computer class! At home, she has an extensive library of educational and entertainment software that she has enjoyed for over three years. The factory school model of teaching is not appropriate for, and will not satisfy, the type of independent learning stimulation to which she is accustomed and her parents have come to expect (Ellmore, Olson, & Smith, 1993). The one-room schoolhouse has expanded to the reaches of a global system without limitations within a matter of decades.

Realistically, successful reform of any type requires a significant investment of time, money, energy, and strong leadership based on quality research. Even though information technology flourishes in many venues, the same might not be directly transferable or necessarily suitable for widespread adoption by educational institutions. Our adapting society must develop critical capabilities for realising the powerful potential of these unprecedented resources. Today's teachers are acutely aware of the lack of self-management, negotiation, collaboration, and reflection skills required of today's students to gain maximum benefit from most currently marketed self-regulated information technology (Harper & Hedberg, 1997). Their hesitation to reinvent education is founded in experience and first-hand knowledge of the classroom environment.

Equal and fair assessment techniques for a multi-disciplinary, individualised course of study must also be evaluated and practised before the basis of education is restructured. Many teachers are not yet computer literate; adequate training in the basic computer skills is a time-consuming addition to their already long list of things that must be done. “The possibilities are great, but the realities are limited” (Children’s Software Review, 1998, ¶ 35), notes one teacher in a 1998 survey on ‘The State of Technology in Classrooms’. The report personalises the key concerns that teachers have about computers in their classes: they are afraid to use them, do not have enough time to use them, do not understand how to use them, and/or see them as more trouble than they are worth.

6.1.4.3 Tomorrow’s Educators

Information technology offers tools, not comprehensive solutions. Productivity software (grade book programs, email notifications, listserv groups) is being designed, implemented, and refined in public and private school systems. Teachers are learning how to take advantage of these new options to simplify duties and streamline paperwork. Educational software (interactive CD-ROMs, real-time websites, information databases) is being developed, tested, and improved in government and business. Educators are experimenting with ways to incorporate these new resources into their coursework and independent study opportunities.

In the first week of 1999, I was encouraged and amazed by the international collaboration of students, teachers, and scientists participating in a GLOBE Training Program (GLOBE, 1999). A skilled staff of three trained educators and three nationally-recognised research scientists, four local university representatives, and 27 active classroom teachers dedicated four days to learning the scientific protocols, understanding the web-based interface, and discussing practical implementation strategies for this real-world application of technology as described on their web site (<http://www.globe.gov>). Global Learning and Observations to Benefit the Environment (GLOBE) is a worldwide network of students, teachers, and scientists working together to study and understand the global environment. Students and teachers from over 6000 schools in more than 70 countries are working with research scientists to learn more about our planet. GLOBE students make environmental observations at or near their schools and report their data through the Internet. Scientists use GLOBE data in their research and provide feedback to the students to

enrich their science education. Global images based on GLOBE student data are displayed on the World Wide Web, enabling students and other visitors to visualise the students' environmental observations.

An incredible wealth of background information and content presentations, ongoing scientific investigations, and relevant data that can be incorporated into science lessons is available for public access right now. Today's teachers are gaining experience and expertise with the non-linear nature of information technology. Tomorrow's educators will enjoy the freedom to exercise their passion for teaching by re-shaping their role as information providers, process monitors, and record-keepers to facilitators, instigators, and directors of the next generation of motivated, informed, and challenged students – our future.

6.1.4.4 Realising the Potential

Our collective mindset must be forward-looking. Today's teachers are not having to start all over again as they often lament, but are standing on the threshold of exciting possibilities. Technologists, administrators, and educational leaders must instil the interest and energy of the children who I watched at Epcot (part of Walt Disney World – Orlando, Florida) in today's teachers, tomorrow's educators. On their 1999 spring breaks, thousands of elementary, intermediate, and high school students opened their minds and exercised their abilities with stimulating interactive multimedia learning resources. The Walt Disney World designers and developers obviously listened to their customers and gave serious attention to their comments and ideas. The furniture is the right size and comfortable, allowing easy access to the screens and manipulatives. The programs are engaging, exciting, and appropriate for each level and type of learner. It was indeed magical to see a six-year old explain the objective of an interactive simulation to his parents and then take their relatively large hands to the touch-screen to enter their selection.

6.1.4.5 Merging Theory and Practice

Innovative programs and university courses are exploring the power and potential of educational technology in science education. As part of a web-based course on the use of multimedia in science education, I, a student residing in the United States, wrote this work for a professor in Western Australia – literally on the opposite side of the planet. Science teachers are learning how to design their own

multimedia lessons to bring their real-world experiences into their classrooms. During the summer of 1998, over 200 science teachers helped take ‘fossil-friendly education to new heights’ as they learned by doing. Quoted on a local newscast live from the UTD dinosaur excavations in Big Bend National Park, one teacher captured the essence of learning and teaching:

I get real excited about doing this. When I go back to the kids, that excitement carries over and makes it really fun for them – they don’t even realise they’re learning! ... What’s amazing is that I’m able to teach very high-level science and math because they love it! (Farr-Addington, 1998)

Information technology enables today’s teachers to transfer this energy from the field to every student in every classroom in every semester. (Video of the live news report, including the teacher interview, was also available for on-demand replay via the broadcaster’s website.) Naturally, technology will continue to advance; however, the key elements of ‘cyber-science’ have been presented and are available to home, business, and educational users. Now is the time for today’s teachers to become involved in the process of transferring information technology to science education. Now is the time for technologists and administrators to listen and respond to the needs and wants of tomorrow’s educators. Educational research must look to today’s teachers for the input needed to direct and successfully merge technological development at the student’s desktop to provide the tools and resources required by tomorrow’s educators.

6.1.5 Common Themes Relevant to ISLE

The ability to process information is critical in today’s global society and is clearly reflected in standards documents for education (see section 2.1). While machines process whatever raw data are entered into the system in a specifically sequenced context, people have an innate ability to process and synthesise sensory, perceptual, and learned data in totally independent contexts derived from individual life experience. “The brain appears to be much like a camera lens: the brain’s ‘lens’ opens to receive information when challenged, when interested, or when in an innocent, childlike mode and closes when it perceives threat that triggers a sense of helplessness” (Caine & Caine, 1994, p. 69). By creating an open, safe, and relevant

learning environment, teachers can naturally attain an appropriate level of content and comfort, and thereby maximise learning opportunities.

Information overload and non-linear processing pose two major challenges to the effective implementation of information technology in both the field trip and university and public/private school classroom settings (Fournier, 1996; Jones, 1990; Tsu, 2000; White, 1999). The rapid rate of change adds yet another dimension to the value of understanding the critical context of learned content. “Teachers need time, and assistance, and examples, and the appropriate opportunity to try things out and make mistakes, before we can remotely expect appropriate, much less seamless, integration of the technology into day to day teaching” (Kessell, 1997, ¶ 44).

Programs in both science education and information technology must address multidisciplinary content and integrated design, plus state and national standards requirements, and local societal expectations for a global community. Efficient representation of knowledge and understanding can be developed through written journals, visually organised in concept maps (Novak, 1996; Trochim, 1986), and electronically presented in web-based projects focused on both science education and information technology (Spitulnik, Zembel-Saul, & Krajcik, 1998). Putting aside the issues of hardware and software acquisition and of system maintenance, the potential of information technology in education will remain an untapped resource until the practical elements of classroom application and curriculum integration are fully developed and efficiently distributed via methods that today’s teachers can directly use in today’s classrooms.

6.2 Case Studies in Support of ISLE

The intent of the ISLE program was to make the focus of the program – information technology – virtually invisible. As such, each of the critical factors of the program development were researched and investigated in separate case studies to isolate and test the techniques combined in the comprehensive ISLE model. A process approach to instructional technology was reflected in concept maps that provided a relevant framework for the virtual field trip, and individual teachers, within the open structure of the World Wide Web.

To investigate the four main factors of the ISLE model implementation, the following section 6.2.1 describes the feasibility of using the World Wide Web to deliver science content to classroom teachers. Section 6.2.2 reviews how a process

approach to teaching and learning was used to encourage communication, collaboration, and creativity to develop a sense of personal relevance and ownership in technology-enhanced projects. Section 6.2.3 suggests the potential and power of using concept maps to ‘draw conclusions’ about student understanding based on the instructional style used in college courses. And finally, section 6.2.4 recommends key content, educational, and support components for design and presentation of virtual field trips on the World Wide Web.

6.2.1 Feasibility of Using the World Wide Web

In order to determine the feasibility of using the World Wide Web to deliver science content to classroom teachers, the question ‘what do you want from the World Wide Web’ was asked to a random sample of graduates from a local university science education program. The purpose was to offer them the opportunity to participate directly in educational reform. Their response actively influenced the development of educational resources and support mechanisms for a graduate-level science education program website (Nix, 1998). Data from this first case study in support of the ISLE model was compared to the national projections concerning the World Wide Web claiming that it is here, we need it, we are using it, it can help, and that science educators are willing to participate in its application. In other words, suggesting that an Internet presence has a tremendous potential value for developing and maintaining active networks within and as a result of university-based science education programs.

The sample data reflected the national conclusions and current understanding about the World Wide Web in science education, strongly supporting the potential value of an Internet presence for science education programs. Specifically, the World Wide Web was shown to be an acceptable tool for use by the ISLE population of classroom teachers. As mentioned in section 2.1, the new challenge to science educators is to take advantage of this versatile medium for gathering and distributing timely information. Local, state, and federal officials have set the aim of current science education reform high. University-level science education programs can help to realise critical goals by implementing relevant website strategies that support, inform, and encourage today’s science educators. The possibilities are intriguing. Therefore, the value of an Internet presence for science education programs to offer support to classroom teachers is virtually unlimited.

The results of this particular case study supported continued maintenance and expansion of the university's science education program web site. By assuming a leadership position and engaging a proactive role to improve science education, the program is expected to benefit from an expanded perspective and continuous infusion of innovative contributions. On a larger scale, the results also support increased training efforts and improved accessibility options for more effective use of a powerful tool that will, regardless of indifference, quickly change the face of science education – for better or for worse. The fact that science educators *are* willing to participate in the development of the Internet as a resource and that they *do* have a need for peer networking and outside support more than justifies the value of an Internet presence and the limitless possibilities for integrating use of the World Wide Web in science education.

6.2.2 A Process Approach to Teaching and Learning

For many reasons, it is easy to lose sight of the fact that educational technology is just another means to an end – not necessarily the end itself. The Everest syndrome (see section 5.4.2) refers to the tendency of teachers to feel the need to use technology simply because it exists. This poses an interesting challenge to both instructors and designers. It is even more complicated for teachers in the public/private school classroom. A process approach to implementing an educational technology course successfully transformed a diverse and remote audience into an actively-engaged network of student-centred educators (Nix, 2001b, 2002). Through focused activities and strategic exercises, the course design encouraged communication, collaboration, and creativity to develop a sense of personal relevance and ownership in technology-enhanced projects. Ultimately, each individual's unique situation was related to the group's common experience. The following scenario highlights the importance of past experiences and specific training as imparted by a director of music (elementary through adult):

In over twenty-four years of teaching experience I have found that people who have been labeled 'tone deaf' (because they have trouble matching pitches) have usually grown up in environments where there was not a lot of music. While teaching in the West Dallas projects I discovered that many children could sing with recorded music and stay on pitch. They could sing with other singers and stay on pitch, but they had trouble matching the pitch

of a piano or a singular instrument. Their ears were simply not accustomed to the timbre of the piano because they had never been exposed to the sound. The more we sang with the piano, the more natural that sound became to their ears; the better they learned to sing. It was a learned skill. I learned during those first years of my teaching that there is no such thing as a 'monotone' – at least a person who remains a monotone if they do not want to be. (Parker & Nix, 1994, p. 12)

In over 16 years of learning, using, and helping others to learn and use a variety of information technology in the business world, I have noticed similar results. Once people overcome the anxiety of using new tools, they are able to see the benefits and apply the options in amazingly effective and efficient ways to solve their unique problems. Taking advantage of these newly discovered resources becomes an exciting and automatic second nature. The same holds true for classroom teachers charged with integrating and implementing educational applications of information technology into their teaching. The key to inspiring individual change was integrating experiential training into each lesson to address the whole person: physically and emotionally, not just intellectually.

Learning from a process approach requires the integration of the physical, emotional, and conceptual portions of the learning psyche. This allows the transfer of knowledge to action within the respective teaching area. Recent literature describes several pedagogical approaches that support integrating experience into conceptual knowledge that encompasses the entire individual, not just the intellectual aspect (Nix, Ledbetter, & Fraser, 2001a). When provided with a clear, relevant, and supportive environment, the teachers' distinct perspective as teacher-students allows for practically immediate transfer. Today's students live and learn in a different society than that in which today's teachers lived and learned. That unchangeable fact has a tremendous impact on the actual implementation versus theoretical potential of information technology in education. I am living proof, armed with the first-hand experience of both developing and delivering my own distance education course.

As part of the second case study in support of the ISLE model, this combined graduate and undergraduate elective was offered primarily to a broad audience of preservice and inservice classroom teachers (Nix, 1999). The affective objective was to improve their attitudes toward information technology. The effective objective was to teach ways to combat information overload and manage the non-linear nature

of today's rapidly advancing opportunities. Experiential training was the basis for the model (review section 6.1.1). By presenting educational technology as an open framework, teachers, administrators, researchers, and curriculum developers learned how to select/apply appropriate tools and develop/adapt to relevant resources that simplify and enhance their classroom teaching and everyday tasks.

Conceptually, each class opened with a team-building activity to focus thinking and provide a common experience on which to build subsequent coursework. Projects were designed to create a need to learn about the hardware and software to express their thoughts and ideas on issues relevant to each individual, shared through formal presentation to the group. Assignments included writing reflective journal entries or posting comments to the online discussion board each week to ensure progress and reviewing current events and advances to reinforce the dynamic nature of the topic. Electronic mail messages and a class web site for notes and references were used throughout both courses to instil good practice and illustrate specific benefits to educators of those particular tools. QuickTime® video clips supplemented the online experience with a visual image of an actual implementation. Portable Document Files (PDFs) of the activity sheets enabled teachers to implement the same practice in their own school classrooms.

Mechanically, the educational technology course used a variety of information technology to combine the richness of multiple approaches in a comprehensive learning environment. Specific content modules were made available through the course management software interface. Private interactive discourses were conducted through the online discussion forum. Semester-specific details were maintained on the public course website. The various components were seamlessly integrated through direct links. Thereby, information technology naturally provided a 'means' for the learning, in contrast to being promoted as an 'end' for the teaching.

It is ironic that the one constant in our society is change. Information technology, like science content and classroom demographics, literally advances daily. There was no way a 15-week course could completely cover all the tools and resources available even right now. *And what would be the point?* Specific skills quickly become obsolete. Teachers are faced with different scenarios each semester. We must learn to develop appropriate tools and relevant resources. Communication, collaboration, and creativity are critical to realising a comprehensive understanding and effective implementation of educational technology.

This process approach lays the foundation for enabling teachers to use educational technology by exercising their personal creativity. Students learned strategies for improving their respective classroom learning environments with the information technology available to them at that time. The anxieties of educational technology were transformed into a natural productivity. Activities were focused on process skills that are emphasised at all grade levels and facilitate integration across the curriculum. Techniques for fostering critical thinking and higher-level reasoning were modelled then related to specific participant issues. The energy previously routed to combating a fear and trepidation of the technology was released to creatively explore specific ways to merge educational theory and classroom practice.

Teaching traditions are slowly, but surely, changing to meet the needs of today's learners. That does not mean that actual experience will not continue to satisfy an important part of the educational puzzle. The structure of the educational technology course was deliberately open and the format presented at a very high level of content knowledge, but with a limited degree of application detail. The teachers were charged with the responsibility of giving and taking what was relevant to and needed for their unique situation. As such, the instructor simply provided a framework for exploring applications of information technology within an educational context and facilitated development of a forum for discussion that supported the sharing of ideas and creation of networks. All participants were continually encouraged to ask questions, trade tips and tricks, and 'think out loud'.

The assumption that teaching online is somehow 'different from actually teaching in the classroom' or 'inherently less than by default' is incorrect. If one takes sufficient time to think about information technology, the possibilities are virtually unlimited. The mindset is what matters most. However obvious on the surface, the deeper realisation of this model is that – with proper application of the appropriate technology – I can virtually teach the way I actually teach. A process approach to teaching was as effective in the on-campus classroom with synchronous discussion and group activities as it was on-line with asynchronous exchanges and discrete individual interactions.

Information technology exposes both university and classroom teachers and their students to an ever-expanding world. Practising communication, collaboration, and creativity allows each to construct their own knowledge and develops a confidence that directly transfers into their respective classrooms – and beyond.

6.2.3 Implementation of Design with Concept Mapping

The information revolution has changed the world of professional education, offering numerous and valuable benefits to both society and education in general. Immediate access to ever-changing facts and figures has made rote memorisation of discrete bits of information obsolete. Recent research on learning about learning shows that the way in which students construct knowledge is paramount to developing understanding and enabling transfer from the classroom to other everyday situations. In response, college-level educators are realising the value of focusing on the transfer of process and construction of knowledge, rather than on the dissemination of a compendium of facts. *But how do we know if our methodologies are effective?* This third case study explored the potential and power of using concept maps to ‘draw conclusions’ about student understanding in different types of college courses (Nix & Ledbetter, 2002).

As noted in section 6.1.2.2 concept mapping provides a simple assessment of the channel capacity (information processing capability) for each individual student, illuminating the point at which information overload and non-linear processing impede learning. Concept maps also provide an effective tool for evaluating conceptual understanding and the ability to transfer knowledge. As suggested by Novak and Symington, they provide an interface between the cognitive framework and textual information.

By design, concept maps help students to move from a linear (text) structure to a hierarchical (psychological) structure and back again (1982, cited in Kinchin, 2000). Similarly, as a potentially valuable contribution to teacher development programs, Nix and Ledbetter (2002) suggested that concept map evaluation and assessment can serve as a guide for educators as they evolve their teaching from traditional methodologies to a more constructivist approach.

The evaluation technique investigated in this case study used concept map analysis as a new method for determining the effectiveness of pedagogical style with respect to the desired learning outcomes. As recommended by Hand (1996), on developing a model to diagnose teachers’ knowledge and roles when adopting constructivist teaching/learning approaches, “emphasis must be placed on developing instruments that allow inservice personnel, researchers, and teachers the opportunity to monitor progress easily and effectively” (p. 221).

Student diagrams were objectively analysed in terms of the number of levels (hierarchy), links (inter-relationships), and items (concepts). This mirrors the procedure set out by Fisher (2000) in that the ratio of links to items gives a measure of the interconnectivity of the map, indicating the depth to which students understand concepts. The number of items compared to the number of links gives an indication of the degree to which students understand the overall subject matter (main idea or given topic). Fewer links than items ($L < I$) indicates rote knowledge of content without context (see Figure 19, Map A). An equal number of links and items ($L = I$) indicates understanding of process within the limited context of the specific instance (see Figure 19, Map B). More links than items ($L > I$) indicates meaningful understanding of the relationships of content and process, demonstrated by the ability to transfer such understanding to other subject areas (see Figure 19, Map C).

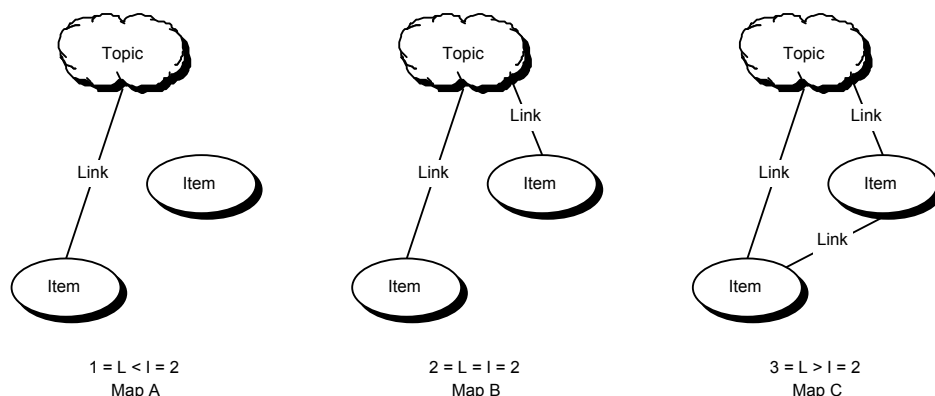


Figure 19. Sample Concept Maps Showing the Possible Relationships Among Number of Links and Items

The number of levels gives an indication of the degree to which students are able to assemble (information overload) and organise (non-linear processing) concepts related to the subject matter (see Figure 20). Based on the number of levels, individual students can be ranked within groups to indicate similar degrees of comfort in manipulating the represented information. This analysis could be useful in determining the homogeneity of the class's understanding. It also could determine effective groupings for customised remediation.

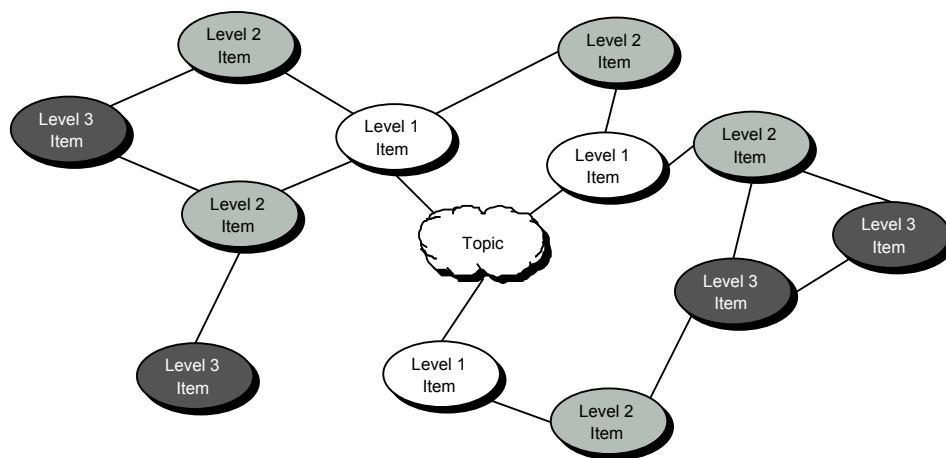


Figure 20. Sample Concept Map Showing the Increase in Number of Levels

A collaborative concept mapping exercise conducted in a Master's level science education research class provides a simple example of the potential gain in understanding evidenced by increasing the number of links. The research students were given a blank sheet of paper and simply instructed to write the word 'density' in the centre of the page and draw a circle around it. Next, they independently created their own unique concept maps by adding associated terms and connecting them all with lines and text to explain the relevance. Then the teachers were grouped into teams of 4-5 and assigned the task of joining their individual maps to form a single big picture of the concept.

Each member of the group had approached the same topic from completely different perspectives based on her/his personal experience, knowledge, and understanding. A teacher trained in biology focused on how density affected plant tissue, a teacher trained in geology diagrammed properties of rocks based on relative densities, and a teacher trained in chemistry explained how density determines the state of matter. By design, the number of links was greater than the number of items. Each individual teachers' understanding of density was expanded after linking the diverse representations of the concept as a member of the group.

The results of this case study in support of the ISLE model reflected the aspects of constructivist practice that were consciously emphasised to realise the learning objectives specific to the course. A quick and simple evaluation of concept maps affords teachers, at all levels, a tool that they can use in their classrooms to assess knowledge and understanding to promote inquiry and high-order thinking. Concept maps are a mechanism sensitive enough to determine where students are in their learning process at any given time, permitting instructors to see what they are

teaching from their students' perspectives. The instructors' ability to match methodology to outcome offers a broad context for enculturation of the constructivist paradigm. Because of the influence of the traditional school-level environment, as Milne and Taylor (2000) reported, this sort of pedagogical change is difficult to realise in individual classrooms. However, if not appropriately implemented, even the best constructivist epistemology is ineffective.

Concept maps offer a snapshot of the students' understanding that the instructor can analyse to determine if a more effective approach for a class is needed. By utilising this multidimensional (real-world) environment in which students personally experience learning through a constructivist approach, the pressure to 'teach to the test' may be relieved, thus allowing teachers to provide an environment conducive to more meaningful and transferable learning for their students.

6.2.4 Presentation as a Virtual Field Trip

Although field trips are nothing new, the evolution of their delivery – from actual site visits to recorded instructional television programs to interactive multimedia CD-ROMs and on to real-time experiences via the World Wide Web – is an exciting and powerful utilisation of Internet technology that enhances science education. To compare science-related virtual field trips objectively, with respect to elements that impact the usability as a teaching tool, a new assessment rubric was designed in collaboration with intermediate and graduate level science educators as part of this fourth case study in support of the ISLE model. The quantity and variety of World Wide Web sites dedicated to virtual field trips reflects an interest and willingness that could help move science education into a new realm.

In their quest to provide experiences that expand students' worldviews, teachers can turn to the Internet as a storehouse of virtual experiences. With respect to science and mathematics education, *are the virtual field trips presented on the World Wide Web adequate and/or educationally sound for their purposes?* To find out, an extensive Internet search was conducted over the second quarter of 1999 to develop and create a listing that summarises the key content, educational, and support components of virtual field trips available on the World Wide Web (Nix, 2000a). Using various Internet search engines, a review of the more prominent web sites was performed to define survey criteria. Interest in the virtual field trip concept is evident in the number of sites dedicated to providing lists of these virtual field

trips. Based on these results, a master list of virtual field trip links was compiled by title and address to eliminate duplicate URLs (Universal Resource Locators).

Three relationships that are particularly important to development of the ISLE model were determined. First, over half of the high-level sites utilised a chronological format, whereas over half of the moderate-level sites were presented in a topical format. Second, more than 50% of both the moderate- and low-level sites employed some form of multimedia features beyond basic html (hyper text mark-up language), while little was incorporated on the high-level sites. Finally, the high-level sites clearly originated from graduate professors and/or students; however, a surprisingly small number of moderate-level and no low-level sites were explicitly created by classroom teachers and/or students.

Virtual field trips are indeed available on the World Wide Web and do provide feasible classroom tools for science teachers. With the current global Internet initiatives underway, virtual field trips will be readily available to teachers and students as a viable application of information technology. With the continually improving delivery and presentation capabilities, they will offer teachers and students a valuable structure for developing real science skills such as observation, inference, prediction, understanding, and problem-solving. The number and variety of sites dedicated to virtual field trips reflects an interest and willingness that could significantly influence science education in today's classrooms.

The potential benefits of virtual field trips are numerous. Teachers gain a cross-curriculum integration strategy, a framework for addressing complex issues and an approach that supports multiple implementation and learning styles over a range of levels with a real-world relevancy. Students gain entry into environments without restrictions or distractions, a chance to discover their personal interests in a scientific context, and the opportunity to independently work ahead, catch up, or review a motivational exercise. Both teachers and students benefit from the opportunities to explore various paradigms of education (Kessell, 1999) and from the chance to start out 'on the same page' with respect to technology and the newness of travelling to another place. Besides all that, virtual field trips are fun (tell a story) and easy (no transportation, food, lodging, waivers, or weather worries), capturing the interest of all participants – actual or virtual.

As incorporated in the ISLE model, the potential of field trips is not restricted to educating students, but can also be applied to training teachers in both information

technology and pedagogy. Actually taking teachers into the field provides a real-life experience that combines the multidisciplinary aspects of system science. Such exposure can then be used to develop an interest in information technology by encouraging teachers to create their own virtual field trip.

Potentially, each time a trip is virtually experienced, the same energy of the actual experience (repeated at UTD in over more than 20 years of MAT field trips) can be transferred to the classroom. This case study provided a tested instrument to gauge the value and enhance the design of virtual field trips as classroom teaching tools for science education. The following summary statement written by a grade 3 teacher, a grade 6 science teacher, and an information technology specialist on teachers' perspectives about participating in the 'Live from Antarctica' virtual field experience, provides incentive to continue developing the concept and improving the content of virtual field trips:

Like the very best field trip, an electronic excursion to this rare and exotic setting will surely fascinate, inspire, and motivate. This makes learning fun and exciting. How can you not want to come along too? (Passport to Knowledge, 1997, ¶ 12)

6.3 Summary of Information Technology Review

Information technology has forced us to look at education in different ways. It has also provided new tools for building innovative learning environments. In section 6.1, changes in curriculum and instruction brought about by the integration of information technology into education were described in the context of learning environments. Constructivism has brought about a shift toward collaborative or cooperative learning, further illuminating the power, potential, and challenge of the effective use of information technology in science education. Concept mapping, by opening a window into the student's mind, offers teachers a way to measure an individual students' development. It offers a way to develop, evaluate, and assess conceptual understanding in support of knowledge transfer – and a means to combat the negative effects of novelty, information overload, and non-linear processing. A holistic approach to teaching and learning facilitates development of this conceptual understanding and knowledge transfer. By way of experiential learning, an emotional

response and intellectual awareness can be promoted through a cyclical pattern of experience, reflection, generalisation, and application.

Section 6.2 presented precursory research that supports the feasibility, approach, implementation, and presentation of the virtual field trip product. As the intent of the ISLE program was to make the focus of the program – information technology – virtually invisible, each of the critical factors of the program development was researched and investigated in separate case studies to isolate and test the techniques seamlessly combined in the ISLE model. A process approach to information technology provided a relevant framework within the open structure of the World Wide Web and was shown to be a feasible tool for delivering science content to classroom teachers in section 6.2.1. Section 6.2.2 supported a process approach to teaching with an emphasis on communication, collaboration, and creativity to foster a sense of personal relevance and ownership in technology-enhanced projects. Section 6.2.3 suggested that the instructional style used in college courses can be evaluated using concept maps, and thereby, adapted to meet the needs of students to improve their understanding in science. And, based on an extensive review of science-related virtual field trips available on the World Wide Web, key content, educational, and support components for the design and presentation mechanisms of the ISLE virtual field trip were identified in section 6.2.4.

In light of this outcomes-focused background, Chapter 7 describes the resulting research methods used in this study.

Chapter 7

RESEARCH METHODS

Referring “to the social, physical, psychological, and pedagogical contexts in which learning occurs and which affect student achievement and attitudes” (Fraser, 1998c, p. 3), the field of learning environment research is broad in terms of both substance and methods. Based on the aims of the program and objectives of this study, a multidimensional research design was selected to increase the understanding of the emergent model, giving special attention to the influence of the rapidly-developing field of information technology, within the classroom learning environment. To address the multi-faceted aspects of the new Integrated Science Learning Environment (ISLE), the research design was grounded in the naturalistic paradigm (Lincoln & Guba, 1985). The scales of the Constructivist Learning Environment Survey provided a critical scaffold for the development and use of new and revised evaluation resources for use with the ISLE program. In fact, the research methods employed were integrated into the overall design in an overt manner to model the evaluation and assessment of teaching and learning based on the constructivist paradigm. As mentioned earlier, the research addressed the following specific questions:

- Question 1: Are new versions the Constructivist Learning Environment Survey (CLES) valid and useful in secondary schools and graduate university courses in Texas?
- Question 2: How effective is the Integrated Science Learning Environment (ISLE) university/field trip course in terms of the degree of implementation of constructivist teaching approaches in the teachers’ school classrooms as assessed by:
 - (a) teachers’ perceptions of the learning environment of their current classroom environment relative to other classes taught by them previously;
 - (b) students’ perceptions of the learning environment of their classroom environment relative to classes taught by other teachers in their school; and

- (c) various qualitative methods (i.e., observation, interview, journal)?

Question 3: How effective is the Integrated Science Learning Environment (ISLE) university/field trip course in terms of:

- (a) teachers' perceptions of the university/field trip learning environment;
- (b) changes in teachers' attitudes to information technology; and
- (c) teachers' conceptual development?

This chapter is comprised of five sections. Section 7.1 explains how various quantitative measures were supported by qualitative measures to provide insight into the effectiveness of the ISLE program. Each of the instruments used to evaluate the ISLE program and its impact are detailed in section 7.2. The data-collection procedures and purposes are reviewed in section 7.3 with respect to the specific research questions. Section 7.4 describes the limitations of the study in terms of sample selection, scheduling issues, course credits, external variables, and instrument administration. And finally, section 7.5 summarises the chapter.

7.1 Combining Quantitative and Qualitative Data

The benefits of moving beyond the traditional practice of choosing either quantitative or qualitative research methodologies have been suggested by Cook and Reichardt (1979), Firestone (1987), Fraser (1988), Howe (1988), and Smith and Fraser (1980). As described in section 5.2, past studies by Aldridge, Fraser, and Huang (1999) and Tobin and Fraser (1998) have successfully combined qualitative and quantitative research methods in studying the classroom learning environment at different 'grain sizes' to show how individual students and the teacher could be investigated also at the class level, school level, or system level. This multilevel approach helps to clarify if particular teachers or students involved in the present study are typical of larger groups.

The combination of qualitative methods and quantitative measures (Fraser & Tobin, 1991) in past studies provided insight into the field trip milieu and evaluation of the near- and far-term effects of exposure to constructivist pedagogy. For example, Manzanal, Barreiro, and Jiménez (1999) combined qualitative and quantitative research methods to investigate the relationship between ecology

fieldwork and student attitudes toward environmental protection. In their study, the independent variable was ‘the performance of fieldwork’ and the dependent variable “consisted of two components: learning the concepts of ecology and the attitude toward the defense of an ecosystem” (p. 437). To support development of a model for integrating environmental education into the school curriculum, a study conducted by Orion, Dubowski, and Dodick (2000) similarly employed “...quantitative tools which evaluated the results obtained from the research population, and qualitative tools which validated the quantitative research tools, as well as contributed to a better understanding of the student’s learning process” (p. 1126).

For the ISLE model, an array of research tools and methods was carefully selected on the basis of each instrument’s validity and reliability and applicability to the overall program goals and specific research questions of this study. Evidence derived from multiple sources was triangulated to ensure that the data were not contradictory, and therefore more likely to accurately describe the investigated item (Miles & Huberman, 1984). Teacher and student perceptions of dimensions of the learning environment were used as dependent variables in the overall evaluation.

Quantitative data were collected with three primary instruments. Teacher-generated concept maps were analysed to determine the teachers’ conceptual understanding of the content presented (Research Question 3c). The Teachers’ Attitudes Toward Information Technology questionnaire (TAT) was used to assess the affective disposition of teachers with respect to using information technology in their classrooms before and after the ISLE experience (Research Question 3b). And modified forms of the Constructivist Learning Environment Survey (CLES) were used to assess the perceived degree of constructivist practices implemented in participant teachers’ school classrooms (Research Question 2). The adult form (CLES-A) was administered in Phase I to evaluate the university/field trip segment (Research Question 3a). Figure 21 illustrates the relationship among the comparative forms (CLES-CT and CLES-CS) that were administered in Phase II to evaluate the public/private school classrooms.

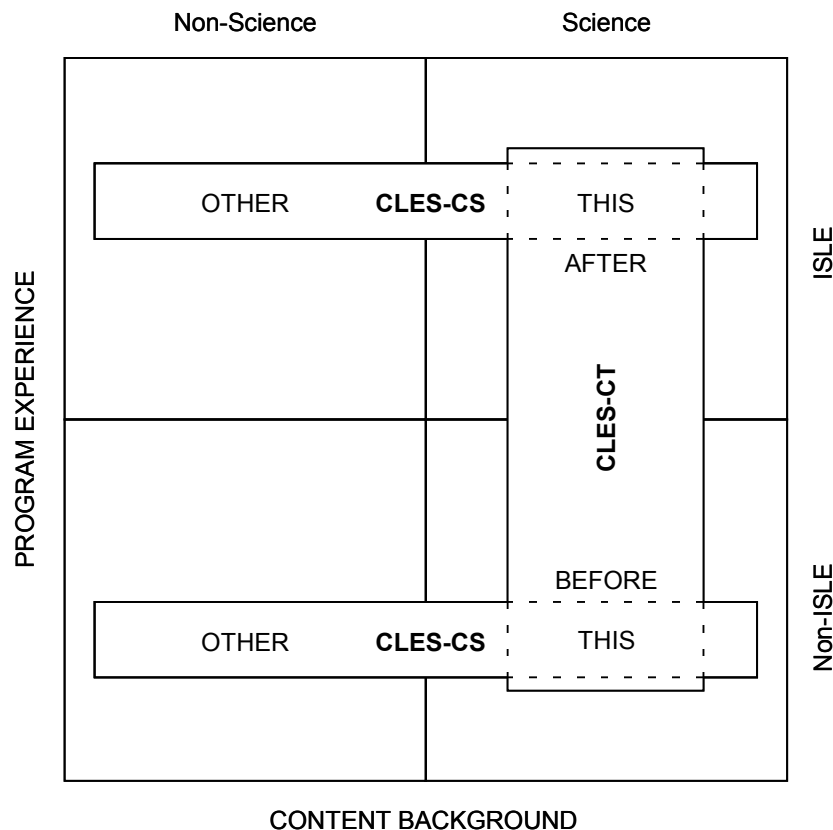


Figure 21. **Relationships Among Comparative Forms of the Constructivist Learning Environment Survey (CLES-CT and CLES-CS)**

Three versions (adult, comparative teacher, and comparative student) of a single learning environment instrument (CLES) were administered to related groups of teachers and students, based on program experience and content background, to evaluate the university/field trip and school classroom learning environments and answer Research Questions 1, 2, and 3. The adult form allowed the teachers to assess the degree of constructivist practice in the learning environment which they experienced as students in the university setting (ISLE program). Then, the comparative teacher form allowed the same teachers to assess the degree of constructivist practice in the learning environments which they created as teachers in the school setting. This evaluation was complemented by their respective students' assessment of the degree of constructivist practice in the same school classroom learning environment.

Various qualitative data analysis methods added a depth of understanding to quantitative descriptions. The Reflective Field Journal (see section 7.2.6) served as the main source of qualitative data. This required component of the ISLE program

was outlined with specific questions to assist teachers in assessing their current perspectives, recognising the relevance of the tools and techniques presented, and developing options for transferring new knowledge and experience to their unique workplace.

The Field Experience Questionnaire (FEQ) was administered at the beginning of Phase I, in conjunction with the university-required Medical Information and Release Form – Adult and Release and Indemnification Agreement for Adult Participation questionnaires. The FEQ contains 13 questions about general travel and outdoor science-related activities (see Appendix III.1). Items 2-11 are multiple-choice questions taken directly from the Student Background and Attitude Form developed by Lisowski (1987) to determine the participant's past experiences and current preferences concerning outdoor learning environments.

Throughout the program, frequent peer debriefing sessions and member checks (Lincoln & Guba, 1985) were conducted to ensure observer credibility and identify personal bias of participants. Detailed observational case study techniques (Bogdan & Bilken, 1998) of the actual events and videotape archives of select group activities, along with examination of informal interviews and archived electronic mail messages (MacNealy, 1999), also supported statistical analysis and interpretation.

Associated physical parameters that influenced the overall research design and specific methodology were detailed in Chapter 4. Because the sample used to evaluate the ISLE program in this study is specific to the reported results, details of the overall population and various subgroups are provided in Chapter 8. Also, data from the subject-based instruments (teacher-generated concept maps, focused on science knowledge, and Teachers' Attitudes Toward Information Technology (TAT) questionnaire, focused on attitudes toward information technology usage) were correlated with teachers' scores on specific scales within the learning environment assessment (CLES) to suggest the possible long-term implications of participation in the ISLE program in Chapter 9. The following section 7.2 describes the development and use of specific instruments used to evaluate the ISLE program.

7.2 Instrument Development and Use

Six primary data collection tools were used to evaluate teaching and learning within the ISLE program and its impact on the public/private classroom learning

environment. As an overview, Table 15 summarises the instrumentation that was specifically used to evaluate the ISLE university coursework and extended field trip (Phase I) and its impact on the participants' teaching practices in their school classrooms (Phase II). The individual instrument, particular form, unique sample group and number within each group, and relative time of administration are listed. It also indicates the specific research question (asked in section 1.2) that is addressed through analysis of the resulting data.

Table 15. **Summary of Instruments Used in the Evaluation of ISLE**

Form	Sample Number and Group(s)	Administration	Research Question
Constructivist Learning Environment Survey (CLES)			
Adult (CLES-A)	7 ISLE Science Teachers and 5 ISLE Non-Science Participants	End of Phase I	1, 3a
Comparative Teacher (CLES-CT)	7 ISLE Science Teachers and 1 ISLE Non-Science Teacher	End of Phase II	1, 2a
Comparative Student (CLES-CS)	1079 Students (Combined) 328 Non-ISLE Science Students 445 ISLE Science Students	Overall Total Prior to Phase I End of Phase II	1, 2b
Teachers' Attitudes Toward Information Technology Questionnaire (TAT)			
Pretest (TAT ₁)	8 ISLE Science Teachers and 5 ISLE Non-Science Participants	Start of Phase I	3b
Posttest (TAT ₂)	7 ISLE Science Teachers	End of Phase II	
Concept Maps (based on Website Contribution Evaluation Rubric)			
Participant-Generated	7 ISLE Science Teachers and 5 ISLE Non-Science Participants	End of Phase I	3c
Field Journal			
Reflective	7 ISLE Science Teachers and 5 ISLE Non-Science Participants	End of Phase I	2, 3

Data from the Teachers' Attitude Toward Information Technology (TAT, section 7.2.1) pretest, adult form of the Constructivist Learning Environment Survey (CLES-A, section 7.2.2), teacher-generated concept maps (based on the Website Contribution Evaluation Rubric, section 7.2.5), and Reflective Field Journal questions (section 7.2.6) were collected during the Phase I research. Data from the TAT (section 7.2.1) posttest and two comparative forms of the CLES (CLES-CT, section 7.2.3 and CLES-CS, section 7.2.4) were collected during the Phase II research.

Participants were also asked to write a spontaneous definition of educational technology to provide a pre-assessment of their understanding and perceptions of information technology in the context of educational settings. Used as part of the qualitative data, this information established a baseline for teachers' attitudes toward and perceptions of information technology. Additional qualitative data (observations, interviews, and journal entries) recorded on individual participation in university activities and guided discussion, as well as from local day trips, provided a pre-assessment of the teachers' understanding and perceptions of information technology in the context of educational settings. The following sections further detail the development, administration, and purpose of each instrument.

7.2.1 Teachers' Attitudes Towards Information Technology (TAT)

Five scales of the Teachers' Attitudes Toward Information Technology (TAT) questionnaire, developed by Knezek and Christensen (1997), were used to assess the teachers' perceptions of information technology using a semantic differential scale (see Appendix III.2). From administration of the TAT to 74 kindergarten through grade 12 teachers in six Texas schools, the internal consistency reliability reported the authors ranged from 0.93 to 0.96 for the scales used in the ISLE program. Based on this indication of the homogeneity of each measure tested in the same north Texas area as this study, the researcher considered it a valid and reliable instrument for assessing teachers' attitudes toward information technology.

Developed by Osgood, Suci, and Tannenbaum (1957), a semantic differential scale gives a quantitative rating of a topic along a continuum defined by bipolar adjective pairs (Gay & Airasian, 2000) to provide a method for indirectly measuring different perceptions of concepts (Van Dalen, 1979). Each position on the continuum is assigned an associated score value. Table 16 shows the adjective pairs used to evaluate each of the following scales:

- 1) value of electronic mail
- 2) value of World Wide Web
- 3) value of multimedia
- 4) impact of computers on personal productivity
- 5) impact of computers on the classroom in general.

Table 16. **Adjective Pairs Used in the Teachers' Attitudes Toward Information Technology (TAT) Questionnaire**

Adjective	Seven-Point Scale							Adjective
Important	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Unimportant
Boring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Interesting
Relevant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Irrelevant
Exciting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Unexciting
Means Nothing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Means a Lot
Appealing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Unappealing
Fascinating	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Mundane
Worthless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Valuable
Involving	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Uninvolving
Not Needed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Needed

The abbreviated version of the TAT was administered by the researcher to all 13 participants (see section 8.1) at the second university class meeting. The purpose was to determine the teachers' initial dispositions toward information technology. In Phase II, the same items were administered to the 7 ISLE science teachers toward the end of the first public/private school semester following the ISLE program to provide posttest data for comparison.

It was emphasised that there are no right or wrong answers as the participants' opinions were what was wanted. Participants were encouraged to respond with their first impressions. They were directed to choose one location between each adjective pair to indicate how they felt about the subject. They were reminded to give an answer for each question and to change their mind about an answer by simply crossing out the original and circling another.

Item responses were hand-coded by the researcher with a number from 1 (negative) to 7 (positive) representing the particular space the respondent marked. Four items in each subscale have the negative adjective in the left-hand or first position, while the other six have the positive adjective in the first position. Scoring is therefore reversed for Items 1, 3, 4, 6, 7, and 9 in each scale. This structure provided an inherent check as to the integrity of the data, indicated by the response patterns. A generally positive attitude produced a zigzag pattern, whereas a neutral response produced a linear alignment of nullifying values. Scores were entered into an electronic spreadsheet for computer processing and averaged over items to produce an overall score.

7.2.2 *Adult Form of the Constructivist Learning Environment Survey (CLES-A)*

As explained earlier in section 7.1, three modified forms of the Constructivist Learning Environment Survey (CLES) were used to assess the perceived degree of constructivist teaching in the university by teachers and in school classrooms by both teachers and their students. From the learning environment instruments described in section 5.1, the CLES was selected for use in this study because of its ability to characterise specific dimensions of the constructivist classroom. The five scales of the CLES provided a critical scaffold that enabled an evaluation of the effectiveness of the ISLE university coursework/field trip and its impact on participating teachers and students in their respective school classrooms.

The adult form of the Constructivist Learning Environment Survey (CLES-A, see Appendix III.3.1) specifically assess participants' perceptions of the ISLE university coursework/field trip learning environment. It is a slightly modified version of the Constructivist Learning Environment Survey originally developed by Taylor and Fraser (1991) and described in section 5.1.6. Like the original CLES, the 30-item CLES-A contains six statements in five scales about practices that could take place in a class or program. Table 17 lists the name and description, along with a sample item, of each scale.

Table 17. Scale Name, Scale Description, and Sample Items for the Constructivist Learning Environment Survey – Adult (CLES-A) Form

Scale Name	Scale Description	Sample Item
Personal Relevance	Relevance of learning to students' lives	I learn about the world beyond my professional setting.
Uncertainty of Science	Provisional status of scientific knowledge	I learn that science has changed over time.
Critical Voice	Legitimacy of expressing a critical opinion	It is acceptable for me to ask 'why do I have to learn this?'
Shared Control	Participation in planning, conducting and assessing of learning	I decide which activities are best for me.
Student Negotiation	Involvement with other students in assessing viability of new ideas	I ask other students to explain their thoughts.

For this study, some phrases and terms were slightly reworded for use with adults in the north Texas area. As Cannon (1996) modified the CLES for use in introductory science classes, the researcher worked with the instructor to ensure that the wording was appropriate for the sample population. For example, the phrase 'It's

OK for me to ask the teacher...’ was replaced with ‘It is acceptable for me to ask...’ and the term ‘school’ was replaced with ‘professional setting’. Care was taken to ensure that the meaning of the original statement was preserved in order to maintain the validity of the instrument.

The CLES-A was specifically designed for use with adults and administered, as was the original, to assess the degree to which the principles of constructivism have been implemented in a program or course. Within the ISLE model, it was used to evaluate the instructors’ teaching both in the university classroom and in the outdoor site locale during the extended field trip.

The researcher administered the CLES-A at the final meeting of the ISLE program to the 12 participants in attendance (see section 8.1). Each participant was encouraged to think about how well each statement described what the ISLE program was like based on her/his individual experience. All participants completely answered each question without hesitation. Some noted qualifying statements on their surveys. For example, one indicated that other students ‘almost never’ asked her to explain her ideas, ‘except for math’. Another specified that her response was dependent on ‘who asked the question’ or ‘who you’re talking to...’. None of the participants had previously been exposed to any form of the CLES.

7.2.3 Comparative Teacher Form of the Constructivist Learning Environment Survey (CLES-CT)

In contrast to the way that the CLES-A assess ISLE participants’ perceptions of their instructors’ learning environment, the comparative teacher form of the Constructivist Learning Environment Survey (CLES-CT) assess those participants’ perceptions of the learning environment which they create in their own school setting. The CLES-CT (see Appendix III.3.2) is a slightly modified version of the adult form (CLES-A) described in section 7.2.2. Minor grammatical changes were carefully constructed to maintain the validity of the base instrument (CLES-A) in the new comparative format, shown in Figure 22.

I teach about the world outside of school.									
In my lessons BEFORE the course...					In my lessons AFTER the course...				
Almost Never	Seldom	Some- times	Often	Almost Always	Almost Never	Seldom	Some- times	Often	Almost Always

Figure 22. Item Layout for the Constructivist Learning Environment Survey – Comparative Teacher (CLES-CT) Form

Figure 22 illustrates how there are two response blocks for each of the same 30 items are presented in side-by-side columns. The left, shaded area begins with ‘In my lessons BEFORE the course ...’, while the right, clear area begins with ‘In my lessons AFTER the course...’. Based on the original CLES developed by Taylor and Fraser (1991) and described in section 5.1.6, the 60-item CLES-CT contains six statements in five scales about practices that could take place in a class or program. Table 18 lists the name and description, along with a sample item, of each scale.

Table 18. Scale Name, Scale Description, and Sample Items for the Constructivist Learning Environment Survey – Comparative Teacher (CLES-CT) Form

Scale Name	Scale Description	Sample Item
Personal Relevance	Relevance of learning to students’ lives	I teach about the world outside of school.
Uncertainty of Science	Provisional status of scientific knowledge	I teach that science has changed over time.
Critical Voice	Legitimacy of expressing a critical opinion	It’s OK for students to ask me ‘why do I have to learn this?’
Shared Control	Participation in planning, conducting and assessing of learning	Students help me to plan what they’re going to learn.
Student Negotiation	Involvement with other students in assessing viability of new ideas	I ask other students to explain their thoughts.

The CLES-CT was specifically designed for classroom teachers to assess the degree to which the principles of constructivism have been implemented in their public/private school classrooms. It asks the classroom teacher to compare the degree to which s/he feels that s/he has implemented the principles of constructivism in his/her own classes following her/his university/field trip experience (AFTER) with previous classes that s/he had taught throughout her/his career (BEFORE). The teachers were directed to read each statement and to think about previous lessons which they had taught, indicating the best response for their teaching BEFORE the course in the left column. Then they were encouraged to read the statement again,

and think about their current and future teaching, indicating the best response for their teaching AFTER the course in the right column.

The researcher mailed the survey to each of the 12 ISLE teachers (see section 8.1) for self-administration, approximately six months after the final university meeting. (See section 7.4.5 for specific limitations.) This period was chosen to allow a reasonable amount of time for the teachers to integrate new techniques into their teaching. The researcher also wanted to collect the responses before the winter holiday break (typically two weeks including December 25 and January 1) to ensure more accurate representation of the classroom practice.

Of the eight surveys returned to the researcher, all questions were completely answered and no additional comments were indicated on the form or received by any other means. It is important to note that half of the teachers did not indicate which course they were reviewing. Two entered the course that they were currently teaching (8th grade Science). One evaluated the entire ‘science education field trip’, while only one entered the desired response, identifying the instruction as ‘ecology’.

7.2.4 Comparative Student Form of the Constructivist Learning Environment Survey (CLES-CS)

The comparative student form of the Constructivist Learning Environment Survey (CLES-CS) was specifically designed for use with secondary students. In this study, it asks the students to compare the degree to which they feel that the principles of constructivism have been implemented in the class taught by their current ISLE teacher relative to classes taught by other teachers (science or other subjects) in their school.

The CLES-CS (see Appendix III.3.3) is a slightly modified version of the Constructivist Learning Environment Survey originally developed by Taylor and Fraser (1991) and described in section 5.1.6. Grammatical changes were carefully constructed to maintain the validity of the base instrument (CLES) in the new comparative format, shown in Figure 23.

I learn about the world outside of school.									
In OTHER classes...					In THIS class...				
Almost Never	Seldom	Some- times	Often	Almost Always	Almost Never	Seldom	Some- times	Often	Almost Always

Figure 23. Item Layout for the Constructivist Learning Environment Survey – Comparative Student (CLES-CS) Form

Figure 23 illustrates how, like the CLES-CT form described in section 7.2.3, the two response blocks for each of the same 30 items are presented in side-by-side columns. The left, shaded area begins with ‘In OTHER classes...’, while the right, clear area begins with ‘In THIS class...’. The 60-item CLES-CS contains six statements in five scales about practices that could take place in a class or program. Table 19 lists the name and description, along with a sample item, of each scale.

Unable to pre-determine which teachers might actually complete the ISLE program, I also trialled the instrument with potential candidates who had participated in traditional field trips offered by the same instructors in prior years (see section 8.1). This dual administration not only improved the statistical rigor of the instrument validation (supported by the total sample of 1079 students of 10 science teachers), but also provided a representative control group (328 students of 5 science teachers who had participated in other field trip programs) for comparing the effects of the ISLE model.

Table 19. Scale Name, Scale Description, and Sample Items for the Constructivist Learning Environment Survey – Comparative Student (CLES-CS) Form

Scale Name	Scale Description	Sample Item
Personal Relevance	Relevance of learning to students’ lives	I learn about the world outside of school.
Uncertainty of Science	Provisional status of scientific knowledge	I learn that science has changed over time.
Critical Voice	Legitimacy of expressing a critical opinion	It’s OK for me to ask the teacher ‘why do I have to learn this?’
Shared Control	Participation in planning, conducting and assessing of learning	I help the teacher to plan what I’m going to learn.
Student Negotiation	Involvement with other students in assessing viability of new ideas	I ask other students to explain their thoughts.

Approximately six months after the final meeting of the ISLE program, the researcher mailed the requested number of surveys to the participating ISLE science

teachers for independent administration at their discretion. (See section 7.4.5 for limitations.) In Phase II, the CLES-CS was administered to 445 students of 5 ISLE science teachers to assess the degree to which the principles of constructivism were evident in specific classroom learning environments within the broader context of the school-level environment.

The teachers were asked to emphasise that there are no right or wrong answers as the students' opinions were what was wanted. Students were encouraged to think about how well each statement describes what the classes are like for them personally, comparing how often each practice occurred in THIS particular science class to OTHER classes. Students were directed to read each statement and think about lessons they had been taught, indicating the best response for the teaching in OTHER classes in the left column. Then they were encouraged to read the statement again, and think about lessons that they had been taught, indicating the best response for the teaching in THIS class in the right column.

Teacher observations indicate that the reading level might be difficult for the younger American students. For example, students did not seem to understand the term 'assessment' and had trouble relating to the phraseology of 'outside of school'. Administration procedures were varied because of the unique restrictions and time constraints. For example, one teacher offered it as an extra credit project, while another presented it as a take-home assignment. As such, many forms were incomplete. Some simply marked the first and last pages, leaving the inside pages blank. It appears that others simply missed the last page. The difference in class composition was clearly evidenced in the character of the responses and comments marked on the surveys. Several wrote 'thank you' at the end, while others clearly indicated their annoyance with the exercise. One rather creatively made a mirrored zigzag pattern within the columnar format.

Overall, the results indicated that the CLES-CS could require more concentration than the average secondary student might be able to maintain.

7.2.5 *Concept Map (Website Contribution Evaluation Rubric)*

As detailed in Chapter 3, each ISLE participant presented his/her background research and field observations in the required form of an individual concept map with supporting text and graphics. These contributions were incorporated into the group's virtual field trip web site.

As described in section 6.2.3, participant-generated concept maps were objectively analysed in terms of the number of levels (hierarchy), links (inter-relationships), and items (concepts) in order to assess the participants' conceptual development of both content and process. Recall that the number of levels gives an indication of the degree to which students are able to assemble (information overload) and organise (non-linear processing) concepts related to a topic. The number of items compared to the number of links gives an indication of the degree to which learners understand the overall subject matter (main idea or given topic).

Although not reported in the results of this study, the Website Contribution Evaluation Rubric (see Appendix III.4) was developed by the researcher to guide participants in constructing their individual concept maps. It lists 10 critical aspects related to the integrated science learning environment project requirements. Each item is rated by the participant and instructor on an 11-point scale ranging from a minimum score of zero (0) for no evidence of the feature, through mediocre (5) work, to a maximum value of 10 for excellent demonstration of the feature. Summation of the scores earned results in an overall evaluation of the work based on 100 total possible points.

Within the ISLE model, the Website Contribution Evaluation Rubric was used primarily to provide a concrete framework to guide development of program-specific projects. It was introduced mid-way through the university coursework, after the teachers had gained substantial background knowledge in the related fields of study to be addressed in their projects. Each participant was given a printed copy of the instrument to help develop his/her specific topic. An example of an excellent web site contribution, based on content from a previous ISLE lesson, was presented and discussed to provide a concrete example. An electronic version of the actual form was also made available for continual reference on the program web site.

New forms of assessment (i.e. how concept maps were used in this model) are an inherent challenge and requirement to the implementation of new learning and teaching styles (i.e. how constructivism was used in this program). None of the teachers had been involved in a collaborative project of this scale. The freedom to exercise personal creativity in the design, development, and delivery of such resulted in a high degree of anxiety. Conditioned by models that 'teach to the test', the constructivist approach to learning and assessment was difficult for the teachers to understand and accept. In the uncertainty of no single right answer (Sprague & Dede,

1999), this rubric established a solid framework for development that promoted a sense of comfort for the participants and helped them to progress in their individual conceptual development.

7.2.6 *Reflective Field Journal*

Twelve participants (all but one who was not seeking course credit) were required to maintain a Reflective Field Journal (see Appendix III.5). A series of 59 guiding questions was provided to highlight key aspects of each field-based activity throughout the program, including day trips executed as part of the university coursework and main events planned for the extended field trip. The field ecology instructor provided examples of journals from previous trips and recommended physical attributes to be considered so that the participants could select appropriate notebooks for their individual use.

Besides providing the participants with a daily log of the field activities and a mechanism for critical self examination (MacNealy, 1999), the main purpose of the field journal was to document anecdotal evidence to support the interpretation of other qualitative and quantitative data collected for this study. Within the ISLE model, this confidential archive was used primarily to raise awareness for further discussion and to initiate a forum for sharing information and observation.

Printed copies of the field journal requirements were distributed at the first class meeting and made available on the program web site. Participants were encouraged to maintain their entries after each day trip and after each excursion on the extended field trip. Complete journals were due on the last day of the trip to ensure that the entries were spontaneous and clearly reflected the knowledge and understanding gained from the experience, rather than further research documented in anticipation of specific results expected by the instructor. The entries were reviewed both qualitatively and quantitatively. Content knowledge was corrected by the instructor if needed. Contextual understanding was noted as insightful or unique where appropriate. A copy of each journal was made before returning the notebooks to the participants.

Journaling offers a tangible way to organise and record multi-sensory field experiences, thus minimising the effects of overload and non-linear processing. The release helps teachers to personalise the creativity inspired by the excitement and energy of the overall learning environment. The benefits of cooperative work are

more deeply appreciated through individual interpretation. This unique artefact also serves as a powerful reminder of the goals and aspirations shared during the experience. Memories and methods are hence made available for repeated reference and future reflection.

The field ecology instructor had used this format successfully for over ten years. Site-specific questions were modified to match the objectives of each particular locale. Although most teachers are openly frustrated by this requirement, they nevertheless treasure the result and realise its value after the fact. The field journal not only gives them insight into their personal and professional perspectives, but it affords them an appropriate opportunity (or often a needed excuse) to focus on themselves and their teaching in the midst of a small group setting.

7.3 Data Collection Procedures and Purposes

This study was conducted in accordance with the Australian Association for Research in Education (AARE) Code of Ethics, 1995 (Australian Association for Research in Education, 1995). No hazardous procedures or harmful materials were used during this research. Program participants were adult volunteers, and therefore no participation/permission slips were required for evaluation of the university/field trip program. The respective teachers obtained approval for school students' participation in the research. All participants were given a choice to participate and were free to withdraw at any time. All data collected will remain confidential and anonymous.

Dr Cynthia E. Ledbetter supervised the data collection, acted as liaison between the researcher and participating instructors, university administrators, classroom teachers, and corroborated class/field observations. The following types of materials and equipment were available for participant use in the university classroom and field locale: digital cameras, laptop computers with general and specialised software, global positioning systems (GPS), scientific probe equipment, satellite telephone, and Internet access. University resources and personnel were available before, during, and after the field trip for development and presentation of the virtual field trip, made available via a public web site hosted through the Science/Mathematics Education Department at The University of Texas at Dallas.

Data were collected throughout this study to investigate the general question of whether or not a teacher's participation in the Integrated Science Learning

Environment (ISLE) program would lead to the teachers' implementation of constructivist learning environments in their respective students' school classrooms. This involved various instruments used to evaluate the integrated learning environment in terms of the degree of constructivist practice in the university, outdoor and public/private classrooms, teachers' attitudes toward information technology, and teachers' conceptual development.

As described in section 1.1.1, this research study was conducted in two distinct segments. The university coursework and extended field trip components were evaluated in Phase I. The public/private school classroom component was evaluated in Phase II. Section 7.2 detailed the actual instrumentation employed within the overall program evaluation. The following sections outline the data collection and analysis for each of the research questions of this particular study.

7.3.1 Research Question 1: Validation and Use of the CLES

Research Question 1 concerns validation of the Constructivist Learning Environment Survey for use in secondary schools in Texas. To validate the Comparative Student (CLES-CS) form, the responses of 1079 school students were subjected to factor analysis (SPSS for Windows, Release 10.0.5, Standard Version) to check the scale structure. Cronbach's alpha coefficient was used as an index of internal reliability and the ANOVA statistic (Gay & Airasian, 2000) was used to check whether each scale was capable of differentiating between the perceptions of students in different classrooms.

The Comparative Teacher (CLES-CT) and Adult (CLES-A) forms were administered to determine the usefulness of the new versions in north Texas. Because of the smaller sample sizes for ISLE science teachers ($N = 8$) on the CLES-CT and for ISLE teachers ($N = 12$) on the CLES-A, descriptive statistics were used to examine the results. The average item mean was calculated to provide a meaningful basis for comparison of scale means and the range was used to indicate the amount of dispersion of responses for each data set. The average item mean, average item standard deviation, and average item variance were calculated to describe the central tendency of the group, a measure of how widely values are dispersed from the average value, and the estimated variance based on a sample for each scale. Additional qualitative data from observations, interviews, and comments were used to support further interpretation of these data.

7.3.2 Research Question 2: Implementation of Constructivist Teaching

To answer Research Question 2, two modified forms of the 30-item Constructivist Learning Environment Survey (CLES) were used to assess how the ISLE experience affected the degree of implementation of constructivist teaching in the participants' respective classrooms. The Constructivist Learning Environment Survey – Comparative Teacher (CLES-CT, section 7.2.3) form was administered to compare the degree to which the ISLE science teachers (N = 7) felt that the principles of constructivism were implemented in their own school classes following the university course experience, relative to classes that they have taught previously throughout their teaching careers. Because of the inherently limited size of the sample, data were analysed using the non-parametric Wilcoxon matched pair test (Bartz, 1981; Kirk, 1984) to compare the teachers' perceptions of the classroom learning environment which they fostered BEFORE and AFTER completing the ISLE program.

The Constructivist Learning Environment Survey – Comparative Student (CLES-CS, section 7.2.4) form was administered to the ISLE science teachers' public/private school students (N = 445) to compare the degree to which the students perceived that the principles of constructivism were implemented in the class taught by the ISLE teacher compared with classes taught by other teachers in their school. To compare the students' perceptions of the classroom learning environment fostered by the ISLE teachers to the classroom learning environments fostered by other teachers at their same school, data were examined using a two-tailed *t* test. The effect size correlation (Becker, 1999) was also calculated using the means and standard deviations to portray the strength of association between variables (Rubin & Babbie, 1993).

7.3.3 Research Question 3: Effectiveness of ISLE Program

The Constructivist Learning Environment Survey – Adult (CLES-A, section 7.2.2) form was administered to all ISLE participants (N = 12) to evaluate the field ecology instructor's teaching for both the university classroom and the field locales in Phase I (Research Question 3a). Based on a posttest-only design (Gay & Airasian, 2000) with a single treatment group, descriptive statistics (means and standard deviations) were used to depict the overall perceptions of the learning environment experienced throughout the ISLE university/field trip course.

To investigate how teachers' perceptions of, and attitudes toward information technology changed over time (Research Question 3b), quantitative results from the Teachers' Attitudes Toward Information Technology (TAT) were supported with qualitative data, particularly self-reports and personal observations. It was administered to ISLE science teachers ($N = 7$) in the second university class and toward the end of the first public/private school semester immediately following the program completion. Data generated by these questionnaires were analysed using the Wilcoxon paired test statistic (Bartz, 1981; Kirk, 1984) to determine difference in means between groups containing fewer than 50 pairs of scores.

To investigate the effectiveness of the university/field trip course in terms of teachers' conceptual development (Research Question 3c), teacher-generated concept maps ($N = 12$) were analysed through both qualitative (field journal entries and an in-depth case study) and quantitative measures (Nix & Ledbetter, 2002). Individual diagrams were objectively analysed in terms of the number of levels (hierarchy), links (inter-relationships), and items (concepts).

Additionally, data generated by these techniques were used to critically evaluate the key content, educational, and support components of the resulting virtual field trip as suggested by Nix (2000a). It is important to remember that the focus of this research was not the dissemination and presentation of scientific facts, but rather the effectiveness of the integrated approach to constructivist teaching and learning. This was made possible by the incorporation of information technology into the teaching and learning in the university classroom, extended field trip, and school classroom environments.

7.4 Limitations of the Study

The ISLE model was openly designed for applicability to other locales and topics; however, several inherent limitations could affect the generalisability of the results. The relatively new (Teachers' Attitudes Toward Information Technology and Website Contribution Evaluation Rubric) and modified (adult and comparative teacher and student forms of the Constructivist Learning Environment Survey) instrumentation could require further testing in more research studies to increase confidence in the replication of interpreted results.

The data can only represent a relatively brief extent of time, and this is yet another challenge to evaluating the full effect of long-term conceptual change. The

data, particularly those collected through the student questionnaires, rely heavily on understanding of the questions and the integrity of the responses. In addition, the sample size, scheduling issues, course credits, external variables, and instrument administration options were potentially limiting factors beyond the control of the researcher. Each of these issues is discussed in the following sections.

7.4.1 *Sample Selection*

Typically, the people interested in extended field-based learning opportunities represent a diverse range of experience and application, including classroom teachers, area science supervisors, curriculum developers, assessment specialists, higher education or community college instructors, online course developers, museum directors, and business professionals in corporate education. Within this intrinsically varied population, logistical and economical limitations were imposed on the selection of the primary, and similarly, secondary samples, as detailed in section 8.1.

The Phase I sample of classroom teachers and school administrators ($N_{\text{Participants}} = 13$) was specifically limited, by design, to those who applied and met the institutional criteria, and were able to participate in the university coursework and extended field trip. Although small, the sample is representative of the population. Due to the homogeneity of the phenomena under study (Van Dalen, 1979), the selected group provided adequate statistical power to indicate a practical difference while minimising the effects of extraneous variables (Gay, 1996; Kirk, 1984). Under these conditions, the data are useful in conceptualising, planning, reporting results, and indicating areas for examination of larger groups (Fraser, 1999).

The Phase II sample of public/private school students ($N_{\text{Students}} = 1079$) was sufficiently large for a meaningful validation of the CLES-CS and determination of differences between the school classroom environments. However, as evidenced by the possible need to modify the new forms CLES slightly, the specific results of this study are limited to north Texas teachers and secondary school students as a result of the particular sample selected. By the same token, as the class size, gender balance, grade level, and school classification varied within the sample, the findings of this study could have general implications and, thus, could encourage the development of larger-scale implementations of the ISLE model.

Given the nature of the variable factors influencing success in a sponsored field trip program, it is difficult to pre-determine the teacher participants. This severely limits, if not eliminates, options for pretesting the teachers' students. Fortunately, for this study, a sample of teachers who had participated in other field trip programs was identified to provide a representative control group (non-ISLE). These traditional field trips were offered by the same university department and conducted by the same instructors within two years prior to the ISLE program implementation.

7.4.2 *Scheduling Issues*

Another imposed limitation was the issue of time and scheduling. Due to variable academic calendars, programs involving extended field trips can be offered successfully to multiple districts over the summer break. This period typically begins in mid-June and ends in late July. Reservations must be confirmed well in advance of the actual trip. Consideration must also be given to the seasonal weather conditions when utilising an outdoor learning environment.

It is difficult, and often impossible, for many teachers to participate in such programs simply because of schedule conflicts. To allow time for the teachers to perform background research and develop a preliminary plan for their field investigations, the university coursework was started toward the end of the spring semester. Unfortunately, this was an extremely busy period for teachers as grades and final school activities are particularly demanding. The teachers were noticeably physically, emotionally, and intellectually drained and admitted a high degree of distraction and inability to focus. The promise of a week in nature, however, did afford the hope and energy of anticipation.

Timing also impacted the design of the research study. Even though a cash deposit was required to ensure each participant's place in the program, this was not collected until the end of the academic year. Again, as there was no way to predict who might apply to and complete the program, it was impossible to implement a pretest/posttest design with the classroom students. This was the main impetus for development of the comparative forms of the Constructivist Learning Environment Survey (CLES-CT and CLES-CS). Recall that the CLES-CT compared the teachers' perceptions of their lessons BEFORE and AFTER the ISLE program. And the CLES-CS compared the students' perceptions of their current science classroom

taught by an ISLE teacher (THIS) to other classrooms (OTHER) taught by other teachers in the same school.

7.4.3 Course Credits

An unavoidable complication to the overall program design was the established practice of offering university credit for three separate courses in conjunction with the university coursework and single extended field trip experience. Each of these courses had a different instructor. Only the field ecology instructor and the researcher/information technology assistant were involved in the preliminary implementation and ISLE program design.

The university required 45 contact hours per class; therefore, each of the three instructors conducted pre-trip and post-trip classes or scheduled individual meetings. It proved difficult for the participants to differentiate amongst the various teaching styles. Multiple project requirements resulted in some confusion and tension for those who elected to enrol for the maximum of nine credit hours. It is understandable that the teachers needed to make the most of their investment in time and tuition fees; however, simultaneously conducting nine credit hours of coursework based on a one-week field experience was a less effective structure for the ISLE model and did impact on the overall results.

7.4.4 External Variables

Among many possible variables, circumstances surrounding two aspects beyond the control of the researcher, namely, participant interaction and field conditions, also influenced the overall outcome of the program. The ISLE model features the uniqueness of the individual, building independently on each participant's prior experience. Ironically, this is realised by focusing on the common experience of the group. Every assemblage is different and the interpersonal relations definitely impact the learning environment for all. In addition, the physical, mental, and emotional fitness of participants is a critical factor in how the group functions and what limitations are placed on both the university coursework and field investigations.

Similarly, the site locale itself strongly influences the teaching and learning opportunities. The weather is quite unpredictable and rapidly changes in Texas, as it does almost everywhere. Many spectacular sites are difficult to access or can be

restricted for various unexpected reasons. For example, flooding limited access to Santa Elena Canyon, described in section 4.2.1. Data collection options are also often limited. National parks are protected areas, and the program design respected – and reflected – these restrictions. Water samples could be chemically analysed and collected in limited amounts, along with photographs. As a result, a day-long excursion to a site beyond the park itself was incorporated into the field activities to allow the teachers to collect geologic samples for use in their classrooms.

7.4.5 *Instrument Administration*

In order to establish and to maintain a comfortable environment as perceived by the participants, the researcher deliberately minimised the overt administration of research components within the ISLE program. It was critical to ensure that the teachers were secure in assuming the role of university student rather than attempting to second-guess the outcomes expected by the field ecology instructor and information technology assistant. Later, it was important that the teachers retained full management of their classes as they had been encouraged to implement elements of the constructivist model.

To this end, and in accordance with university regulations and ethics, all participation in the research study was voluntary. It was decided that the teachers would be able to administer the comparative forms of the CLES (CLES-CT and CLES-CS) to themselves and to the students in their classes. Involving the teachers by asking them to administer the surveys (according to the printed instructions) reinforced the notion of their ability to perform action research and, hence, continually improve their classroom learning environment beyond the ISLE experience.

Combined with the lack of required face-to-face contact after Phase I (the university coursework and extended field trip), Phase II (the public/private school classroom) data collection was difficult for several reasons, including declining teacher interest and energy, student apathy, and institutional restrictions. Each of these issues, described in the following paragraphs, similarly affected the survey results of both ISLE and teachers and students.

Teachers are typically busy people because they are dedicated to their profession for the sake of their students. Those who give up time with friends and family to better themselves by participating in programs over extended breaks, like

ISLE, tend to take on other opportunities and projects throughout the school term. Each teacher started a new academic year within a month of the virtual field trip release. This afforded them the chance to adjust their teaching style more easily; however, they also had to prepare for a new cadre of students and, in some cases, a new administration or physical location. These immediate challenges can be rightfully distracting and are likely to take priority over optional survey administration.

Another factor was the decision to administer the Phase II surveys just before the major holiday break. To gain an accurate picture, it was necessary to allow as much time as possible for the teachers and students to acclimate to their new classroom environments. Unfortunately, this time of year is inherently chaotic with the numerous celebrations and excitement of winter activities. A few teachers agreed to administer the student surveys but, for undetermined reasons, were unable to administer and return them. For example, one replied that she would need 150 surveys and indicated the mailing address. Another said “I would be happy to administer the survey to my students”, but was not able to do so in the end. However, as most teachers did return the teacher surveys, the researcher attributes the less than expected return rate to factors beyond the teachers’ immediate control.

Unlike the teachers who simply tend to wear themselves out toward the end of a semester, some students tend to lapse into an apathetic or disinterested mode. Clearly, this could impact on the survey results. For example, one teacher was able to administer the student surveys during an unexpected class. Shockingly, the entire school was being punished for general misbehaviour. Their ‘day off’, to be filled with picnics and parties, was completely cancelled. Not surprisingly, the students’ hostility was evident in inappropriate comments, response patterns, and lewd drawings added to the surveys. Of course, this was *not* a typical situation. Most teachers were able to return reasonable results. Several of their students drew smiles and wrote ‘thank you’ on their forms.

Institutional restrictions also complicated the student data-collection process. Several teachers noted on their completed teacher surveys that they would not be able to administer the surveys. For example, one teacher reported that “the lead teacher sets my biology curriculum for the most part, so I’m limited as to what I can do. ...I’m sorry, but I will not be able to do the student surveys for you.” There was some leniency and the teachers seemed to want to participate for the most part. One

teacher offered students extra credit for completing the surveys on their own time. When they asked why she would do that, she simply told them that the information was needed by a friend working on her doctorate. Similarly, another teacher was told that ‘before and after school would be okay’. The researcher attributes the acceptable rate of administration and subsequent return to that fact that allowing the teachers to administer the students surveys was a less intrusive method.

7.5 Summary of Research Methods

This chapter summarises the research methods used to evaluate the Integrated Science Learning Environment (ISLE) program introduced in Chapter 1. Section 7.1 explained how combining qualitative methods and quantitative measures provided insight into the field trip milieu and evaluation of the implementation of constructivist pedagogy in schools. Each of the instruments used to evaluate the program and its impact were detailed in section 7.2. Note that each of the sample groups are detailed in a later section, 8.1.

The data collection procedures, conducted in accordance with the Australian Association for Research in Education (AARE) 1995 Code of Ethics, and purposes were reviewed in section 7.3 with respect to the specific research questions asked in section 1.2. Data were collected throughout the ISLE program to investigate the general question of whether or not a teacher’s participation in the Integrated Science Learning Environment (ISLE) program would lead to the teachers’ implementation of constructivist learning environments in their respective students’ school classrooms.

Quantitative data were collected with three primary instruments. The Teachers’ Attitudes Toward Information Technology (TAT) questionnaire was used to assess the affective disposition of teachers with respect to using information technology in their classrooms before and after the ISLE experience. Teacher-generated concept maps were analysed to determine the teachers’ conceptual understanding of the content presented during the ISLE program. Three modified forms of the Constructivist Learning Environment Survey (CLES) were used to assess: 1) teachers’ perceptions of the ISLE instructors’ use of constructivist approaches to teaching during the ISLE university/field trip program (CLES-A), 2) teachers’ perceptions of the degree of implementation of constructivist teaching in their school classrooms (CLES-CT), and 3) students’ perceptions of their ISLE

teachers' science classroom learning environment (CLES-CS). Data also were used to determine the usefulness of the CLES-A and CLES-CT and the validity of the CLES-CS in north Texas.

Various qualitative methods added a depth of understanding to quantitative descriptions investigating the internalisation of basic principles. The Reflective Field Journal served as the main source of qualitative data. Throughout the program, frequent peer debriefing sessions and member checks (Lincoln & Guba, 1985) were conducted to ensure observer credibility and identify personal bias among participants. Detailed observational case study techniques of the actual events and videotape archives of selected group activities, along with examination of informal interviews and archived electronic mail messages, also supported statistical analysis and interpretation.

Section 7.4 described the limitations of the study in terms of sample selection, scheduling issues, course credits, external variables, and instrument administration. This study was concerned primarily with the teachers' learning environment and the students' learning environments. As such, the research focus was not the dissemination and presentation of scientific facts, but rather the effectiveness of the integrated approach to constructivist teaching and learning. Strategically incorporating information technology into the teaching and learning implemented in the university classroom, outdoor field trip and school classroom environments enabled an open design that can be tested in other locales with other topics.

Chapter 8 describes the ISLE sample and program results.

Chapter 8

ISLE PROGRAM RESULTS

This study was designed to evaluate the Integrated Science Learning Environment (ISLE) program in terms of promoting a more constructivist classroom learning environment, attitudes toward information technology, and conceptual understanding. Three key instruments were used to assess the effectiveness of the emergent program design: the Constructivist Learning Environment Survey (CLES), Teachers' Attitudes Toward Information Technology (TAT) Questionnaire, and teacher-generated concept maps. To address the general question of whether changing teachers' learning environments might affect a change in their respective students' learning environments, this chapter presents the quantitative and qualitative data associated with the three specific research questions delineated in section 1.2:

- Question 1: Are new versions the Constructivist Learning Environment Survey (CLES) valid and useful in secondary schools and graduate university courses in Texas?
- Question 2: How effective is the Integrated Science Learning Environment (ISLE) university/field trip course in terms of the degree of implementation of constructivist teaching approaches in the teachers' school classrooms as assessed by:
- (a) teachers' perceptions of the learning environment of their current classroom environment relative to other classes taught by them previously;
 - (b) students' perceptions of the learning environment of their classroom environment relative to classes taught by other teachers in their school; and
 - (c) various qualitative methods (i.e., observation, interview, journal)?
- Question 3: How effective is the Integrated Science Learning Environment (ISLE) university/field trip course in terms of:
- (a) teachers' perceptions of the university/field trip learning environment;

- (b) changes in teachers' attitudes to information technology; and
- (c) teachers' conceptual development?

This chapter is comprised of four main sections. The following section 8.1 describes the sample of teachers and students used for both Phases I and II (the university coursework/extended field trip and public/private school classroom, respectively). To answer Research Question 1, section 8.2 describes the results from various validation analyses of data obtained from the administration of three new versions of the Constructivist Learning Environment Survey (Adult, Comparative Teacher, and Comparative Student) in graduate and secondary schools in north Texas. To answer Research Question 2, section 8.3 presents data from administration of the CLES forms to assess student and teacher perceptions of constructivist practices in school classrooms in Phase II.

To answer Research Question 3, section 8.4 uses details from qualitative sources (course assignments, journal entries, observations, and interviews) to support quantitative data from questionnaires in evaluating the effectiveness of the university/field trip program in Phase I. The three instruments assess teachers' perceptions of the ISLE program (section 8.4.1), teachers' attitudes towards information technology (section 8.4.2), and a concept map test to assess teachers' conceptual development (section 8.4.3).

8.1 Sample

This section describes the four distinct, yet related, sample groups from which data were collected to assess the ISLE program. Phase I involved teacher samples (described in section 8.1.1) and Phase II involved student samples (described in section 8.1.2). As defined in section 1.2.2, 'instructors' refer to university classroom educators at the postgraduate level and professional trainers in a respective field; 'teachers' refer to preservice and inservice classroom teachers in public/private schools; 'educators' refer to instructors, teachers, and other professional trainers; and 'students' refer to K-12 children in public/private school classrooms. Figure 24 illustrates the relationships among the various sample groups for Phase I and Phase II, based on program experience (ISLE or non-ISLE) and content background (science or non-science).

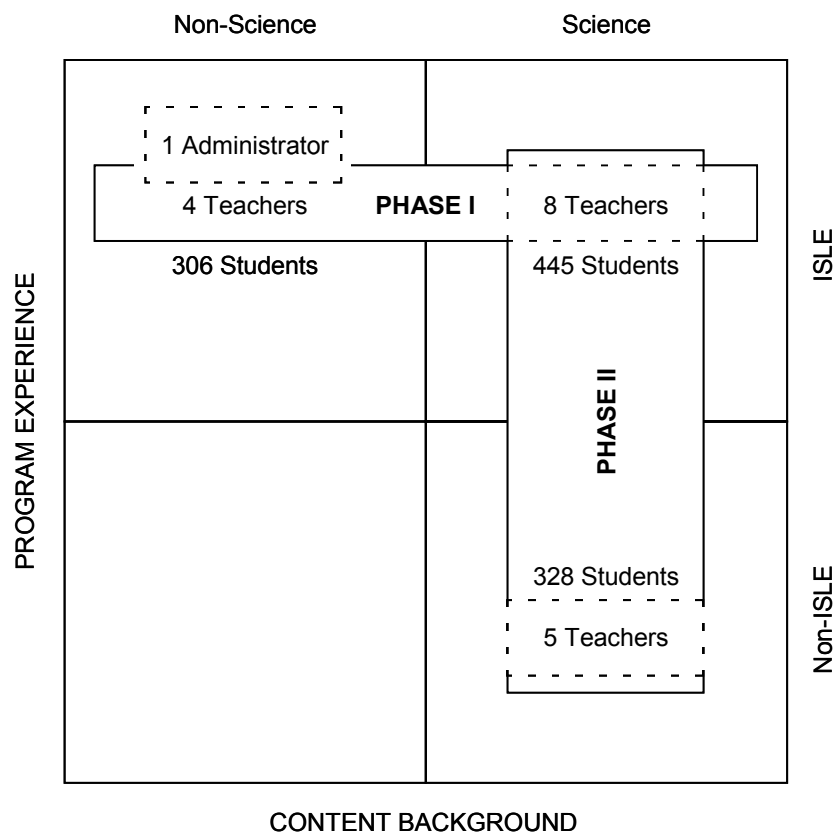


Figure 24. Relationships Among Sample Groups

As described later in section 8.1.1.1, Phase I (the university coursework/extended field trip) involved preservice and inservice teachers with both science and non-science backgrounds. Phase II (the public/private school classroom) involved a subset of Phase I teachers comprised of inservice teachers with science backgrounds only (described in section 8.1.1.2) and their respective classroom students (described in section 8.1.2.1). For comparison, data were also collected from a student control group representing inservice teachers with science backgrounds similar to the Phase II sample. As described in section 8.1.2.2, these comparison teachers had experienced similar field-based coursework offered by the same university department, prior to development of the ISLE model.

8.1.1 Phase I Teachers

Conducted in summer 2000, the university classroom/extended field trip segment (Phase I) was initiated and supported by the efforts of Hal Groeneboer, a high school chemistry teacher for the Duncanville Independent School District. Funded in part by a grant from the National Science Foundation (NSF), the actual

cost to teachers was approximately \$250 US, covering transportation, national park entrance and camping fees, and all but two meals. In addition, most participants opted to pay tuition fees for three, six or nine optional credit hours. Teachers were responsible for securing their personal gear (including toiletries, hiking boots, and field notebooks) and encouraged to share basic items (including tents, binoculars, and select field identification books). The instructors provided a complete reference library, required sampling tools and equipment, and a full menu with plenty of snacks. For logistical reasons, enrolment was limited to 24 participants. This total included the three instructors, one grant manager, one information technology assistant (the researcher), and one campsite director.

Marketed as a Woodrow Wilson National Fellowship Foundation's Teacher Outreach Institute (TORCH), the ISLE program was sponsored by the Department of Science/Mathematics Education at The University of Texas at Dallas (UTD). The summer professional enrichment course was advertised nationally, through websites hosted by NSF, Duncanville, and UTD; statewide, through conference and science educator networks; locally, with flyers distributed to nearby schools; and, internally, to classes offered within the Schools of Natural Sciences and Mathematics and General Studies at UTD. The primary sample was limited, by design, to classroom teachers and university students who applied and met the institutional criteria, and were able to participate in the university coursework and extended field trip.

For Phase I (the university coursework/extended field trip) investigations, the total sample consisted of 12 preservice and inservice teachers with both science and non-science backgrounds and one administrator from the Dallas-Fort Worth metroplex ($N_{\text{Participants}} = 13$). Seven participants were directly associated with the Master of Arts in Teaching (MAT) program offered through UTD's Science/Mathematics Education Department. One was recruited from the business program in a science education elective course and six had completed MAT field trips prior to the ISLE program. Four joined the program as teachers seeking certification through UTD's Teacher Development program. With respect to age, five were between 18-30 years, four were between 36-40 years, and four were 46 years or above. Three were male; 10 were female. All but two participants had a home computer; one of these was able to access the Internet through a television device.

The ISLE teacher sample was stratified by educational background, to allow for comparison of teachers with (science) and without (non-science) specifically relevant content training. Phase II (the public/private school classroom) investigations involved a subset of the Phase I sample comprised of inservice teachers with science content backgrounds only as the focus of this study was on teaching in the science classroom.

8.1.1.1 University Classroom/Extended Field Trip Teachers (ISLE Composite)

The Phase I assemblage of 12 teachers represented one elementary school (grades 1-5), eight middle schools (grades 6-8), and three high schools (grades 9-12). With respect to years of teaching experience, one was preservice, two had completed their first year, four had 2-5 years, one had 6-10 years, two had 11-15 years, and two had 15 years or more years in the classroom. Eleven had earned Bachelors degrees and one held a Master of Arts in Teaching degree. Of those 12 degrees, nine were awarded in a content area within the natural sciences. The remaining areas of study included history (2) and mathematics (1).

8.1.1.2 Public/Private School Classroom Teachers (ISLE Science)

Of the total Phase I population, 8 teachers had science-related content backgrounds (AC, AL, BD, GO, LB, LH, MS, and RF). One teacher (AL) was seeking teacher certification through the UTD teacher development program, while the others were directly associated with the Master of Arts in Teaching (MAT) program offered through UTD's Science/Mathematics Education Department. Student-dependent teacher investigations in Phase I (TAT and CLES-CT) were limited in that one ISLE science teacher (MS) did not have classes to survey the following year (due to retirement).

8.1.2 Phase II Students

The Phase II student sample of school students consisted of a diverse range of age, level, ability, and other demographic characteristics. In general, this assemblage represented nine independent districts, including eight different public schools and two private, parochial schools. With respect to individual classes, the number of students ranged from 5 to 30 per period, while the number of classes taught ranged from 1 to 6 per teacher. The number of students per teacher ranged from 30 to 144

each. Irrespective of the teachers' program experience and content background, the overall student sample used to validate the CLES-CS was comprised of 1079 students in 59 classes represented by 12 teachers.

Phase II investigations were limited in that two Phase I participants did not have classes to survey the following year (due to retirement or preservice status), two did not collect or return the data, and three reported administrative policy restrictions for not participating in the study. Subsequently, this Phase II student sample was stratified based on their respective teachers' content background (limited to science teachers only) and with similar university classroom/extended field trip participation, to allow for comparison of teachers with and without specific program experience (ISLE and non-ISLE, respectively).

8.1.2.1 Public/Private School Classroom Students of ISLE Teachers

Of the 8 ISLE science teachers, one had retired and two (BD and GO) reported administrative policy restrictions for not providing Phase II student information. Their supervisors did not agree to administration of the student surveys based on privacy issues at the district level.

Therefore, of the total Phase II population, the student data for five ISLE science teachers (AC, AL, LB, LH, and RF) was comprised of 445 students in 25 classes. It is important to remember that these teachers were directly associated with the Master of Arts in Teaching (MAT) program offered through UTD's Science/Mathematics Education Department and had completed the summer 2000 field trip based on the ISLE model.

8.1.2.2 Public/Private School Classroom Students of Non-ISLE Teachers

For comparison, data were also collected from a student control group represented by the students of inservice teachers with science backgrounds comparable to those in the Phase II sample. These classroom teachers had experienced similar university coursework/extended field trip within two years prior to development of the ISLE model. Randomly solicited through email broadcasts and telephone discussions, each had participated in previous university coursework/extended field trip programs (non-ISLE) taught by the same instructors. This secondary sample was further limited to those MAT teachers who had a science

content background and were able to administer the survey instrument in their respective public/private school classrooms.

Of the total Phase II population, the student data for five science teachers (BT, EC, KM, LH, and TG), who had participated in alternative field trips programs, was comprised of 328 students in 19 classes. It is important to remember that these teachers were directly associated with the Master of Arts in Teaching (MAT) program offered through UTD's Science/Mathematics Education Department and had completed previous MAT field trips that were not based on the ISLE model. Coincidentally, one of the teachers surveyed before the ISLE implementation (LH) also participated in the ISLE program.

8.2 Validity and Use of New Versions of the Constructivist Learning Environment Survey (CLES) in North Texas (Research Question 1)

Three modified versions of the Constructivist Learning Environment Survey (CLES), originally developed by Taylor and Fraser (1991) and described in section 5.1.6, were used to assess the degree of constructivist practice evident in the university/field trip classroom or public/private school classroom settings. Each new form includes 30 items with a five-point frequency response scale (Almost Always, Often, Sometimes, Seldom, and Almost Never). All three forms address the five scales of the Constructivist Learning Environment Survey which are: 1) Personal Relevance, 2) Student Negotiation, 3) Shared Control, 4) Critical Voice, and 5) Uncertainty of Science.

In developing the adult form (CLES-A, see Appendix III.3.1), some phrases and terms were slightly reworded for use with adults in north Texas. The ISLE participants (N = 12) used this new form to evaluate the field ecology instructor's teaching in Phase I, encompassing the university classroom, the local day trips, and the extended field trip.

A unique format, in that two response blocks for each of the same 30 items are presented in side-by-side columns, was field tested as part of the Phase II investigations. The comparative teacher form (CLES-CT, see Appendix III.3.2) is a slightly modified version of the adult form (CLES-A). The ISLE classroom teachers (N = 8) used the comparative teacher form to compare the degree to which s/he feels that s/he has implemented the principles of constructivism in her/his own school

classrooms immediately following her/his university/field trip experience (AFTER) with previous classes that they have taught throughout their careers (BEFORE).

Similarly, the classroom students of both ISLE and non-ISLE science teachers ($N_{\text{ISLE}} = 445$ and $N_{\text{Non-ISLE}} = 328$) used the comparative student form (CLES-CS, see Appendix III.3.3) to compare the degree to which they feel that the principles of constructivism have been implemented in the class currently taught by their teacher (THIS) with classes taught by other teachers (OTHER) in their school.

Research Question 1 asks if the new versions of the CLES are valid and useful in secondary schools and graduate university courses in Texas. The following section 8.2.1 describes the validation of the comparative student form (CLES-CS) in public/private school classrooms. Because the small sample of adults and teachers does not permit similar validation analyses, the results reported are restricted to inferring the usefulness of the CLES-A and CLES-CT in north Texas. Section 8.2.2 describes use of the adult form (CLES-A) in graduate school. And section 8.2.3 describes use of the comparative teacher form (CLES-CT) in public/private schools.

8.2.1 Validation of the Comparative Student Form of the Constructivist Learning Environment Survey (CLES-CS) for Use in Secondary Schools

The Constructivist Learning Environment Survey – Comparative Student form (described in section 7.2.4) was administered to all Phase II public/private school classroom students (see section 8.1.2). Comprised of the classes of ISLE and non-ISLE, science and non-science, preservice and inservice teachers, the classroom students were asked to evaluate the teaching practices that currently take place in the teacher's current class (THIS), as well as the teaching that they currently experience in other teachers' classes (OTHER). Designed with the same side-by-side columnar format as the CLES-CT, items in the left column begin with 'In OTHER classes...', while items in the right column begin with 'In THIS class...'. Overall, the 60-item CLES-CS contains six statements in five scales (Personal Relevance, Uncertainty of Science, Critical Voice, Shared Control, and Student Negotiation) rated on a five-point frequency response scale (5 = Almost Always, 4 = Often, 3 = Sometimes, 2 = Seldom, and 1 = Almost Never) for the two cases (THIS and OTHER).

The purpose of this section is to report the validity and reliability of the comparative student form of the Constructivist Learning Environment Survey (CLES-CS) for use in secondary schools in Texas. Data were collected from a

combined sample of 59 classes, represented by 12 teachers and comprised of 1079 students. Of the ISLE teachers, five had content backgrounds in science (AC, AL, LB, LH, and RF), while one (CB) did not. All six of the teachers who attended alternative field trip programs had content backgrounds in science (BT, EC, FO, KM, LH, and TG). Note that one participant (LH) administered the CLES-CS as both a teacher from another program (before Phase I) and as an ISLE teacher (after Phase I). One teacher (FO) was not associated with the Master of Arts in Teaching (MAT) program. Subject to the limitations described in section 7.4, these results can be generalised beyond the particular study sample only with caution.

The student survey responses were recorded in an electronic spreadsheet by the researcher. Statistical analysis procedures were performed with assistance and guidance from Dr Jill Aldridge and Professor Barry Fraser of the Science/Mathematics Education Centre at Curtin University of Technology. SPSS for Windows was used to compute the results based on the factor structure (presented in section 8.2.1.1), internal consistency reliability and discriminant validity (presented in section 8.2.1.2), and the ability to distinguish between different classes and groups (presented in section 8.2.1.3).

8.2.1.1 Factor Analysis of the CLES-CS

Factor analysis (Kim & Mueller, 1982) is a statistical technique used in data reduction to identify a small number of underlying variables, or factors, that explain most of the variance observed in a much larger number of manifest variables. Using both cases (THIS and OTHER) of the CLES-CS data acquired in Phase II, factor and item analyses were conducted in order to identify faulty items that could be removed to improve the internal consistency reliability and factorial validity of the five scales in the comparative student version of the CLES.

As frequently used in the validation of learning environment instruments, the student data were subjected to principal components factor analysis with varimax rotation (in which the factor axes are kept at right angles to each other) to check the scale structure. Four items appeared to be problematic for the students: item 6 was reverse-scored; item 7 was negatively-worded; and items 3 and 25 were ambiguously interpreted. Removal of items 3 and 6 in the Personal Relevance scale, item 7 in the Uncertainty of Science scale, and item 25 in the Student Negotiation scale enhanced the reliability of the instrument. Following removal of these four items, all of the

other 26 items had a factor loading of at least 0.4 on their *a priori* scale and no other scale for the analyses for both THIS and OTHER. Table 20 presents the resulting factor loadings for both cases of the CLES-CS.

Table 20. **Factor Loadings for the Constructivist Learning Environment Survey – Comparative Student (CLES-CS) Form**

Item	Factor Loading									
	Personal Relevance		Uncertainty of Science		Critical Voice		Shared Control		Student Negotiation	
	THIS	OTHER	THIS	OTHER	THIS	OTHER	THIS	OTHER	THIS	OTHER
1	0.66	0.56								
2	0.48	0.44								
4	0.71	0.63								
5	0.63	0.59								
8			0.67	0.63						
9			0.54	0.65						
10			0.44	0.54						
11			0.64	0.68						
12			0.51	0.62						
13					0.60	0.56				
14					0.64	0.60				
15					0.65	0.62				
16					0.48	0.46				
17					0.55	0.51				
18					0.53	0.52				
19							0.66	0.61		
20							0.57	0.57		
21							0.75	0.72		
22							0.71	0.73		
23							0.76	0.74		
24							0.54	0.47		
26									0.62	0.58
27									0.70	0.71
28									0.79	0.75
29									0.69	0.66
30									0.65	0.66
% variance	7.0	5.6	8.0	8.1	8.7	7.5	11.5	10.2	10.3	9.2
Eigenvalue	1.83	1.51	2.06	2.18	2.26	2.02	2.98	2.75	2.67	2.49

N = 1079 students in 59 classes in north Texas. (Items 3, 6, 7, and 25 were omitted.)

THIS refers to the ISLE teachers' current class; OTHER refers to classes taught by teachers in the same school who did not participate in the ISLE program.

Principal components factor analysis with varimax rotation and Kaiser normalization confirmed the *a priori* structure of the CLES-CS. The percentage of the total variance and eigenvalue associated with each factor are also shown at the bottom of Table 20. The total amount of variance accounted for by the 26 items within the five scales is 45.5% for THIS and 40.6% for OTHER, and ranged from 5.6% to 11.5% for different scales and cases. The eigenvalues range from 1.83 to 2.98 for THIS and from 1.51 to 2.75 for OTHER. Overall, these data provide strong support for the factorial validity of the five-scale comparative student version of the Constructivist Learning Environment Survey (CLES-CS).

8.2.1.2 *Internal Consistency Reliability and Discriminant Validity of the CLES-CS*

Reliability analysis explores the properties of measurement scales and the items of which they are comprised. Cronbach's alpha coefficient was used as an index of internal consistency reliability for each of the scales for two units of analysis (individual and class mean). Table 21 shows that the alpha coefficients of different CLES-CS scales were high, ranging from 0.74 to 0.85 for THIS and from 0.68 to 0.83 for OTHER with the individual as the unit of analysis. Using the class mean as the unit of analysis, scale reliability estimates ranged from 0.87 to 0.93 for THIS and from 0.69 to 0.88 for OTHER.

To assess the extent to which a scale is unique in the dimension that it covers and is not included in another scale in the same instrument, the mean correlation of a scale with other scales, also reported in Table 21, was used as a convenient index of discriminant validity. In the teachers' current classes (THIS), the mean correlation of a scale with the other scales varied between 0.28 and 0.32 with the individual as the unit of analysis and between 0.28 and 0.39 with the class mean as the unit of analysis. In classes taught by other teachers (OTHER), the mean correlation of a scale with the other scales varied between 0.25 and 0.27 with the individual as the unit of analysis and between 0.16 and 0.34 with the class mean as the unit of analysis. These results suggest that each scale assesses a unique dimension and that, while there is some overlap between raw scores on scales, they are relatively independent of each other. Additionally, the factor analysis results support the independence of factor scores.

Table 21. **Internal Consistency Reliability (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation with Other Scales), and Ability to Differentiate Between Classrooms (ANOVA Results) for Two Units of Analysis for the Constructivist Learning Environment Survey – Comparative Student (CLES-CS) Form**

Scale	Unit of Analysis	Alpha Reliability		Mean Correlation with other Scales		ANOVA η^2	
		THIS	OTHER	THIS	OTHER	THIS	OTHER
Personal Relevance	Individual	0.75	0.68	0.29	0.25	0.20**	0.07
	Class Mean	0.91	0.69	0.35	0.22		
Uncertainty of Science	Individual	0.74	0.78	0.32	0.26	0.18**	0.11**
	Class Mean	0.87	0.87	0.39	0.18		
Critical Voice	Individual	0.77	0.74	0.28	0.26	0.12**	0.09**
	Class Mean	0.87	0.80	0.35	0.34		
Shared Control	Individual	0.84	0.83	0.28	0.27	0.12**	0.07
	Class Mean	0.91	0.84	0.28	0.16		
Student Negotiation	Individual	0.85	0.82	0.31	0.27	0.12**	0.10**
	Class Mean	0.93	0.88	0.38	0.29		

** $p < 0.01$

N = 1079 students in 59 classes in north Texas. (Items 3, 6, 7, and 25 were omitted.)

THIS refers to the ISLE teachers' current class; OTHER refers to classes taught by other teachers in the same school who did not participate in the ISLE program.

The η^2 statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

8.2.1.3 Ability of the CLES-CS to Differentiate between Classes

As described in Chapter 5 and consistent with Stern, Stein, and Bloom's (1956) terms of private beta press (the idiosyncratic view that each person has of the environment) and consensual beta press (the shared view that members of a group hold of the environment), an important distinction in learning environment research has to do with whether the class or personal form of the instrument is used. Therefore, a desirable characteristic of the actual form of a classroom environment scale is that it is capable of differentiating between the perceptions of students in different classrooms. Students in the same class should see its environment relatively similarly, whereas average class perceptions should vary from class to class.

A one-way analysis of variance (ANOVA) was performed for the scores to determine the ability of each CLES-CS scale to differentiate between the perceptions

of students in different classrooms. Table 21 reports the results in terms of η^2 , which is the ratio of 'between' to 'total' sums of squares and provides an estimate of the strength of association between class membership and the dependent variable (CLES-CS scale). The amount of variance in scores accounted for by class membership (η^2) ranged from 0.12 to 0.20 for THIS and from 0.07 to 0.11 for OTHER for the different CLES-CS scales. The results were statistically significant ($p < 0.01$) for nearly all scales and cases, with the exception of the OTHER case for Personal Relevance and Shared Control. This suggests that nearly all scales of the CLES-CS are able to differentiate between the perceptions of students in different classes.

In summary, the factor structure, internal consistency reliability, discriminant validity, and the ability to distinguish between different classes and groups were supported for the comparative cases (THIS and OTHER) of the CLES-CS. The overall results validate use of the CLES-CS form with students in public/private schools in north Texas.

8.2.2 Use of the Adult Form of the Constructivist Learning Environment Survey (CLES-A) in University Settings

The Constructivist Learning Environment Survey – Adult form (described in section 7.2.2) was administered to all ISLE program participants (see section 8.1.1). Comprised of preservice/in-service teachers and an administrator, the graduate students were asked to evaluate the instructors' teaching in Phase I, the university coursework/extended field trip. One science teacher did not complete the survey. Although small, the final sample of 12 is representative of the population and thus acceptable for examining the usefulness of the CLES-A in a north Texas university. Seven had science backgrounds and five had non-science backgrounds.

The conceptual strength and psychometric structure of the questionnaire were established in previous studies based on rigorous testing using quantitative and qualitative methods as detailed in section 5.1.6. For this study, some phrases and terms were slightly reworded for use with adults in the north Texas area, just as Cannon (1996) modified it for use in introductory science classes. The researcher reviewed changes with other adults and university instructors to ensure that the wording was appropriate for the specific sample. Care was taken to ensure that the meaning of the original statement was preserved in order to maintain the validity of

the instrument. The items of a single scale are grouped together under a simple scale name (Personal Relevance, Uncertainty of Science, Critical Voice, Shared Control, and Student Negotiation) to provide a contextual cue for respondents.

To illustrate the variability of responses, Figure 25 shows the maximum, mean, and minimum values (on a five-point frequency response scale) returned for each learning environment scale of the CLES-A. Descriptive statistics were used to summarise the basic features of this small and homogeneous sample ($N = 12$). The average item mean is commonly used to describe the central tendency of a group. It is simply computed by adding the individual scores and dividing by the total number of respondents. Its advantage is that it provides a meaningful basis for comparison of scale means when the number of items varies from scale to scale. The range, or difference between the maximum and minimum values, indicates the amount of dispersion. Note that the vertical scale is partially represented as the range of values varies by 1.25 units.

The sole reverse-scored item (question 6) in Personal Relevance was not problematic for the graduate students as all results were assigned a value of 4 or 5. However, three scales (Uncertainty of Science, Critical Voice, and Student Negotiation) did reflect a wider range of scores. This indicates that the questions might be ambiguous or might not reflect unique factors.

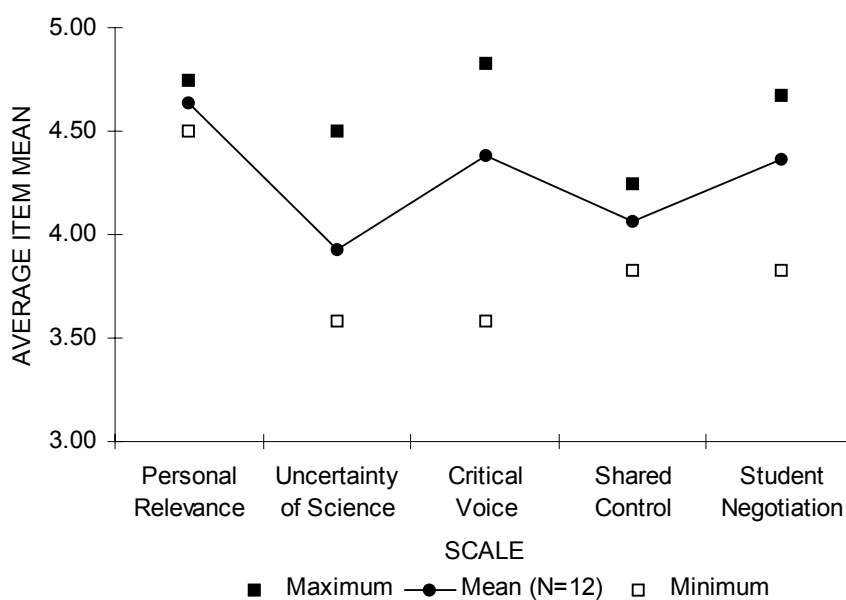


Figure 25. **Maximum, Mean, and Minimum Values for the Adult Form of the Constructivist Learning Environment Survey (CLES-A)**

Closer examination of the data reveals subtle differences based on content training that could account for the range of values. Table 22 summarises the average item mean (used to describe the central tendency of a group), average item standard deviation (a measure of how widely values are dispersed from the average value), and average item variance (the estimated variance based on a sample) returned for each scale for participants with science and non-science background.

Table 22. Average Item Mean, Average Item Standard Deviation, and Average Item Variance for the Adult Form of the Constructivist Learning Environment Survey (CLES-A) Based on Content Background (Science and Non-Science)

Scale	Background	Average Item Mean	Average Item Standard Deviation	Average Item Variance
Personal Relevance	Science	4.69	0.64	0.41
	Non-Science	4.57	0.50	0.25
Uncertainty of Science	Science	4.12	1.02	1.04
	Non-Science	3.67	0.84	0.71
Critical Voice	Science	4.36	0.73	0.53
	Non-Science	4.40	0.89	0.79
Shared Control	Science	4.26	0.70	0.49
	Non-Science	3.77	0.68	0.46
Student Negotiation	Science	4.60	0.66	0.44
	Non-Science	4.03	1.00	1.00

$N_{\text{Science}} = 7$; $N_{\text{Non-Science}} = 5$

These data and the following observations suggest that the differences in responses could be attributable to content background. For participants with science backgrounds, the only three scores of 1 or 2 (MS and RF) were recorded for items 9, 10, and 12 in the Uncertainty of Science scale. For participants with non-science backgrounds, three scores of 2 (CB, LL, and MM) were recorded for items 9 and 11 in the Uncertainty of Science scale and two scores of 1 and 2 (CB and MM) were recorded for item 29 in the Student Negotiation scale.

Three comments, from two non-science teachers, were noted on the forms. For items 15 and 18 of the Critical Voice scale, GB added remarks that qualified the questions as dependent on 'who' (referring to the instructor) was being evaluated. This confusion is a result of the fact that three separate courses were offered in conjunction with the single extended field trip experience (see section 7.4.3). For

item 29 of the Student Negotiation scale, MM limited the explanation of ideas to topics ‘except for math’. Supported by other qualitative evidence from observations and interviews, the unfamiliarity of scientific terminology and methodology for teachers without science backgrounds could be problematic when using this version of the CLES with a multidisciplinary sample.

The administrator (LL), also with a non-science background, changed responses to item 10 of the Uncertainty of Science scale and item 19 of the Shared Control scale by one unit in the positive direction. Also, supported by other qualitative evidence from observations and interviews, the unfamiliarity of pedagogical terminology and methodology for participants without teaching backgrounds could be problematic generally when using this version of the CLES.

Consistent with the reported use of modified versions of the CLES with university students (Cannon, 1996) and secondary school teachers (Johnson & McClure, 2002), these results support use of the CLES-A form with teachers in north Texas. However, based on results specific to content background, these data suggest that the language of the new CLES-A could need to be revised to better reflect adult interpretation in the context of science learning environments.

8.2.3 Use of the Comparative Teacher Form of the Constructivist Learning Environment Survey (CLES-CT) in Secondary Schools

Four months after the university coursework/extended field trip (Phase I), the Constructivist Learning Environment Survey – Comparative Teacher form (described in section 7.2.3) was administered to all inservice teachers who had participated in the ISLE program (see section 8.1.1.1). Items contained within the CLES-CT are identical to items contained within the CLES-A, except for the side-by-side columnar format of the comparative instrument (detailed in section 7.2.3).

The ISLE inservice teachers were asked to evaluate their teaching BEFORE and AFTER they completed the program. All ISLE science teachers – except one (MS) who, due to retirement, did not have classes to survey the following year – completed the survey (N = 7). Only one of the four ISLE non-science teachers (CB) completed the CLES-CT. The final sample of 8 teachers is representative of the population and thus acceptable for examining the usefulness of the CLES-CT.

To illustrate the variability of responses, Figure 26 shows the maximum, mean, and minimum values (on a five-point frequency response scale) returned for

each learning environment scale of the CLES-CT for the BEFORE case. Similarly, Figure 27 shows the maximum, mean, and minimum values (on a five-point frequency response scale) returned for each learning environment scale of the CLES-CT for the AFTER case. Note that the same vertical scale is partially represented as the ranges of values vary by 1.88 units and 1.62 units, respectively.

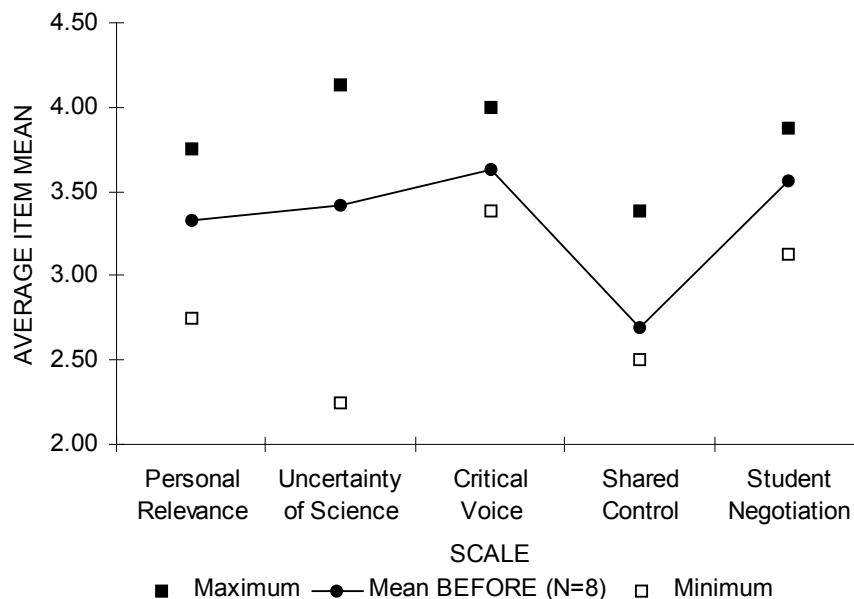


Figure 26. **Maximum, Mean, and Minimum Values for the BEFORE Case of the Comparative Teacher Form of the Constructivist Learning Environment Survey (CLES-CT)**

The patterns are comparable, except that the AFTER case was scored slightly higher than the BEFORE case. Also, even though the maximum-minimum spread noticeably increased, the mean value for the Personal Relevance scale nevertheless showed more improvement than did the means of the other scales. Remember that the other forms (CLES-A and CLES-CS) ask the students to evaluate their common teacher. The fact that the different teachers performed a self-assessment in completing the CLES-CT could account for this increased range.

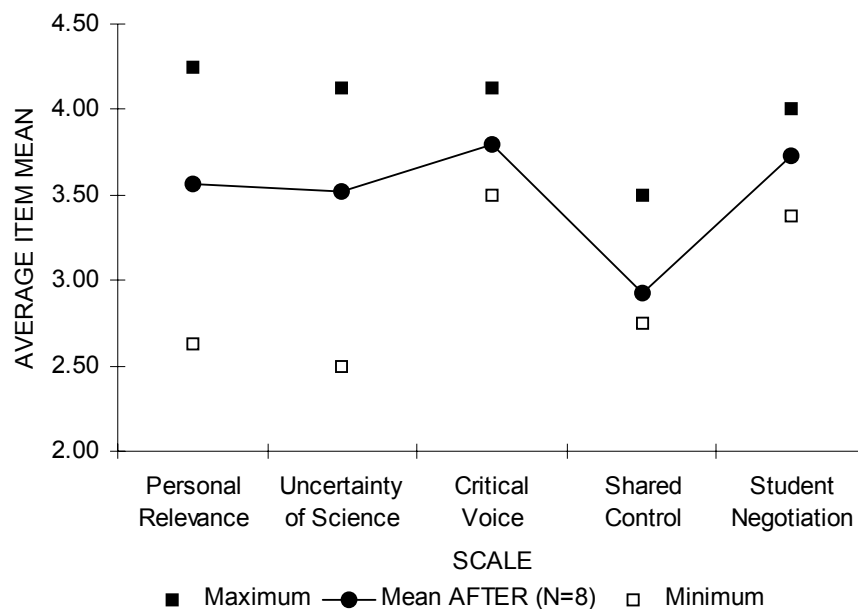


Figure 27. **Maximum, Mean, and Minimum Values for the AFTER Case of the Comparative Teacher Form of the Constructivist Learning Environment Survey (CLES-CT)**

The sole reverse-scored item (question 6) in Personal Relevance did not appear to be problematic for the secondary teachers in the BEFORE case; however, results for the same question in the AFTER case are lower than expected and do not appear to be consistent with values for the other 5 items in the same scale. Values for the Uncertainty of Science also reflect a wider range of scores for both cases. This indicates areas that could be more strongly influenced by the teachers' experience.

Closer examination of the data reveals subtle differences based on the comparative format that could account for the range of values. Table 23 summarises the average item mean (used to describe the central tendency of a group), average item standard deviation (a measure of how widely values are dispersed from the average value), and average item variance (the estimated variance based on a sample) returned for each scale for each case (BEFORE, AFTER, and COMBINED).

No participants wrote comments on the survey forms, suggesting that they had become accustomed to the language of the CLES. However, two important features were noticeable in the tabulation of raw data. Of the 42 items that received lower scores (1 or 2) in the BEFORE case, 33 (79%) also received lower scores in the AFTER case. Further comparison showed that, although the values varied among individuals, 7 teachers duplicated their responses for all six items of some scales, scoring the AFTER case exactly as the BEFORE case. Specifically, responses for

BEFORE and AFTER were the same in 3 instances for Personal Relevance, in 5 instances for Uncertainty of Science, in 3 instances for Critical Voice, in 4 instances for Shared Control, and in 4 instances for Student Negotiation. One teacher equally scored all scales, for both cases, of the entire survey.

Table 23. **Average Item Mean, Average Item Standard Deviation, and Average Item Variance for the Comparative Teacher Form of the Constructivist Learning Environment Survey (CLES-CT) by Case (BEFORE, AFTER, and COMBINED)**

Scale	Case	Average Item Mean	Average Item Standard Deviation	Average Item Variance
Personal Relevance	BEFORE	3.33	0.95	0.83
	AFTER	3.56	0.90	0.81
	COMBINED	3.45	0.93	0.86
Uncertainty of Science	BEFORE	3.42	1.16	1.35
	AFTER	3.52	1.13	1.28
	COMBINED	3.47	1.14	1.30
Critical Voice	BEFORE	3.63	0.87	0.76
	AFTER	3.79	0.85	0.72
	COMBINED	3.71	0.86	0.74
Shared Control	BEFORE	2.69	1.01	1.02
	AFTER	2.92	1.09	1.19
	COMBINED	2.80	1.05	1.10
Student Negotiation	BEFORE	3.56	1.17	1.37
	AFTER	3.73	1.20	1.44
	COMBINED	3.65	1.18	1.39

N = 8 ISLE Science and Non-Science teachers

BEFORE refers to the teachers' classroom practice prior to experiencing the ISLE program; AFTER refers to the same teachers' classroom practice following the ISLE program.

The similarity in responses does not appear to be linked to the school setting (i.e. public versus private, at risk versus talented and gifted, or state versus parochial status). Based on qualitative data from interviews and observations, the reasons cited for the teachers not changing their classroom practice with respect to three scales (Critical Voice, Shared Control, and Student Negotiation) included curriculum control by administration and classroom management issues.

In summary, the new side-by-side format does show reasonable promise for reflecting differences that could increase further over time. Interestingly, the responses in the other two scales (Personal Relevance and Uncertainty of Science), that were not similar, seem to be linked to content background and teaching

experience. For example, the non-science preservice teacher showed the greatest difference in BEFORE (2.67 and 2.50) and AFTER (3.50 and 3.17) scores for Personal Relevance and Uncertainty of Science (respectively).

These results are consistent with the reported use of modified versions of the CLES with secondary school teachers (Johnson & McClure, 2002). Based on the conceptual strength and psychometric structure of the questionnaire demonstrated by previous studies (detailed in section 5.1.6), the validation of the CLES-CS with a large sample (reported in section 8.2.1), and the acceptable use of the CLES-A with adults (described in section 8.2.2), these results support the usefulness of the CLES-CT form with adults in public/private school teachers in north Texas.

8.3 Effectiveness of ISLE Program in Terms of Implementation of Constructivist Teaching in Public/Private School Classrooms (Research Question 2)

Research Question 2 concerns the effectiveness of the university/field trip course in terms of the degree of implementation of constructivist teaching approaches in the teachers' school classrooms. This section presents data collected from administration of the new versions of the Constructivist Learning Environment Survey (comparative teacher and comparative student) described in the previous section, 8.2. Combined with qualitative data from interviews, observations, and journal entries, this quantitative evaluation represents student and teacher perceptions of constructivist practices in Phase II.

The impact of the ISLE program on public/private school classrooms was investigated through administration of the comparative forms of the CLES. The results of the comparative teacher form (CLES-CT) are described in section 8.3.1 to provide insight into the teachers' perceptions of their school classroom teaching. The results of the comparative student form (CLES-CS) are described in section 8.3.2 to provide insight into the students' perceptions of their school classroom learning. And finally, in section 8.3.3, a case study is provided of one teacher's and her students' changes in perceptions of the school classroom learning environment associated with participating in the ISLE program.

Building on the trends in curriculum and instruction described in section 6.1.1, the ISLE program was designed to leverage the link between the effective use of information technology in science education and the theory of constructivism.

Because today's teachers and administrators are the products of traditional teaching, they have limited experience and superficial understanding of this recently-revived approach to teaching and learning.

A positive benefit of the information revolution is that constructivism will be forced into play because it is impossible for a teacher to use didactic methodology in a technology-rich classroom; however, as Milne and Taylor (2000) reported, this sort of pedagogical change is difficult to realise in individual classrooms. To help teachers to internalise the basic principles of constructivist practice, the field ecology instructor and information technology assistant (also the researcher) teamed to present the participants with first-hand experience as 'techno-constructivists', a term coined by McKenzie (2000) to describe professional educators who use technology in constructivist ways. Chapter 3 and Chapter 4, respectively, examine the conceptual and logistical frameworks of this covert implementation.

8.3.1 Teachers' Perceptions of their School Classroom Environments BEFORE and AFTER ISLE (Research Question 2a)

Four months after the university coursework/extended field trip (Phase I), the impact of the ISLE program on public/private school classrooms (Phase II) was investigated through administration of the comparative forms of the CLES. In this section, the results of the comparative teacher form (CLES-CT) provide insight into the teachers' perceptions of their school classroom teaching.

The CLES-CT has a side-by-side columnar response format (detailed in section 7.2.3). This format enables respondents to provide their answer to each item for two occasions, namely, BEFORE and AFTER participating in ISLE. Based on the acceptable use of the CLES-CT with this sample, the instrument was considered to be valid and reliable as described in section 8.2.3. The inservice science teachers who had participated in the ISLE program (see section 8.1.1.1) were asked to evaluate their teaching before and after experiencing the ISLE program. All ISLE science teachers completed the survey except for one (MS). Due to retirement, she did not teach the following year. The final sample of 7 teachers is representative of the population and thus acceptable for this particular study.

As typically performed in learning environment studies, this small sample size does not permit the use of parametric statistical tests (Pace & Stern, 1958). Therefore, a non-parametric model, which does not assume a normally-distributed

population and does not require interval-level measurement, was employed. Similar to a pretest/posttest design (Gay & Airasian, 2000), descriptive statistics (means and standard deviations) and a Wilcoxon matched pair signed rank T test were used to characterise changes on the CLES (Craft, 1990). It is important to keep in mind that the teachers answered the BEFORE case by recalling how they thought things used to be in their classrooms and does not constitute a true pre-post model. The potential for inaccurate representation of their retrospective perceptions is an inherent weakness of the design.

The mean item scores were calculated for each learning environment scale of the CLES-CT (Personal Relevance, Student Negotiation, Shared Control, Critical Voice, and Uncertainty of Science) on a five-point frequency response scale (5 = Almost Always, 4 = Often, 3 = Sometimes, 2 = Seldom, and 1 = Almost Never) for two cases (BEFORE and AFTER). To show the difference in each, Figure 28 graphically presents the average item mean scores of the CLES-CT both BEFORE and AFTER the ISLE program experience. Note that the maximum range of values varies by a total of 0.19 units.

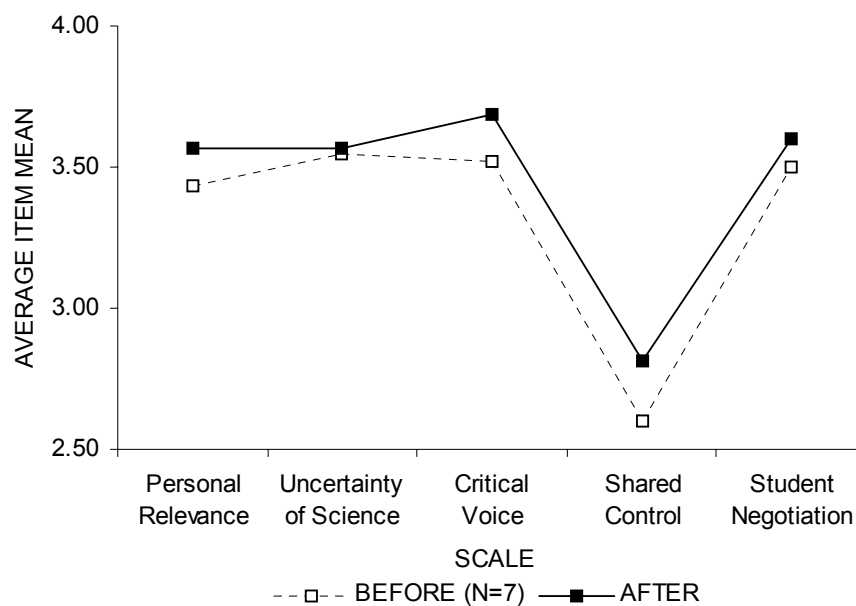


Figure 28. **ISLE Science Teachers' Perceptions of Classroom Learning Environment BEFORE and AFTER ISLE: Average Item Means for the Comparative Teacher Form of the Constructivist Learning Environment Survey (CLES-CT)**

For this sample of ISLE science teachers, the average item mean scores for both the BEFORE and AFTER cases ranged from 2.60 to 3.69. These values indicate

that the practices encompassed by all scales of the CLES-CT, with the exception of Shared Control, were perceived by teachers to occur with a frequency of between Sometimes (3.00) and Often (4.00). The actual differences between average item mean scores for the BEFORE and AFTER cases were 0.14 for Personal Relevance, 0.02 for Uncertainty of Science, 0.17 for Critical Voice, 0.21 for Shared Control, and 0.10 for Student Negotiation. The AFTER values are higher than the BEFORE values for every scale, indicating a slight, but positive, overall increase in the teachers' perceptions of constructivist practices in their teaching after experiencing the ISLE program.

Qualitative data collected from teacher journal entries also support this pattern in the quantitative data. When the ISLE teachers were asked how they would use constructivist methods to integrate what they had learned in Phase I into their classroom teaching in Phase II, the science teachers typically responded that they would perform the same hands-on activities in their classrooms. For example, teacher BD stated: "When we use our stream tables, I think that I will give the group rocks to place around to see if they can determine where it will erode first and then draw before and after." Another teacher (LB) anticipated that "by using this activity (Rope Trick), I can teach my students to work together to solve problems".

Based on additional qualitative data from interviews and observations, the similarity in responses does not appear to be linked to the school setting (i.e. public versus private, at-risk versus talented and gifted, nor state versus parochial status). Strict curriculum control by administration and classroom management issues were cited as the main reasons for continuation of prior learning environment practices with respect to three scales (Critical Voice, Shared Control, and Student Negotiation). Because this sample is limited to science teachers only, the other two scales (Personal Relevance and Uncertainty of Science) were assumed to be valued in the context of their prior training and, therefore, likely to be taken for granted.

Although not included in this quantitative analysis, non-science teachers also interconnected the ISLE experiences to support their specific teaching areas. For example, teacher CG noted that, for a social studies project, he planned to have his students "use brochures and maps to explain what, when, where, why they will go the direction that they choose". A mathematics teacher (MM) responded conceptually on a high level, stating that "I think one way you could stress the importance of leaving things how you found them would be to have several 'stations'

with different activities. In order for the activities to work, the person who did the activity before you must have it put back the way it started.”

Unlike the other forms (CLES-A and CLES-CS) that ask about someone else’s teaching, the CLES-CT is a self-assessment. As mentioned in section 8.2.3, one would not expect the individual perceptions of one’s own teaching to match other teachers’ self perceptions. Further analysis of the science teachers’ CLES-CT data is summarised in Table 24 in terms of the average item mean (illustrated in Figure 28), the average item standard deviation, and the results of Wilcoxon T tests.

The Wilcoxon matched pair signed rank statistic (T) is suitable for use with small samples. (For larger samples of 25 or more, the T values approximate a normal distribution and a t statistic could be computed.) It determines the likelihood of the mean difference happening as a result of chance variation. To be significant at 0.05 level, T must be less than the one-tailed critical value. The effect size was not calculated because this test uses ranked values to account for the smaller sample size. The paired T -value would result in an upwards bias (Becker, 1999).

Table 24. Average Item Mean, Average Item Standard Deviation, and Wilcoxon Matched Paired Comparison (T) for Science Teachers’ Perceptions of Classroom Environment on the Comparative Teacher Form of the Constructivist Learning Environment Survey (CLES-CT) for Lessons BEFORE and AFTER the ISLE Program

Scale	Average Item Mean		Average Item Standard Deviation		Difference in Classroom Teaching
	BEFORE	AFTER	BEFORE	AFTER	T
Personal Relevance	3.43	3.57	0.53	0.42	5.0
Uncertainty of Science	3.55	3.57	0.64	0.66	9.0
Critical Voice	3.52	3.69	0.43	0.47	1.5*
Shared Control	2.60	2.81	0.76	0.75	5.0
Student Negotiation	3.50	3.60	1.20	1.24	5.0

* $p < 0.05$, $T = 2.0$

N = 7 ISLE Science teachers

BEFORE refers to the teachers’ classroom practice prior to experiencing the ISLE program; AFTER refers to the same teachers’ classroom practice following the ISLE program.

Table 24 shows that T was significant at the 0.05 level only for the Critical Voice scale. Although changes were statistically significant only for Critical Voice, Table 24 shows that changes were positive for all five scales of the CLES.

In summary, the data suggest that the ISLE program (Phase I) was effective in terms of changes in the degree of implementation of constructivist teaching approaches in the teachers' public/private school classrooms (Phase II) as perceived by the ISLE science teachers.

8.3.2 Students' Perceptions of their School Classroom Environments (Research Question 2b)

As with the CLES-CT, four months after the teachers experienced the university coursework/extended field trip (Phase I), the impact of the ISLE program on public/private school classrooms (Phase II) was investigated also through administration of a second comparative form of the Constructivist Learning Environment Survey. In this section, the results of the comparative student form (CLES-CS) provide insight into the students' perceptions of their school classroom learning.

Students of the inservice science teachers who had participated in the ISLE program (see section 8.1.2.1) were asked to evaluate not only their current science classroom learning environments (THIS), but also the general learning environment of other classrooms in their school (OTHER). Differences between THIS and OTHER in student perceptions of learning environments were used in evaluating science teachers' experience with the ISLE program. Furthermore, a control group of students of inservice science teachers (see section 8.1.2.2) who had participated in field trips for the same Master of Arts in Teaching (MAT) program that were not based on the ISLE program (non-ISLE) also completed the survey.

Based on the validity of the CLES-CS for use in secondary schools in north Texas, the instrument was considered to be useful and reliable as described in section 8.2.1. Items contained within the CLES-CS (detailed in section 7.2.4) are presented in a side-by-side columnar format identical to the CLES-CT. The only difference is that the statements are phrased in language suitable for children, rather than adults. Descriptive statistics (means and standard deviations) and t tests were used to characterise the results for this new version of the CLES (Craft, 1990). The mean item scores were calculated for each learning environment scale of the CLES-CS

(Personal Relevance, Student Negotiation, Shared Control, Critical Voice, and Uncertainty of Science) on a five-point frequency response scale (5 = Almost Always, 4 = Often, 3 = Sometimes, 2 = Seldom, and 1 = Almost Never) for two cases (THIS and OTHER).

The focus of the study was to determine the effectiveness of the ISLE program. The data were examined using the individual student as the unit of analysis. The results for the CLES-CS are discussed in two ways. First, section 8.3.2.1 compares the students' perceptions of classroom environment for the ISLE science teachers with their perceptions for other teachers within their same school (THIS versus OTHER for students of ISLE science teachers only). The purpose of this analysis was to determine, from the perspective of the same students, how the ISLE science teachers' classroom environments differed from the environments of other teachers' classes.

Secondly, section 8.3.2.2 compares ISLE science teachers' students' perceptions of classroom environment with the perceptions of students of a control group of teachers who had attended a different field trip offered by the same university (ISLE versus non-ISLE). The purpose of this analysis was to determine, from the perspective of their respective students, how ISLE science teachers' classroom learning environments differ from those of teachers who experienced a similar university/field trip program that did not employ the ISLE model. These data suggest the possible impact of the ISLE program in terms of the teachers' ability to implement constructivist practice in their school classrooms.

Five ISLE science teachers (AC, AL, LB, LH, and RF) administered the CLES-CS student surveys. These teachers represent 445 public/private school students in 25 different classes. Five control science teachers who attended a previous field trip program (BT, EC, KM, LH, and TG) administered the student surveys. These teachers represent 328 public/private school students in 19 different classes. The final sample is representative of the population.

8.3.2.1 Comparison of Classroom Environments of ISLE and Other Teachers (THIS and OTHER)

To show the differences between the students' perceptions of the learning environments in the ISLE science teachers' classroom (THIS) versus overall environment for other teachers' classroom throughout the same school (OTHER),

Figure 29 graphically contrasts the average item mean scores of the CLES-CS using the individual as the unit of analysis. Note that the maximum range of values varies by a total of 1.52 units.

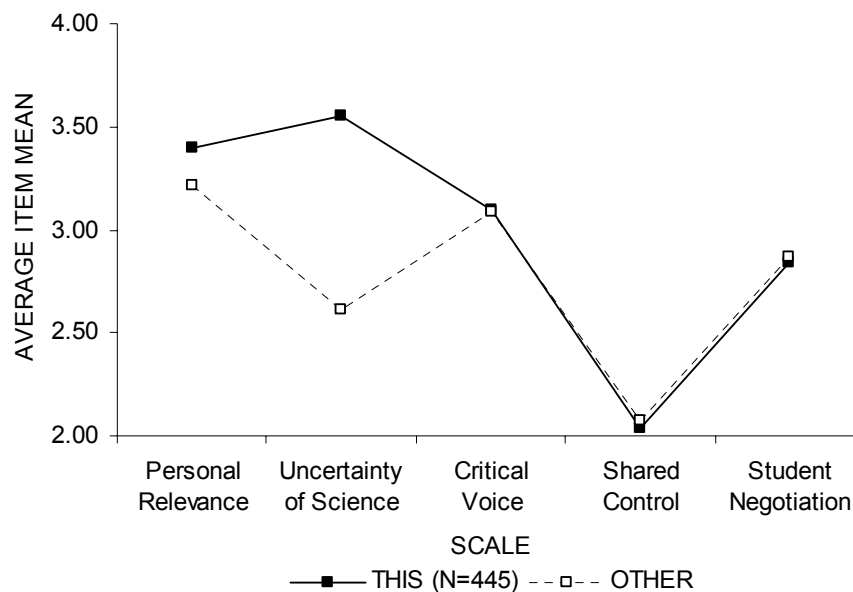


Figure 29. Students' Perceptions of ISLE and Other Teachers in the Same School: Results for the Comparative Student Form of the Constructivist Learning Environment Survey (CLES-CS)

For the ISLE science teachers' students, differences between the average item mean scores for THIS and OTHER were +0.19 for Personal Relevance, +0.94 for Uncertainty of Science, +0.02 for Critical Voice, -0.04 for Shared Control, and -0.02 for Student Negotiation. The range of these values (from 2.03 to 3.55) indicates that the practices encompassed by all scales of the CLES were perceived by the students to occur with an overall frequency of between Seldom (3.00) and Often (4.00) in the public/private schools for both ISLE science and other teachers.

The small differences between scores for THIS and OTHER on three of the scales of Critical Voice, Shared Control, and Student Negotiation suggest consistent perceptions about administrative policy and classroom management policy. Because this sample was limited to science teachers only, data for the other two scales (Personal Relevance and Uncertainty of Science) were likely to be skewed in the positive direction due to the specific emphasis on science-related content. The average item mean scores for Personal Relevance was 3.40 for ISLE teachers and 3.21 for teachers who had participated in other field trip programs. These data suggest that students perceive science as personally-relevant more often than not.

The greatest difference in average item mean scores was reported for Uncertainty of Science, ranging from 3.55 for ISLE teachers to 2.61 for teachers who had participated in other field trip programs. These data suggest that the ISLE teachers might present science in a way that demonstrates the uncertainty of science more often than teachers who attended alternative field trip programs.

In order to further investigate the differences in students' perceptions of the constructivist approaches present in their current ISLE science teacher's class (THIS) as compared with other teachers' classes (OTHER), scores were examined using a two-tailed *t* test for dependent samples. Also, the effect size (Becker, 1999) was also calculated using the means and standard deviations of two groups (THIS and OTHER) to portray the magnitude of the differences between the groups (Rubin & Babbie, 1993). Table 25 presents the results for each scale, assuming equal variances.

Table 25. Average Item Mean, Average Item Standard Deviation, Effect Size, and *t* Test for Dependent Samples of Differences Between Students' Perceptions of ISLE and Other Teachers in the Same School (THIS and OTHER) on the Comparative Student Form of the Constructivist Learning Environment Survey (CLES-CS)

Scale	Items	Average Item Mean		Average Item Standard Deviation		Difference	
		THIS	OTHER	THIS	OTHER	Effect Size	<i>t</i>
Personal Relevance	4	3.40	3.21	0.84	0.75	0.12	4.50**
Uncertainty of Science	5	3.55	2.61	0.78	0.95	0.48	20.86**
Critical Voice	6	3.10	3.08	0.90	0.87	0.01	0.63
Shared Control	6	2.03	2.10	0.83	0.83	0.04	-2.39*
Student Negotiation	5	2.84	2.86	0.99	0.93	0.01	-0.86

* $p < 0.05$, $t = 1.96$; ** $p < 0.01$, $t = 2.58$ (Items 3, 6, 7, and 25 were omitted.)

N = 445 students in 25 classes taught by 5 ISLE science teachers.

THIS refers to the ISLE science teacher's current class; OTHER refers to classes taught by other teachers in the same school.

The data in Table 25 show that differences between the classroom environments of THIS (ISLE science teachers) and OTHER (other teachers in the same school) are statistically significant ($p < 0.01$) for Personal Relevance and Uncertainty of Science. Not surprisingly, this indicates that students perceive the

ISLE science classroom as more relevant and uncertain in terms of content. At $p < 0.05$, the difference between THIS and OTHER for Shared Control is also statistically significant, yet in the opposite direction. These data suggest that students of ISLE teachers might not feel as comfortable about opening discussion within the science classrooms as do students of teachers who attended other field trip programs. However, this unexpected discrepancy could likely be attributed to the nature of the subject. For example, literature lessons may be based primarily on group review and interactive dialogue. Science lessons are typically based on experimentation that may be perceived as reporting of concrete information rather than independently formulated hypotheses. This might impact on the students' perceptions of the learning environment in that their questioning and participation is elicited in other classes, while the same is inherently enacted in the science classroom.

The effect size for each scale is also shown in Table 25. The effect sizes range from nearly nothing for Critical Voice, Shared Control, and Student Negotiation (0.04 to 0.01), to approximately one tenth of a standard deviation for Personal Relevance (0.12) and up to almost half of a standard deviation for Uncertainty of Science (0.48). The smaller effect sizes could suggest that the areas over which the administrative units appear to have strict control are resistant to change based on the ISLE program. By the same token, the magnitude of the larger effect sizes suggests that the ISLE program could be having an educationally important effect in improving the learning environment indicators over which the teachers evidently feel they have some control.

Additional qualitative data from the ISLE science teachers' journals support this interpretation. Teacher AC expressed this in the following entry. "Since my curriculum is Life Science and very set, the only things that I could incorporate are the medicine plants and some information on the plants. I would love to figure out how I could incorporate more". Teacher RF echoed this limitation as well. "Although Erosion and Deposition is now supposed to be in 7th grade science, I have much more to use when teaching [about the] Cretaceous period, faulting, igneous rocks, angle of repose, fossilization, chemistry (and its application), volcanoes, dikes, sills, earth history".

As an interesting aside, in contrast, qualitative data for the ISLE non-science participants suggested creative ways in which they might integrate what they learned into their curricula. Teacher GB noted that "I could integrate what I have learned into

almost any class, such as, English by reading about environments, dinosaurs and ancient history.” The administrator (LL) expressed yet another viewpoint in her statement that “I will use this information to view the upcoming political issues, on pollution, from a much broader perspective”.

8.3.2.2 Comparison of the Science Classroom Environments of ISLE Teachers with Teachers Who Attended Other Field Trip Programs

Data for the ISLE science teachers’ classrooms also were compared to results for the science classrooms of teachers who attended alternative field trip programs (see section 8.1.2.2). Using the individual as the unit of analysis, Figure 30 graphically presents the average item mean scores for the CLES for teachers who experienced ISLE and for teachers who had a different field trip program experience (ISLE and non-ISLE). The maximum range of values varies by a total of 1.56 units.

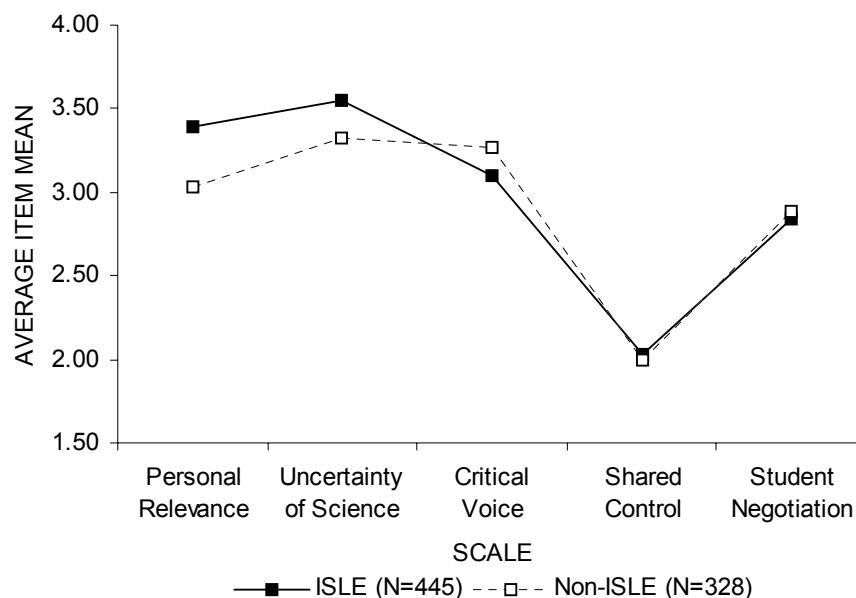


Figure 30. **Students’ Perceptions of Science Classroom Environment for ISLE Teachers and Teachers from Other Field Trip Programs: Results for the Comparative Student Form of the Constructivist Learning Environment Survey (CLES-CS)**

Students of the science teachers who attended other field trip programs (non-ISLE) perceived their science classrooms as slightly more constructivist than did students of the ISLE science teachers for two scales (Critical Voice and Student Negotiation). For the science teachers’ students, differences between the average item mean scores for ISLE and non-ISLE were +0.37 for Personal Relevance, +0.23

for Uncertainty of Science, -0.17 for Critical Voice, +0.04 for Shared Control, and -0.05 for Student Negotiation. Again, the range of these values (from 2.03 to 3.55) indicates that the practices encompassed by all scales of the CLES were perceived by the students to occur with an overall frequency of between Seldom and Often in science classrooms in the public/private schools for both ISLE and non-ISLE teachers.

In order to further investigate the differences in students' perceptions of the constructivist approaches present in the ISLE science teachers' classrooms (ISLE) as compared to other science teachers' classrooms (non-ISLE), CLES scale scores for the case of the current science classroom were examined using a two-tailed t test for independent samples. The effect size was also calculated to provide a measure of the magnitude of differences. Table 26 presents the results for each scale, assuming equal variances.

Table 26. Average Item Mean, Average Item Standard Deviation, Effect Size, and t Test for Independent Samples for Differences Between ISLE and Other Teachers on the Constructivist Learning Environment Survey (CLES-CS)

Scale	Average Item Mean		Average Item Standard Deviation		Difference Between Programs	
	ISLE	Non-ISLE	ISLE	Non-ISLE	Effect Size	t
Personal Relevance	3.40	3.03	0.84	0.96	0.20	5.65**
Uncertainty of Science	3.55	3.33	0.78	0.92	0.13	3.68**
Critical Voice	3.10	3.27	0.90	1.11	0.08	-2.28*
Shared Control	2.03	1.99	0.83	0.94	0.02	0.60
Student Negotiation	2.84	2.89	0.99	1.07	0.02	-0.61

* $p < 0.05$, $t = 1.96$; ** $p < 0.01$, $t = 2.58$ (Items 3, 6, 7, and 25 were omitted.)

$N_{ISLE} = 445$ students in 25 classes taught by 5 ISLE science teachers; $N_{Non-ISLE} = 328$ students in 19 classes taught by 5 non-ISLE science teachers.

ISLE refers to science teachers who participated in the ISLE program; non-ISLE refers to science teachers who participated in a different field trip program.

Table 26 shows that differences between the science classroom learning environments of ISLE and non-ISLE teachers are statistically significant ($p < 0.01$) for Personal Relevance and Uncertainty of Science. Interestingly, this indicates that students perceive the science classrooms of ISLE teachers as more relevant and the

topic more uncertain than do students in classrooms of teachers who attended other field trip programs. This suggests that the differences in these two scales might not be attributable solely to the nature of the course content. In fact, the data indicate that Personal Relevance and Uncertainty of Science scales could have been directly impacted by the ISLE program.

Again, at $p < 0.05$, differences between ISLE and non-ISLE teachers are also statistically significant for Critical Voice, yet in the opposite direction. This surprising difference suggests that students of ISLE teachers might not feel as comfortable about opening discussion within the science classrooms as do students of non-ISLE teachers. However, qualitative data suggest that this unexpected discrepancy could be a consequence of the overall school-level environment. Although the teachers' experience in the science classroom and the average number of students in each science class did not vary considerably, the basic demographics of the school did differ notably. The non-ISLE science teachers' schools were all characterised by a large total enrolment in urban and suburban settings. In contrast, the ISLE science teachers' represented two small parochial, one medium rural, and only two large suburban schools. This difference in overall demographics might account for the students' different perceptions of the learning environment, particularly reflected in the Critical Voice scale.

The effect size for each scale is also shown in Table 26. Using the individual as the unit of analysis, the effect sizes range from nearly nothing for Shared Control and Student Negotiation (0.02), to approximately one tenth of a standard deviation for Uncertainty of Science (0.13), and up to one fifth of a standard deviation for Personal Relevance (0.20). As before, the smaller effect sizes suggest that the areas over which the administrative units appear to have strict control are resistant to change based on the ISLE program. By the same token, the magnitude of the larger effect sizes suggest that the ISLE program could be educationally important for improving the learning environment indicators over which the teachers' evidently feel they have some control (i.e., Personal Relevance and Uncertainty of Science).

In summary, the data suggest that the ISLE program (Phase I) was effective in terms of the degree of implementation of constructivist teaching approaches in the teachers' public/private school classrooms (Phase II) for the ISLE science teachers, as perceived by their respective students.

8.3.3 Case Study: Comparison of One Teacher's and Her Students' Perceptions of Classroom Environment (Research Question 2c)

As mentioned in section 5.2, learning environments research has a broad range of applicability for today's diverse educational issues. The ISLE model integrated the use of new versions of the CLES, addressing three of the 12 major lines of past classroom environment research (Fraser, 1998a). First, to investigate differences between students and teachers in their perceptions of the same classroom environment, learning environment instruments can provide feedback information as a basis for reflection upon, discussion of, and systematic attempts to improve classrooms at all levels. Second, by combining quantitative and qualitative methods within the same study, learning environments research can provide an opportunity to use discrepancies between perceptions of the learning environment as a basis to guide improvements in classrooms. And, third, incorporating an understanding of psychosocial learning environments into teacher education provides a number of potentially valuable ideas and techniques for overall improvement in the classroom.

Unpredictably, one of the control group science teachers (LH), who previously had participated in another field trip program, also participated in the ISLE program, thus affording the opportunity for an in-depth case study. As a result, students' CLES-CS data from her classes surveyed the year BEFORE the ISLE program, students' CLES-CS data from her classes surveyed the year AFTER the ISLE program, and her own perceptions on the CLES-CT for those same classes both before and after the ISLE program, were used to develop the following investigation. In addition, as depicted in Figure 31, these data could also be compared with the average science teachers' CLES-A data from the ISLE program itself. This section examines how the teaching which she received throughout the ISLE program (Phase I) could have impacted on the learning environment in her science classrooms (Phase II), as perceived by herself and her respective classroom students.

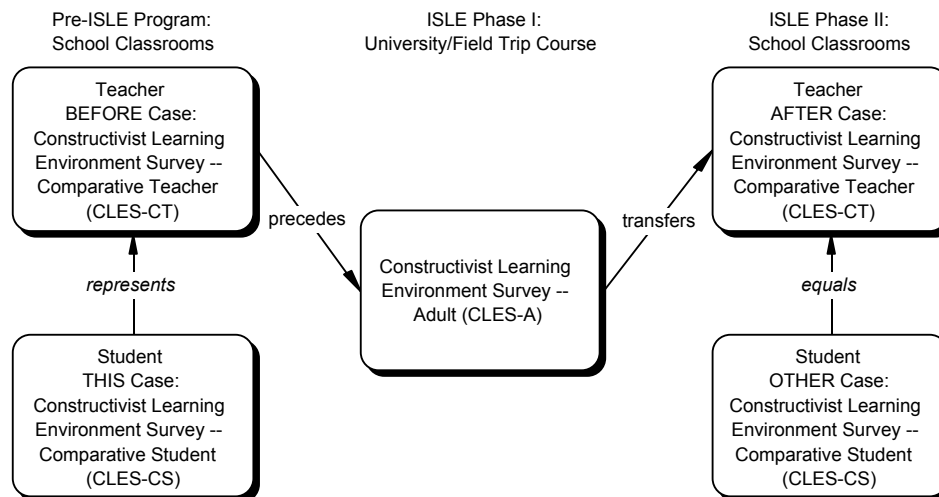


Figure 31. Relationships Between Instruments Used to Compare Teachers' and Students' Perceptions in the ISLE Model

Figure 31 shows how this unique instance might be represented as a pretest/posttest design (Gay & Airasian, 2000) that encompasses the complete ISLE model. The first set of students' perceptions (pretest), provided as CLES-CS scores for the science teacher's classroom, should correspond with the teacher's self-assessment of her teaching before the ISLE program, reported as the BEFORE case on the CLES-CT. Similarly, the second set of students' perceptions (posttest), provided as CLES-CS scores for the science teacher's classroom, should correspond with the teacher's self-assessment of her teaching after the ISLE program, reported as the AFTER case on the CLES-CT. These data, in turn, should correspond with the overall ISLE science teachers' perceptions of the constructivist practice modelled by the instructors in Phase I, provided as CLES-A scores, and also should be reflected in the learning environment changes evidenced in Phase II.

The particular case study teacher, LH, was a female participant (77% of the sample) over the age of 46 years (31% of the sample). She had between 11 and 15 years of teaching experience (15% of the sample) and was presently teaching at the secondary level (88% of the sample) in a large, suburban, public school. She did have a computer (85% of the sample) and access to the Internet (92% of the sample) in her home. She held a Master of Arts in Teaching in Science Education awarded by the Department of Science/Mathematics Education at the University of Texas at Dallas and had participated in numerous science education field trips to the same area and with the same instructors before the ISLE program was implemented. The possible impact of the ISLE program on this specific classroom learning environment

is described below in terms of changes in the teacher's perceptions, changes in the students' perceptions, and differences between the teacher's and students' perceptions of the same classroom.

Using the individual as the unit of analysis, the following figures graphically compare these perceptions of the classroom learning environments. Figure 32 compares this teacher's perceptions of the classroom learning environment using the results of the CLES-CT (BEFORE and AFTER) for one science teacher (LH). Figure 33 compares the students' perceptions of the classroom learning environment using the results of the CLES-CS (THIS only) for two independent groups of students (ISLE and non-ISLE). And Figure 34 compares the teacher's and students' perceptions of the same classroom learning environment using the results of the CLES-CT and CLES-CS after the ISLE program. The mean item scores were calculated for each learning environment scale of the CLES (Personal Relevance, Student Negotiation, Shared Control, Critical Voice, and Uncertainty of Science) on a five-point frequency response scale (5 = Almost Always, 4 = Often, 3 = Sometimes, 2 = Seldom, and 1 = Almost Never).

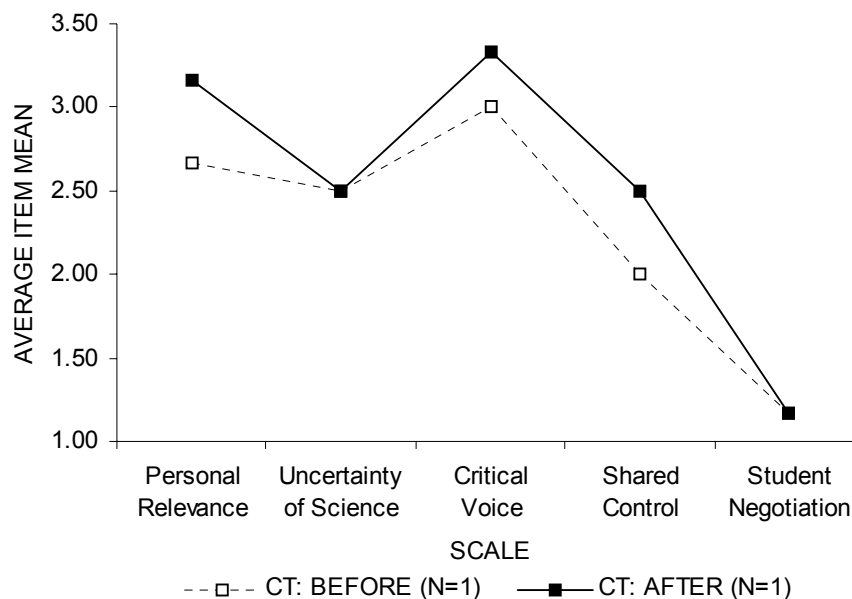


Figure 32. **Change in One Science Teacher's Perceptions of Classroom Learning Environment: Case Study Results (BEFORE and AFTER) for the Comparative Teacher Form of the Constructivist Learning Environment Survey (CLES-CT)**

As self-assessed using the comparative teacher form of the CLES (see section 7.2.3), the data shown in Figure 32 reflect a change in the positive direction for three

scales (Personal Relevance, Critical Voice, and Shared Control) for this teacher. Based on this teacher's ISLE program experience, there was no perceived change in the other two scales of the CLES (Uncertainty of Science and Student Negotiation). This indicates that the teacher perceived her teaching after the ISLE program to be more constructivist in nature, particularly with respect to Personal Relevance (+0.50), Critical Voice (+0.33), and Shared Control (+0.50).

Qualitative observations support this evaluation. Although the teacher had participated previously in many similar field trips, her leadership role could be characterised as one of service. For example, if someone developed a foot blister after an arduous hike, she would treat it and monitor that person's performance throughout the duration of the trip. As the ISLE model was designed to foster collaboration through team building activities covertly built into Phase I, participants in the ISLE program assumed more equal personal and professional designations. Each member readily accepted a dual role to support the group effort, working as both teacher and student, trainee and mentor, or guide and backup, as appropriate. It is reasonable to infer that this teacher thereby sensed a higher level of value and self-efficacy within the group; hence, the measurable increase in her perceptions of Personal Relevance, Critical Voice, and Shared Control.

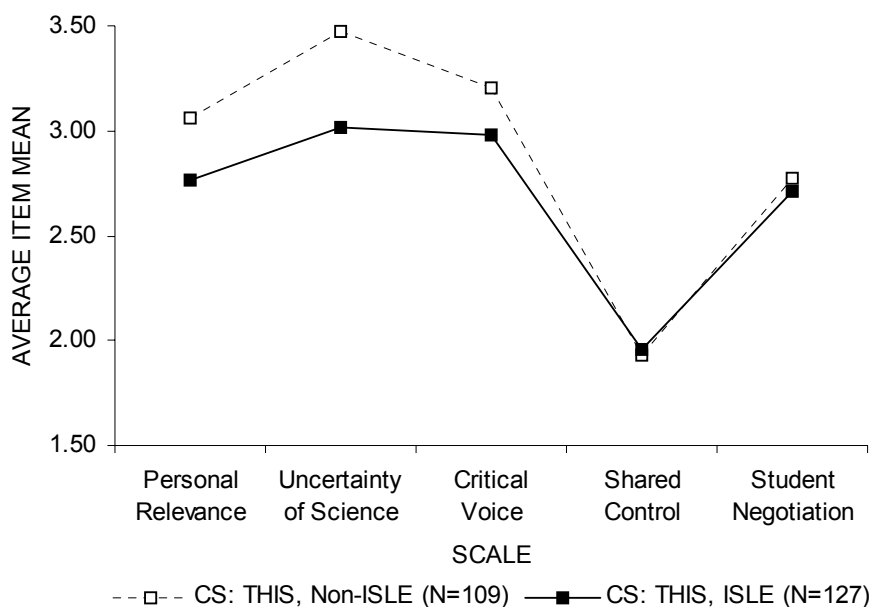


Figure 33. **Comparison of Students' Perceptions of Classroom Learning Environment for Two Programs (ISLE and Non-ISLE): Case Study Results for the Comparative Student Form of the Constructivist Learning Environment Survey (CLES-CS)**

Figure 32 shows the change in the teacher's perceptions of the classroom environment BEFORE and AFTER the ISLE university/field trip program. Paradoxically, as evaluated using the comparative student form of the CLES (see section 7.2.4), the data shown in Figure 33 reflect noticeable differences in the negative direction for differences between students' perceptions of ISLE and other field trip programs for all but two scales: Shared Control (+0.03) and Student Negotiation (-0.07). Students perceived the science classroom environment to be less constructivist in nature, particularly with respect to Personal Relevance (-0.30), Uncertainty of Science (-0.46), and Critical Voice (-0.22), after ISLE than when the teacher undertook another field trip program.

Although this analysis involved independent samples, the qualitative evidence could reflect an inherent aspect of any pioneering change. For the most part, today's students expect to be taught just as their parents and teachers were taught. Described in section 6.1.1, the constructivist paradigm involves students in an interactive process, allowing them to learn through discovery and experience. Determination of whether or not the students were prepared to assume responsibility for their own learning was beyond the scope of this particular study; however, the data indicate that a measurable change in the school classroom was perceived by the ISLE teacher's students (Figure 33).

It is also useful to compare the teacher's perception of the classroom environment to that of the students who comprise the contemporary classes. Figure 34 shows results from two different versions of the comparative forms of the CLES. The AFTER case of the CLES-CT and the THIS case of the CLES-CS assessed the classroom learning environment following the teacher's completion of the ISLE program. The magnitude of the differences in teacher and student perceptions were somewhat similar in all but one scale, Student Negotiation (-1.54). As typical of classroom assessments, the teacher's perceptions were generally more positive for Personal Relevance (+0.40), Uncertainty of Science (-0.51), Critical Voice (-0.22), and Shared Control (+0.54).

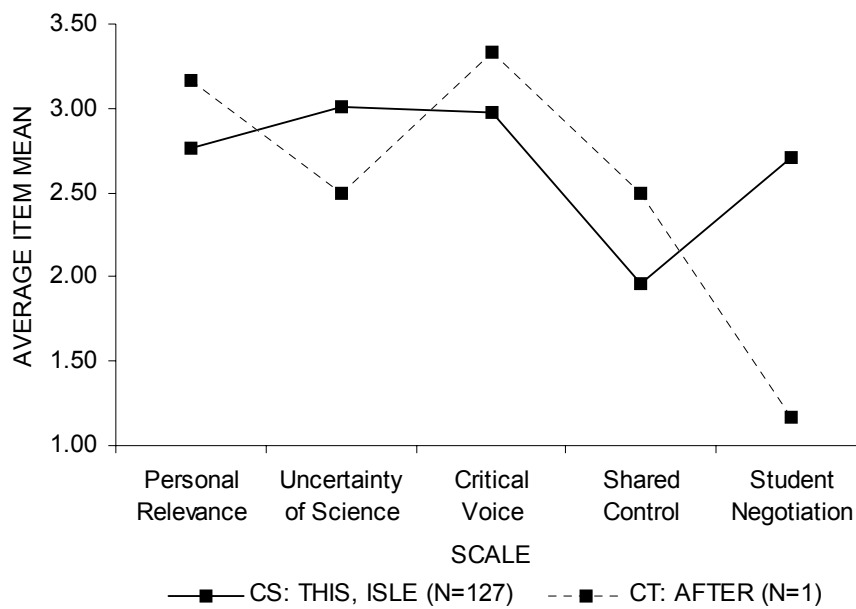


Figure 34. **Difference in One Teacher's and Students' Perceptions of the Same Classroom Learning Environment: Case Study Results for the Comparative Forms of the Constructivist Learning Environment Survey (CLES-CT and CLES-CS) after ISLE**

Interestingly, the same anomaly for Student Negotiation was evident in the results of the pretest comparison. The students' perceptions of this aspect was noticeably more positive than that of the teacher (+1.61). On further investigation, it was discovered that the teacher had severe hearing loss in the midrange tones. As this scale concerns the students' involvement with other students in assessing the viability of new ideas, the teacher's consistently lower ratings could be explained by her difficulty with the awareness of such casual discussion in a larger classroom setting.

In summary, this case study illustrates how qualitative data can be incorporated to support quantitative data based on a comprehensive study and illuminates the usefulness of an in-depth case study. It also demonstrates one way in which learning environments research can be used to improve the learning environment in school classrooms through teacher education and professional development in model university classrooms and across integrated science learning environments.

8.4 Effectiveness of ISLE University/Field Trip Program in Terms of Teachers' Perceptions of Classroom Environment, Attitudes to Technology, and Conceptual Development (Research Question 3)

While the previous section examined the impact of the ISLE program on the public/private school classroom (Research Question 2), this section reports on the effectiveness of the university/field trip course (Research Question 3). The learning environment fostered by the university instructors in Phase I is assessed in three subsections. To answer Research Question 3a, which concerned the teachers' perceptions of the ISLE course, the results of the adult form of the Constructivist Learning Environment Survey (CLES-A) are discussed in section 8.4.1. Research Question 3b concerned changes in the teachers' attitudes toward information technology. Section 8.4.2 presents data from the teachers' Reflective Field Journal and responses on the Teachers' Attitudes Toward Information Technology (TAT) questionnaire to answer Research Question 3b. Qualitative and quantitative data from observations, reflective field journals, and individual concept maps are discussed in section 8.4.3 to answer Research Question 3c which specifically addresses the teachers' conceptual development.

8.4.1 Effectiveness of ISLE University/Field Trip Program in Terms of Teachers' Perceptions of the Learning Environment (Research Question 3a)

One of the primary goals of Phase I was for the university instructors to model constructivist teaching practice for the teachers and administrator. To evaluate this aspect of the ISLE university/field trip program, the Constructivist Learning Environment Survey – Adult form (a useful instrument for this population as shown in section 8.2.2) was administered to all ISLE program participants (see section 8.1.1). The composite group of 12 preservice/in-service teachers and one administrator were asked to evaluate the instructors' teaching in Phase I, the university coursework/extended field trip. Seven science teachers (all but one) and five non-science participants completed the survey.

Based on a posttest-only design (Gay & Airasian, 2000) with a single treatment group, the purpose of these CLES-A data was exploratory in nature. Descriptive statistics (means and standard deviations), used to characterise use of this new version of the CLES, also depict the overall perceptions of the learning environment (Craft, 1990) for the combined sample of science and non-science ISLE

participants (refer to section 8.2.2). The small sample size does not support analysis of differences between the mean individual scores (to determine the distinct views of each individual) and mean class scores (to represent the collective view of whole classes of participants) typically used in learning environment studies (Pace & Stern, 1958). It is important to remember that these data reflect the ISLE participants' perceptions only of Phase I (the university coursework/extended field trip) and that each component of the ISLE program was presented in the same way to all participants, regardless of content background.

The mean item scores were calculated for each learning environment scale of the CLES-A (Personal Relevance, Student Negotiation, Shared Control, Critical Voice, and Uncertainty of Science) on a five-point frequency response scale (5 = Almost Always, 4 = Often, 3 = Sometimes, 2 = Seldom, and 1 = Almost Never). To distinguish the perceptions of participants with science and non-science training, Figure 35 graphically contrasts the average item mean scores on the CLES-A for science and non-science participants. Note that the maximum range of scores varies by a total of 1.02 units. For comparison, as reported in Figure 25, the average item mean score for the combined sample of 12 participants (science and non-science) was 4.64 for Personal Relevance, 3.93 for Uncertainty of Science, 4.38 for Critical Voice, 4.06 for Shared Control, and 4.36 for Student Negotiation. These values indicate that the practices encompassed by all scales of the CLES-A, except Uncertainty of Science, were perceived to occur with an overall frequency of between Often and Almost Always.

The average item mean difference between science and non-science participants on each scale ranged from 0.12 for Personal Relevance to 0.57 for Student Negotiation. It is interesting that the science participants' scores are slightly higher than the non-science participants' scores on all scales except Critical Voice, for which the average item mean difference is 0.04. This anomaly supports the claim that the ISLE program was delivered to all participants in the same way. Evidently Critical Voice was perceived to be independent of content generally. In contrast, the other four scales were perceived as being somewhat dependent (grounded intellectually and emotionally) on prior knowledge and comfort level based on conceptual understanding in science-rich areas.

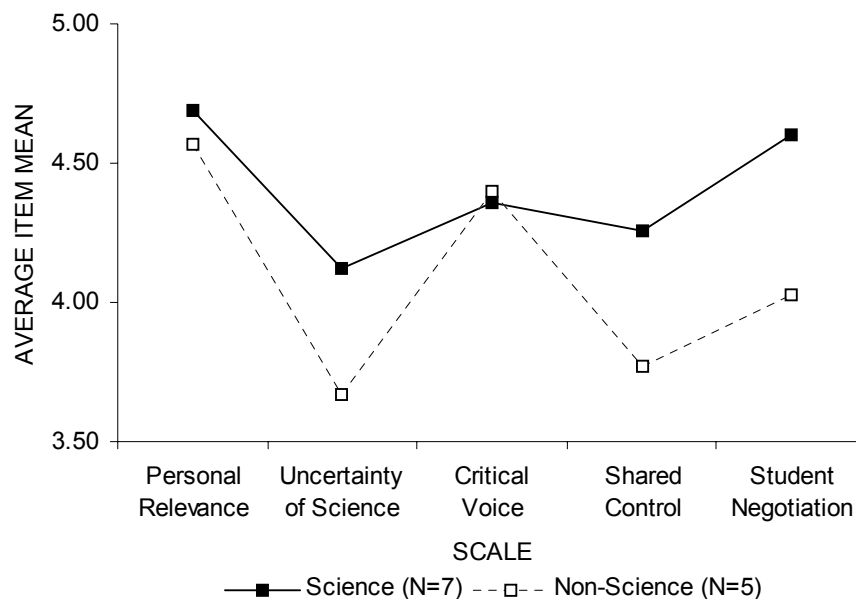


Figure 35. Participants' Perceptions of Teaching in Phase I: Average Item Mean for the Adult Form of the Constructivist Learning Environment Survey (CLES-A)

Qualitative data support this quantitative data interpretation. When asked about learning science on the extended field trip, a science teacher (AC) responded: “My curiosity is struck and I dig to find the answers.” Another science teacher (AL) noted in her journal: “You [field ecology instructor] set a good example for me as a teacher to follow.” A non-science teacher (GB) stated that her frustrations about learning science in the field were a result of “not feeling competent in doing the data samples”; however, she added that “the good point is that we have direct access to real scientists to ask our questions”. Another non-science teacher (CG) noted in his journal that “hands-on work is the best way to learn” and “gets the mental juices flowing” to foster creativity.

In summary, the data suggest that the instructors’ teaching in Phase I of the ISLE program successfully modelled constructivist pedagogy for the ISLE participants, particularly for science teachers.

8.4.2 Effectiveness of ISLE University/Field Trip Program in Terms of Teachers’ Attitudes to Information Technology (Research Question 3b)

Throughout the ISLE program, the main feature of the model – information technology – was transparently integrated into the scientific processes and pedagogical procedures. Detailed in Chapter 3 and Chapter 4, a process approach to

information technology-supported instruction was used to develop a relevant framework for the virtual field trip within the open structure of the World Wide Web. Phase I was focused on teaching and learning, rather than tools and techniques, to help teachers to internalise the value of information technology for their students in Phase II. Research Question 3b concerns the effectiveness of the university/field trip course in terms of changes in teachers' attitudes to the integration of information technology into their teaching.

Section 6.2 described how each of the distinctive factors of the ISLE model was researched and investigated in separate case studies to isolate and test the techniques combined in the comprehensive ISLE model. These preliminary case studies supported several aspects of integrating information technology specific to this sample. The World Wide Web was determined to be an appropriate mechanism for delivering science content to classroom teachers. The process approach to teaching and learning was shown to encourage communication, collaboration, and creativity. And, more importantly, a process approach could be used to promote a sense of personal relevance and ownership in technology-enhanced projects. Practically, the design and presentation of virtual field trips on the World Wide Web was assessed in terms of key content, as well as educational and support components.

Combined with qualitative data from interviews, observations, and journal entries, quantitative data were collected regarding changes in teachers' attitudes to the integration of information technology throughout Phases I and II of the ISLE program. Section 8.4.2.1 describes the ISLE teachers' perceptions of use of information technology in the university classroom/extended field trip segment (Phase I) as reflected in terminology and responses to field journal questions. In section 8.4.2.2, changes in the teachers' attitudes toward information technology are presented in terms of the results of the pretest/posttest administration of the Teachers' Attitudes Toward Information Technology (TAT) questionnaire. In summary, section 8.4.2.3 documents the transfer of this change into their public/private school classrooms (Phase II) through examples of the teachers' actual and intended integration of information technology based on their ISLE program experience.

8.4.2.1 *Qualitative Information about Teachers' Attitudes to Information Technology in Phase I*

Qualitative data from interviews, observations, and journal entries were used to assess the impact of the instructors' use of information technology in the university classroom/extended field trip segment (Phase I) on teachers' attitudes to information technology. The goal was to make an impact on the ISLE teachers' attitudes to the implementation of technology in their respective public/private school classrooms (Phase II).

The seamless integration of information technology in the ISLE program was covert (refer to section 3.4.1). Maintaining a comfortable, non-intrusive, team-oriented environment was critical to achieving the desired outcomes. Discussed in depth in section 5.4.3, teachers' attitudes toward information technology have a major impact on the way in which they learn – *and teach*. It was important to minimise emphasis on the actual hardware and software to develop the conceptual recognition of the role of technology applications in education. At the same time, the ISLE model afforded the teachers the time and the opportunity to experiment with new tools and resources in a supportive environment. Therefore, the effectiveness of the instructors' modelling of technology-supported teaching must be inferred from changes reflected in the teachers' comments concerning the use of information technology in an educational setting.

In the first formal class meeting, as part of an introduction led by the information technology assistant (also the researcher), all program participants were asked to write their spontaneous definition of 'educational technology'. The purpose of this exercise was to pre-assess their understanding of and preconceptions toward information technology in the context of teaching (refer to section 7.2). The field ecology instructor and information technology assistant (the researcher) used this information to establish a baseline for teachers' attitudes toward and perceptions of information technology. Additional qualitative data (observations, interviews, and journal entries) were recorded on individual participation in university activities and guided discussion, as well as from local day trips, to support assessment of changes in the teachers' understanding and perceptions of information technology during and after the ISLE program.

The total sample of 13 participants (section 8.1.1), although small, is representative of the population and thus acceptable for this study. It is worth

mentioning that four of the non-science teachers (AL, CB, CG, and MM) had completed an educational technology course taught by the information technology assistant during the semester prior to the ISLE program. Also, two science teachers (GO and LB) had recently completed a marine science course taught by the field ecology instructor and supported by the information technology assistant. These students were thereby more familiar with the instructors' interpretations of and expectations for applications of information technology.

Not surprisingly, responses varied widely within each group, with nearly all approaching the topic at a general level. The term 'information' was used in three definitions, while reference was made to 'tools' in five separate instances. The word 'computer' was mentioned once. As shown in the following quotation, only one teacher (GB, non-science) specified how the concept might be realised in the classroom:

Educational technology is combining information in a visual, hands-on learning environment. Students learn by seeing, hearing, doing and interacting. The computer allows one to do all. It also allows one to perform research to gain more information. It allows students to present their research in an interesting way rather than just doing a boring oral presentation.

At the other extreme, one science teacher (RF) openly expressed his negative attitude: "Educational technology is a hindrance – it substitutes learning about technology for the science that should be learned." Another science teacher (AC) alluded to her lack of training and preparation with respect to emerging applications for teaching: "Educational technology is a tool that could be used more widely if set up properly and explained more where to find it and how to use it."

As noted in their journal entries (recorded after completion of the university classroom instruction and throughout the extended field trip), both science and non-science teachers' attitudes toward integrating information technology became more informed and more positive. For example, teacher AC later stated that her perspective of field work changed drastically in that: "All the equipment and detail in doing field work surprised me. The collaboration of everyone and team work required were amazing." Teacher BD found it "interesting to see how different people used the instruments". Also enrolled in the photographic field collections course, she responded to a field ecology question as follows: "The artefacts I plan to

use [in my classroom teaching] are my personal slides, which I hope to incorporate into PowerPoint [electronic presentation software], books, and the web [virtual field trip] we all will create.”

Similarly, the teacher most opposed to using technology initially (RF) responded that: “This year I intend to have much more reported to me than in the past in the form of [electronically] charted and graphed collected data with some sort of analysis.” In fact, he eagerly anticipated transferring part of his ISLE program experience by adding technology to his classroom teaching as indicated in the following excerpt:

This next year I will be using probes for the first time – [the probes] just came in right before we left. I haven’t even taken them out of the box yet. So the testing [on-site data collection] we did at each location is something I can adapt to my classes immediately.

Non-science teachers also developed an enhanced appreciation of information technology throughout the ISLE program. For example, a first-year history teacher (CB) cited a benefit of the unrestricted access to the virtual field trip archive: “This [Furry or Fuzzy? activity] was fun! Now I have the instructions to do this in class and I may use this for my other summer class on dispelling stereotypes about Native Americans.” Another advantage is that the virtual field trip product provided a classroom resource that represented the teachers’ first-hand experience in a protected area. Collecting of any sort is strictly prohibited in national parks. Along this line, teacher GB stated:

I didn’t collect any artefacts from the site, but I do have examples of sedimentary rock, igneous and metamorphic rocks at home. I plan on using the Dirt Cake activity to show how rivers and streams impact the fossil record. Also, the pictures we took will be incorporated into visual lessons. These pictures can be used to develop lab exercises, games, and tests.

Additional comments reflected the teachers’ renewed energy and excitement toward using technology to organise, analyse, and present their own work for the ISLE program. Several directly referenced producing the virtual field trip product on their return from the field. Teacher AC wrote that she “look[ed] forward to completing this project so that others can at least get a glimpse of what Big Bend has to offer”. In reflecting on the single class that overtly focused on technology

(detailed in section 4.1.8), teacher LB aptly expressed the common sentiments of her peers:

We then began a study of the maps of Big Bend and discussed what types of rocks were where and why. The computer lab was our next trip where we discussed our various themes [individual field investigations] and looked at organizing this material [as a website]. I am looking forward to using a lot of the projects that we are doing in class in my own classroom. Finally I am excited about the project [virtual field trip] that I am going to be involved in creating.

In summary, the data suggest that the instructors' teaching in Phase I of the ISLE program successfully modelled the seamless integration of information technology in an educational context. Equally importantly, the deliberate design of the ISLE model supported positive change for all ISLE participants along a spectrum of individual comfort and proficiency levels of information technology adoption.

8.4.2.2 Changes in Teachers' Attitudes Toward Information Technology on the TAT

One of the primary goals of Phase I was for the university instructors to model the appropriate use of information technology for the public/private school classroom teachers and administrator. To assess changes in the teachers' attitudes to information technology as a result of the ISLE program, the Teachers' Attitudes Toward Information Technology (TAT) questionnaire (described in section 7.2.1) was administered to all ISLE program participants (see section 8.1.1) using a pretest-posttest design (Gay & Airasian, 2000). The TAT has five scales that assess attitudes toward Electronic Mail, World Wide Web, Multimedia, Personal Productivity, and Classroom Productivity. The TAT pretest was administered at the second university class meeting (Phase I) to determine the teachers' initial dispositions. The TAT posttest was administered toward the end of the first public/private school semester following the ISLE program (Phase II).

Descriptive statistics (means and standard deviations) and the Wilcoxon matched pair signed rank T test were used to characterise the teachers' overall change in attitudes toward information technology (Craft, 1990). Although all 13 participants completed the pretest questionnaire, only one non-science teacher (CB) and seven ISLE science teachers (AC, AL, BD, GO, LB, LH, and RF) returned the posttest questionnaire. Because of the focus on science content, the sample used to

answer this part of Research Question 3 is limited to the seven ISLE science teachers only (see section 8.1.1.2). This sample size does not support parametric analysis of pre-post differences between attitude scores. Therefore, a non-parametric model, which does not assume a normally-distributed population and does not require interval-level measurement, was employed.

Scores for each attitude scale of the TAT (Electronic Mail, World Wide Web, Multimedia, Personal Productivity, and Classroom Productivity) were obtained on a 7-point semantic differential scale (1 = least positive and 7 = most positive). Figure 36 graphically presents the average item mean scores of the ISLE science teachers for the pretest and posttest TAT. Note that the vertical scale is partially represented as the maximum range of values varies by 0.76 units.

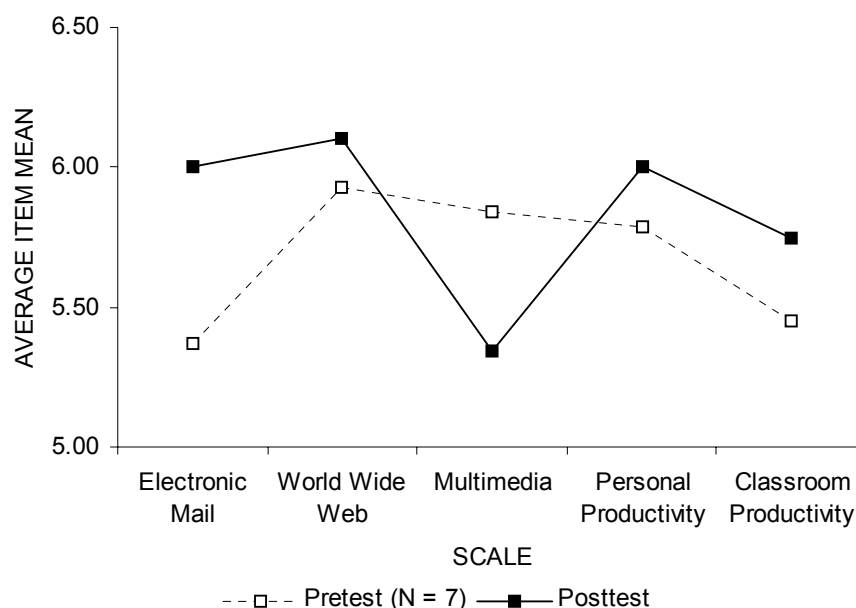


Figure 36. **ISLE Science Teachers' Attitudes Toward Information Technology: Pretest/Posttest Results of the TAT Questionnaire**

The difference between the average item mean scores for the sample of 7 ISLE science teachers was 0.63 for Electronic Mail, 0.17 for World Wide Web, 0.50 for Multimedia, 0.21 for Personal Productivity, and 0.30 for Classroom Productivity. In spite of the fact that the scores were relatively high (ranging from 5.34 to 6.10) overall, these values indicate a positive change in teachers' attitudes toward information technology in all but one scale of the TAT (namely, Multimedia).

In the context of the ISLE model (detailed in section 3.1), these results are not unexpected. Throughout the ISLE program, computers were used at the

individual's discretion. Through electronic mail, teachers asked questions, turned in work, and shared ideas. They used the World Wide Web to research and study topics related to the course. They experienced multimedia in the form of an electronic presentation and additional resources, like CD-ROMs. Scientists expect to use function-specific devices for their work. Presenting the computer as simply another tool demonstrates its power as a dynamic resource. Therefore, the researcher believes that the lower posttest score for the Multimedia scale indirectly reflects the teachers' better understanding of what 'information technology' encompasses and how it can be applied to enhance teaching and learning.

Further analysis of the TAT data is summarised in Table 27 for each scale in terms of the average item mean, average item standard deviation, and the Wilcoxon T value. The Wilcoxon matched pair signed rank statistic (T) is suitable for use with small samples. (For larger samples of 25 or more, the T values approximate a normal distribution and a t score statistic could be computed.) It determines the likelihood of the mean difference happening as a result of chance variation. To be significant at 0.05 level of significance, T must be less than the one-tailed critical value. The effect size was not calculated because this test uses ranked values to account for the smaller sample size. The paired T -value would result in an upwards bias (Becker, 1999).

Table 27. Average Item Mean, Average Item Standard Deviation, and Wilcoxon Matched Paired Comparison (T) for Pretest and Posttest Results for the Teachers' Attitudes Toward Information Technology Questionnaire (TAT) for ISLE Science Teachers

Scale	Average Item Mean		Average Item Standard Deviation		Difference in Teachers' Attitude
	Pretest	Posttest	Pretest	Posttest	T
Electronic Mail	5.37	6.00	1.41	1.05	4.0
World Wide Web	5.93	6.10	1.18	0.92	12.5
Multimedia	5.84	5.34	1.11	1.59	-9.0
Personal Productivity	5.79	6.00	1.20	1.02	12.0
Classroom Productivity	5.45	5.75	1.44	1.01	10.0

* $p < 0.05$, $T = 2.0$

N = 7 ISLE Science teachers

Although the data show that T was not statistically significant for any scale, qualitative details, and the researcher's prior experience, support it as useful for evaluation for the ISLE program. In the second case study in support of the ISLE model (section 6.2.2), a process approach to integrating information technology did impact on a larger sample (Nix, 2001b, 2002). The lack of statistical significance could be attributed to a 'ceiling effect' as the scores were relatively high in both the pretest and posttest. Also, because this instrument measures a self-assessed attitudes, the scores could be upwardly biased. Finally, teachers are typically 'teacher-pleasers' and might have reported higher scores inadvertently.

Nevertheless, the single case of a negative change in Multimedia does warrant notice. The researcher and instructor interpreted this as an indicator of affirmative progress. As the teachers' understanding of how to use information technology to support and enhance learning increased with their experience in the ISLE program, they recognised that the tools and resources can be more than fast-paced, full-colour, stereophonic entertainment. This common misconception about educational technology is often attributed to the 'edutainment' value of multimedia simulations (refer to section 5.4.3).

Discussion of innovative uses of information technology inspired individual creativity and opened new possibilities for education in general. Based on additional qualitative observations, it is not unreasonable to presume that the non-science teachers' perspectives enriched the entire experience and offered insight into teaching science to students of different learning styles. By realising the value of integrating applications of information technology through their individual learning experience within the ISLE program, the teachers were empowered to transfer appropriate uses to their individual teaching practice in the public/private school classrooms as further supported in section 8.4.2.3.

In summary, the data suggest that the ISLE program (Phase I) facilitated a positive, but statistically nonsignificant, overall change in the participants' attitudes toward information technology.

8.4.2.3 Qualitative Information about Teachers' Application of Information Technology in School Classrooms in Phase II

If not implemented, even the best pedagogy is ineffective. As stated in section 1.2, the ultimate goal of the ISLE program was to initiate a change in the

students' public/private school classroom learning environments by changing the teachers' university classroom/extended field trip learning environment. To that end, this section documents the transfer of the positive overall change in the participants' attitudes toward information technology into their public/private school classrooms (Phase II). Examples of the teachers' actual and intended integration of information technology based on their ISLE program experience are presented to evaluate this component of the study.

Along with the limitations discussed in section 7.4.5, this sort of long-term change is difficult to document without direct observation over an extended period of time (which was beyond the scope of this study). However, subsequent reports of the impact of the ISLE program on the public/private school classroom are positive and powerful. The holistic approach to teaching and learning promoted through the ISLE model (see section 3.4.1) was designed to seamlessly integrate all aspects of the learning environment; therefore, it is difficult to separate the results into individual topics. As such, the teachers' integration of information technology into their classrooms was directly tied to their implementation of constructivist teaching practice. Real-world applications of new tools and resources in Phase I similarly provided timely and relevant uses and ideas for extension to Phase II.

Several questions (see Final Reflections in Appendix III.5) were added to the Field Journal requirements (see section 7.2.6) to help the teachers discover and develop innovative ways to integrate information technology into their teaching. Intended to measure the information and teaching applications acquired in Phase I, the following questions were asked to guide the participants' reflection on their learning and to guide development of their teaching:

- 1) Into what part of the curriculum that you teach will you integrate what you learned today?
- 2) How will you use hands-on activities to accomplish the integration?
- 3) What artefacts will you use to help your students to attain this knowledge or skill?
- 4) How will you check to see if your students 'got it'?

Based on their responses and other unsolicited comments, a list of teacher-generated ideas for using the virtual field trip in the diverse classroom settings, sorted by grade level and subject matter, was added to the end product of the ISLE

program, the virtual field trip made available as the Global Environment Change website. These creative ideas, reproduced in Appendix IV, were recommended by actual field trip participants as starting points for Early Elementary, Upper Elementary, and Secondary class lessons for using the information that they helped to make available to virtual field trip visitors. In addition to these lesson ideas, additional information on pedagogy and practice was also archived on the website to support integration into classroom teaching (for example, see Ledbetter, 2000a).

The participants of past Master of Arts in Teaching (MAT) field trips offered through UTD's Science/Mathematics Education Department program unanimously report using artefacts (photographs, samples, activities, stories, and other concrete items) from their summer experience in the first few weeks of the following school year (for example, see Ledbetter, 1999a). Immediate transfer is typical of almost all successful professional development programs, and the ISLE program was no exception. The notable difference is that other participants' relics (i.e., digital photographs, data sets, and full project reports) were made easily accessible to all individuals through the virtual field trip (Global Environment Change website). Because each member played an active role in the development of this resource, the teachers (both science and non-science) had an inherent understanding of what was available to them and how it might be useful to improving their students' learning. (Refer to section 3.2.) More importantly, they had internalised their ability to transfer the comfort and skills needed to support their individual use of information technology through constructivist pedagogy through the ISLE program. The following select examples support this overall development.

To support inquiry-based teaching (see section 6.1.1), teacher MS incorporated photographs from the digital image bank (a collection of digital photographs taken by participants in Phase I and presented in a gallery format for use in Phase II) into a PowerPoint presentation required for another class. Rather than captioning each slide with the descriptive facts and figures, she introduced each image with a question that stimulated higher-order critical thinking and developed observation skills. Having been associated with the university instructors for several years, it was interesting that she adopted this new approach to teaching.

To support the visual representation of knowledge (see section 6.1.2), teacher BD similarly used the digital image bank several months later to create a presentation about weather. Although this topic was not directly addressed in the ISLE program,

she realised the value and took advantage of the availability of this virtual field trip website to integrate her ISLE program experience into her classroom teaching. A rather quiet participant, she had some trouble producing her final project and therefore she spent several hours working on the computer in the information technology assistant's office. Establishing a network of like-minded educators with a common experience enabled her to share this subsequent work not only with the instructors, but also with her peers at other schools in addition to colleagues at her own school.

To support hands-on learning (see section 6.1.3), the experiential activities performed in Phase I (university classroom and extended field trip) were also archived within the virtual field trip (Global Environment Change website). Participants and other visitors had access to the online teacher instructions and student worksheets as needed. A casual remark made by teacher AC in an educational research class provides encouraging evidence of the internalisation and transfer of the ISLE experience. One year after participating in the ISLE program, she had retrieved an activity from the virtual field trip website and implemented it with the students in her public school classes.

On a larger scale, teacher LB reported conducting a full-day tree transect with all of the science students in her private school. She completed the educational technology course taught by the ISLE program's information technology assistant (also the researcher) during the following semester. As part of her assignment for that university coursework, she used information technology to enhance the tree transect lesson. Demonstrating the value of the comprehensive ISLE experience, she independently commented: "I put this lesson together outside the textbook using the University of Texas at Dallas Science Education's trip to Big Bend, Texas in the Summer of 2000 as a template."

In summary, the data suggest that the positive change in the teachers' attitudes toward information technology during their ISLE program experience (Phase I) led to a similarly positive pedagogical change in the integration of information technology in their public/private school classrooms (Phase II).

8.4.3 Effectiveness of ISLE University/Field Trip Program for Teachers' Conceptual Development (Research Question 3c)

The ISLE model (see Chapter 1) was designed to foster constructivist pedagogy by enabling the participants to effectively use information technology to create the virtual field trip website in Phase I. The purpose of this approach was to produce an information technology-supported product that the teachers understood and knew how to use in their classrooms to promote inquiry and high-order thinking in Phase II (school classroom implementation). To that end, the third primary goal of the ISLE program centred on the teachers' conceptual development in Phase I.

Now, more than ever before, success in today's information-driven society requires a personally-relevant, context-sensitive, content-rich strategy for science education. As explained in Chapter 2, professional development and graduate science education programs must directly address the specific needs and wants of today's science teachers. Because the classroom and information technology learning environments are continuously subject to rapid and profound change, the ISLE program utilised experiential training activities and concept mapping exercises to help teachers to think about science in a different way, encouraging them to ask and answer the *why* and *how* of the *what* and *where*.

The next subsections specifically address Research Question 3c which concerns the effectiveness of the university/field trip course (Phase I) in terms of teachers' conceptual development. Section 8.4.3.1 describes the instructors' introduction and expansion of concepts throughout the ISLE program in terms of the metaphors used in the lessons supported with qualitative observations and comments in the teachers' reflective field journals. The ways in which the teachers represented their conceptual understanding of both content and process in individual concept maps is examined quantitatively in section 8.4.3.2. And finally, an in-depth case study is presented in section 8.4.3.3 to document one science teachers' conceptual development throughout Phase I of the ISLE program.

8.4.3.1 Qualitative Information About the Effectiveness of the University/Field Trip Program in Terms of Stimulating Teachers' Conceptual Development in Phase I

The fact that teachers might know the content does not necessarily mean that they can teach the content in meaningful and understandable ways. As such, the

ISLE program incorporated experiential training exercises to help participants to conceptualise the purpose of authentic inquiry and to think about ways to implement the same pedagogical methods in their unique classrooms. Approaching learning holistically facilitated the development of conceptual understanding and the transfer of knowledge to action within the respective teaching area. A critical aspect in realising the ISLE model, the university/field trip instructors aimed to integrate practical experience into conceptual knowledge to encompass the entire individual, not just the intellectual aspect.

The university instructors used both information and technology in the context of learning about *what* the team investigated by emphasising *why* the process and purpose mattered. As detailed in section 4.1.1, each class meeting incorporated an experiential training activity associated with a related aspect of information technology, the modelling of educational technology in content-based instruction, and collaborative discussion requiring peer and mentor interaction, along with individual reflection and contribution to the group as a whole. For example, the Community Juggling activity was used to introduce and to focus thinking about complex inter-relationships and how to manage information presented in a non-linear fashion. Similar cases were developed for other activities, including If I Had a Hammer, Rope Tricks, Who Was I?, and Balancing Acts.

These types of experiential training activities served as powerful physical and conceptual metaphors for merging educational and scientific theory and practice throughout the ISLE program to help teachers to develop a conceptual framework based on their know-how that was elucidated within the logistical framework. Through team-based experiences, the university instructors were able to establish a personally-relevant commonality among the learning environments by continuously applying information technology as part of the group investigations into water quality, plant diversity and weather conditions. The power of the model is that each teacher could make practical sense of each occurrence in an individual context.

Immersing the participants in an extended field experience cultivated a new awareness and exposed them to different perspectives. Each member of the team was encouraged to observe and practice new approaches and different methodologies in the safe environment fostered within the ISLE model. Reflective field journal questions (see section 7.2.6) were designed to guide individual participants' exploration. The following qualitative observations and comments in the teachers'

reflective field journals support the university instructors' expansion of concepts throughout the ISLE program in terms of the metaphors introduced in the university classes and referenced in the field and post-trip discussions.

Interestingly, there was a subtle distinction between teachers in their initial viewpoints of the physical setting based on their content background. The non-science teachers exuded a positive curiosity toward the novel environment, while the science teachers entered with hints of underlying fear and trepidation. For example, to help participants to deal with the issue of information overload, the teachers were asked to describe their feelings when looking toward 'The Window', a V-shaped gap in the mountains that surrounded the group campsite in 'The Basin' area. A non-science teacher (CG) noticed "the difference between two different worlds: beyond the Window it is very dry and hard for plants to grow; within the Basin much more green life abounds. It's a wonderful feeling looking out to see a site I never imagined." A science teacher (BD) commented on the diversity of the plants: "The plants are taller and seem to match the geology of the area. The desert floor is more flat and the plants are typically smaller. The Window is really neat; the sunsets are particularly wonderful. It is interesting to see the different colors throughout the day."

Deliberately designed to shift the teachers' focus on 'parts' to the 'whole', the virtual field trip website provided a mechanism for fitting the parts into a whole. This proved more difficult for the science teachers because of their preconceived notions of science. For example, a science teacher (AL) stated that: "The hardest thing about learning science in the field is putting the big picture together in my mind and on paper. The easiest is observing and performing the experiments." In contrast, a non-science teacher (GB) reported: "After this trip my perspective changed because I now have a better understanding about the 'why' of Big Bend. Now when I go there, I see more than just rocks and cacti. I actually see the geologic history. This experience has changed my whole perspective of Big Bend."

Overall, the final outcome was realised as each participant evidenced a broader perspective and deeper understanding of facts presented in context of the 'big picture'. For example, one science teacher (AC) reported that "seeing sedimentary rock, volcanic rock and other geological stuff was very interesting up close once I figured out what to look for and at. I also liked learning more about the flora because now it's more than a tree or bush." The non-science administrator (LL)

said that she “will always support those who see the need and have the knowledge for protecting our soil and air, as I now see the full circular picture on the importance of this issue”.

In summary, the qualitative data suggest that the science teachers’ conceptual development changed from studying science as a series of discrete ‘parts’ to seeing the value of scientific information positioned in the greater context of a delicately balanced, open-ended system. In parallel, the non-science teachers’ conceptions of science as a separate and distinct subject developed toward the idea that science was an integral part of their environment and could be dealt with as such irrespective of the discipline or topic of discussion. By involving non-science teachers alongside science teachers, each gained an appreciation of the others’ area of expertise and interest, beyond the university instruction and field observation. This benefit was demonstrated when a science teacher exclaimed that the way in which a non-science teacher had explained a political process to him was exactly how he had approached a scientific principle to his students. Such multi-faceted insights allow teachers to integrate information into a coherent whole for all types of learners, thereby affecting the learning environment of their classrooms by meeting the needs and interests of a diverse student body.

8.4.3.2 Content Representation in Teacher-Generated Concept Maps

Concept maps (see section 6.1.2) can provide a snapshot of the individual’s degree of subject matter knowledge and understanding at the time when the diagrams were constructed. As described in section 6.2.3, concept map analysis consequently can reflect the effectiveness of the instructional approach used in a particular context. The number of items (I) compared to the number of links (L) gives an indication of the degree to which learners understand the overall subject matter (main idea or given topic) as detailed in Table 28. The number of levels gives an indication of the relative degree to which learners are able to assemble (information overload) and organise (non-linear processing) concepts related to the subject matter. The number of levels tends to increase as the learners’ abilities to incorporate larger amounts of information develops meaningfully. This can be measurable in concept maps. In order to manage the links and items effectively, the learner must necessarily create less linear structures by linking information through adding more levels.

Table 28. Degree of Understanding Indicated by Possible Relationships of the Number of Links Compared to the Number of Items in Concept Maps

Relationship	Degree of Understanding
$L < I$	Rote knowledge of content without context
$L = I$	Understanding of process within the limited context of the specific instance
$L > I$	Meaningful understanding of the relationships of content and process, demonstrated by the ability to transfer such understanding to other subject areas

'L' is the number of links and 'I' is the number of items used in the concept maps.

Specifically, a dual approach to concept map development (based on the instructors' prior experience described in section 6.2) was implemented to emphasise both content and process within the ISLE program. The entire group created a top-level concept map over the first three class meetings. Then, individual maps were constructed over the remainder of the meetings to support higher-level concepts. Chapter 3 elaborates the conceptual framework in which participants were repeatedly exposed to activities and instruction in a hierarchical fashion. Through this design, key concepts were addressed from multiple perspectives to accommodate multiple learning styles and levels of understanding.

All but one participant (LH) created concept maps as the basis for their contribution to the virtual field trip website. The total sample of 12 science and non-science participants (section 8.1.1), although small, is representative of the population and thus acceptable for examining the ways in which the teachers represented their conceptual understanding of both content and process in individual concept maps.

Final participant-generated concept maps were evaluated at the end of Phase I to determine the participants' ability to manage content and process within the broader context of a global environmental system (based on an extended field trip to a natural area). As detailed in section 6.2.3, individual diagrams were objectively analysed in terms of the number of levels (hierarchy), links (inter-relationships), and items (concepts). Table 29 summarises the results of this concept map analysis. As the complete top-level map was given, the actual count was reduced by one level, two links and seven items (including the main topic) to produce the final adjusted count.

Table 29. Results of Concept Maps for ISLE Program Participants

ISLE Participant	Adjusted Count			Analysis
	Levels - 1	Links - 2	Items - 7	Links ? Items
GO	2	6	6	=
AC	3	20	21	<
CG*	3	7	7	=
LL*	3	23	23	=
MM*	3	15	15	=
AL	4	20	18	>
BD	4	15	15	=
CB*	4	30	25	>
MS	6	28	28	=
RF	6	32	29	>
GB*	8	36	32	>
LB	8	46	31	>

* = Non-science content background; Links = Items (rote knowledge)

Not surprisingly, the resulting images reflected each participant's experience with the topic and purpose; however, the trends do not appear to be related to content background. Ranges were similar for both science and non-science participants, respectively, in terms of the number of levels (2–8 and 3–8), links (6–46 and 7–36), and items (6–31 and 7–32). Overall, the data in Table 29 show that the maps were nearly evenly split between an equal (50%) or greater (42%) number of links as compared to the number of items ($L > \text{ or } = I$). This indicates that, at the end of Phase I, nearly all participants possessed an understanding of process within the limited context of the specific instance and meaningful understanding of the relationships of content and process, demonstrated by the ability to transfer such understanding to other subject areas. The single instance of links less than items ($<$) for teacher AC is a direct result of the analytical nature of the investigation into the specifics of the group's water chemistry test results. Her project was designed to document the facts and figures of the group's findings in the field, not to explain or interpret the data.

Individually developed from each participants' perspective, the concept maps were directly related to each one's unique life experience, thereby making more sense within his/her particular frame of reference. Again, this attribute appears to be independent of content background as science and non-science participants fell within nearly all groups equally. This also could indicate that all participants gained information regarding science irrespective of their prior content knowledge and

experience in science. By design, the participants had to work together to successfully create a coherent web-based product. Focusing on a single topic enabled the participants to explore their area of interest more fully. Placing their individual work into the broader context of the group's virtual field trip website enabled the learners to produce a deeper, more meaningful contribution to the whole.

One of the ISLE program goals was to support teachers in constructing their own knowledge. These results suggest that, as the science teachers assumed responsibility for their learning, they were able to make more complex representations of relevant content, indicating more meaningful learning. Discussion of innovative uses of information technology might have inspired individual creativity and opened new possibilities for science education that were reflected in their more conceptual approach to managing science content.

As science becomes more individually meaningful, the non-science teachers were able to see how the concepts fit together across many categories and in more than one situation. Like the science teachers, non-science participants too were able to limit the number of topics addressed in their final projects and more precisely place each in context by identifying more inter-relationships.

In summary, the data suggest that the methodology used to implement a constructivist paradigm within the ISLE program was appropriate and successful in increasing participants' conceptual understandings. As a facilitated group, participants developed the top-level structure of a common concept map to provide a general framework for independently-created, seamlessly-integrated maps.

8.4.3.3 Case Study: A Teacher's Transition from Linear to Non-Linear Conceptual Structure

As mentioned in section 6.2.3, the way in which students construct knowledge is paramount to the development of understanding that enables transfer from the classroom to other everyday situations. By design, the ISLE program used concept mapping to help participant teachers to move their knowledge framework from a linear structure to a more net-like structure. The purpose of this change was to give them a way to manage the large amounts of facts made available through information technology. This also helped them to realise multiple ways to integrate their topics with other areas to develop a broader perspective that addresses the needs of a more diverse, global community. This conceptual development was anticipated

to have long-term effects on the teachers' ability to incorporate information technology effectively into their respective classroom learning environments.

To minimise the pressure put on the participant teachers to perform to the university instructors' expectations, the initial concept maps developed in the last university classroom lesson before the extended field trip (see section 4.1.10) were not collected. The purpose of that exercise was to focus the participants' attention on their individual field investigations to reduce the negative effects of information overload. This important step helped to maintain the perspective developed in the university classroom and facilitated the transfer of knowledge and understanding into the field. The tentative project topics were tabulated, potential crossovers were suggested, and a complete listing of initial field investigations was distributed to each participant. Serving as a starting point based on prior knowledge and expected field conditions, these initial concept maps represented each participant's conceptual understanding of the content within the context of the extended field trip segment of Phase I.

Unpredictably, one of the ISLE science teachers (AL) voluntarily provided an unsolicited copy of her initial concept map to the information technology assistant, thereby affording the opportunity for an in-depth case study. As a result, this section presents evidence of one teacher's conceptual development throughout Phase I of the ISLE program. The possible impact of the ISLE program on this specific teacher's conceptual development is described in terms of the difference between the initial and final concept maps which she generated for her individual contribution to the virtual field trip website. Quantitative concept map data from her initial drawing, combined with qualitative details from her reflective field journal, were compared to her final drawing.

The subject, a female participant (77% of the sample) between the ages of 18 and 25 years (23% of the sample) and with between 2 and 5 years of teaching experience (31% of the sample), was teaching at the secondary level (88% of the sample) in a small, suburban, parochial, private school. She did have a computer (85% of the sample) and access to the Internet (92% of the sample) in her home. She held a Bachelor of Science degree and was seeking Teacher Certification at the University of Texas at Dallas. Additionally, she was one of four ISLE program participants recruited from the educational technology class.

This ISLE science teacher's initial concept map, presented in Figure 37, was examined using the same procedure used in the previous section 8.4.3.2. Incorporating an equal number of links and items (13 and 13), this concept map resulted in a linear structure. Supported by a limited number of levels (3), this preliminary depiction of her contribution to the virtual field trip website indicates a rich knowledge of geomorphology presented in a rather traditional format.

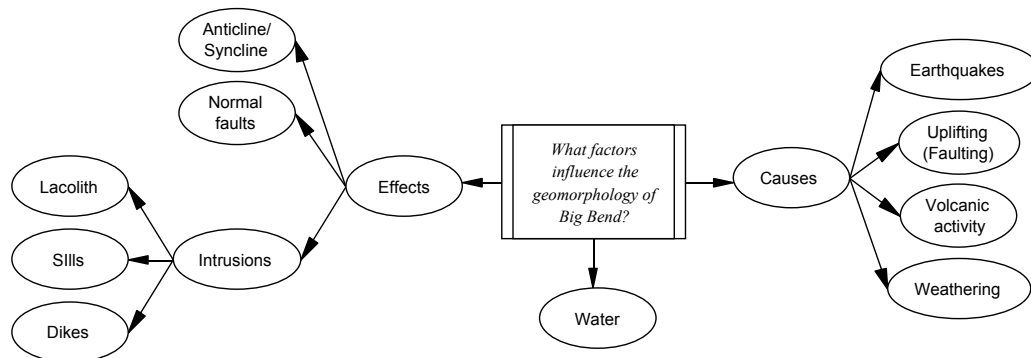


Figure 37. Initial Concept Map Drawn by Case Study Teacher (ISLE Science)

Based on direct observations made by the researcher and the field ecology instructor, this teacher exhibited a strong tendency toward the rote memorization of content and possessed a basic understanding of related processes in the university classroom. The ISLE program was designed to transition this type of information management (linear) into a more meaningful context with a conceptual approach to processing the content within the context of the process (non-linear). As evidenced in the following excerpts, this transition was facilitated through the reflective journal questions, implemented throughout the extended field trip segment of Phase I.

When asked what she saw when looking toward ‘The Window’, she was the only participant to draw a picture instead of using text to describe her vision. Out of character, she did not respond in any way when asked to reflect on how she felt about what she had learned that day. This is in keeping with her literal interpretation of science. Illustrated in the following quote, she used the term ‘concept’ in an unexpected sense. The instructors interpreted her meaning to infer the abstract nature of textbook knowledge as opposed to real-world observation. The potentially negative effects of sensory overload which she expressed also appear to have been balanced by the first-hand experience. Her written response to the question “What

are your frustrations about learning science in the field and what are the good points?” was:

Learning science in the field is awesome but the amount of information taken in is massive. I want to see as much and do as much as possible but that leaves no time to process information. The good point is that the information learned is not just a concept anymore. A visual image is now formed and concepts blend together to make sense now.

As the group spent more time working together in the field, personal and professional relationships developed through spontaneous conversations and discussions based on individual projects for the virtual field trip website. One benefit of this type of informal, peer-to-peer and learner-to-teacher collaboration was evident in her response to the question “Into what part of the curriculum that you teach will you integrate what you learned today?”:

I teach earth science so I will have nice slides of different rock formations, faulting, desert flora, and desert fauna. The students will see these things in their natural habitat and I can add a personal experience, which adds to the slides. This entire trip of geology, ecology and man’s impact on Big Bend can be used in several areas of earth science.

When asked how she would use hands-on activities to accomplish the aforementioned integration into her classroom, her response turned back toward a more discrete implementation based on reconstructed physical models. In contrast, when asked how she would evaluate her students’ understanding of the concepts represented in the activity, she noted:

If the students understand the information then they can recreate the structures whether it be geology or fossils. They can also write a reflection of what they learned.

These anecdotes were supported by her own views of teaching and learning. She felt that she personally learned best “by seeing things over and over” and “by doing the procedures and listening”. She added that “I can read and memorize easily, but the information does not stay in memory unless I have seen it or done it”. When queried about learning science in the field, she noted that “the hardest thing about

learning science in the field is putting the big picture together in my mind and on paper. The easiest is observing and performing the experiments.”

These statements reflect her conceptual development, which also was indicated by the changes made to create her final concept map, shown in Figure 38. Incorporating more links (22) than items (18), this concept map resulted in a non-linear structure. Compared to the initial map (shown in Figure 37), this was a positive change of +9 links and +5 items. Although the number of levels (3) did not increase, she did add a link to another participant’s project for the virtual field trip website (Volcanic Activity). In contrast to her initial concept map, this depiction of her contribution indicates a new understanding of the complex inter-relationships of the content and context that she presented in less linear (more conceptual) design.

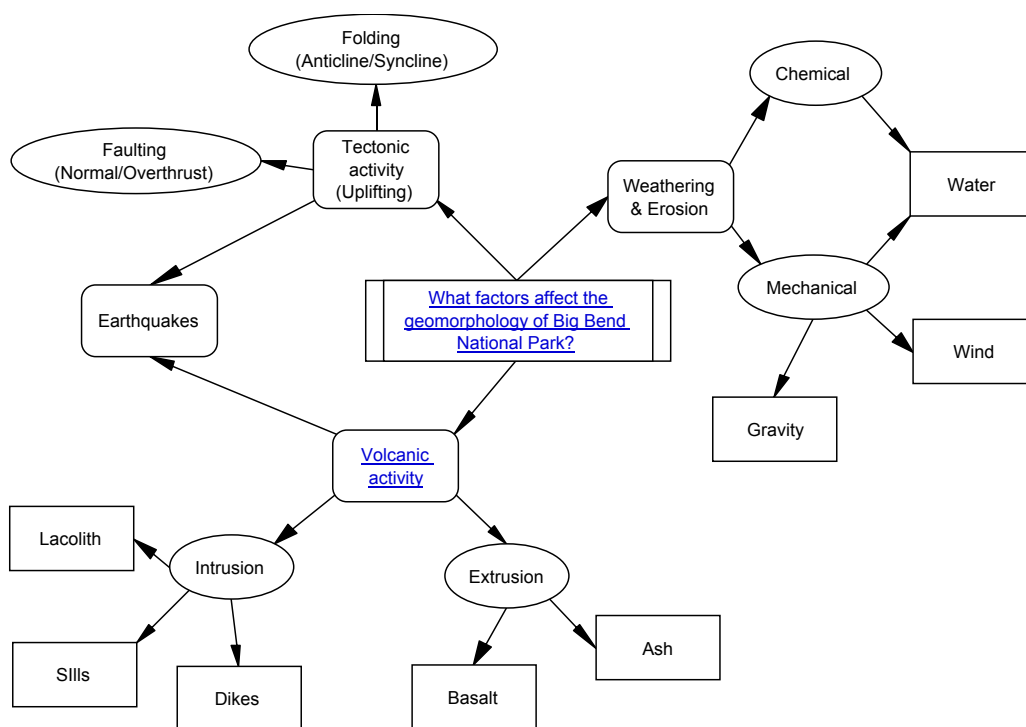


Figure 38. Final Concept Map Drawn by Case Study Teacher (ISLE Science)

As her level of comfort and depth of understanding increased, corresponding changes were also evident in her journal responses. She responded to a later question concerning how she felt about her learning as follows:

I feel I am progressing in my learning because I remember the things I learn – because it’s not just college credit; it’s bringing the information into the classroom to benefit the kids. I have a whole group of students counting on me to teach them so I take my classes more serious now.

In turn, she indicated that her perspective of field work changed drastically as a result of the extended field trip. Subsequently, she noted that “what I liked best about learning on field trips is the visual learning connecting with the concepts already learned. I liked hearing the professors talk about the different areas of science and asking them questions about everything.”

In summary, this case study suggests that this science teacher did develop conceptually in terms of content and process as a result of the overall ISLE program. By gaining experience with new pedagogical approaches to teaching with appropriate applications of information technology, she is better prepared to implement the same changes in her school classroom to benefit her students.

8.5 Summary of ISLE Program Results

This chapter presented quantitative and qualitative data that were combined to answer the specific research questions delineated in section 1.2. Section 8.1 described the various samples of teachers ($N_{\text{Total}} = 18$) and students ($N_{\text{Students}} = 1079$) used for both Phases I and II (the university coursework/extended field trip and public/private school classroom, respectively).

Research Question 1 asked if the new versions of the Constructivist Learning Environment Survey (CLES) valid and useful in secondary schools and graduate university courses in Texas. In response, section 8.2 details the results from the administration of three new versions of the Constructivist Learning Environment Survey (Adult, Comparative Teacher, and Comparative Student), showing that the new versions the Constructivist Learning Environment Survey (CLES) are valid and useful in secondary schools and graduate university courses in Texas.

Data from 1079 students in 59 classes in north Texas were subjected to principal components factor analysis with varimax rotation and Kaiser normalization, confirming the *a priori* structure of the CLES-CS. Items 3, 6, 7, and 25 were removed to enhance the reliability of the modified instrument. The factor structure, internal consistency reliability, discriminant validity, and the ability to distinguish between different classes and groups were supported for the comparative cases (THIS and OTHER) of the CLES-CS.

Data from 12 adults enrolled in a graduate course in north Texas supported the usefulness of the CLES-A form. However, based on results specific to content background, these data suggested that the language of the new CLES-A could need

to be revised to better reflect adult interpretation in the context of science learning environments. Similarly, data from 8 teachers supported the usefulness of the CLES-CT form with adults in public/private school teachers in north Texas.

Research Question 2 concerned the effectiveness of the Integrated Science Learning Environment (ISLE) university/field trip course in terms of the degree of implementation of constructivist teaching approaches in the teachers' school classrooms. Section 8.3 described how the comparative forms of the Constructivist Learning Environment Survey (CLES) were used to investigate teachers' perceptions of their school classroom teaching (CLES-CT) and students' perceptions of their school classroom learning (CLES-CS). Further, qualitative data were used to support interpretation of these results.

Specifically, to answer Research Question 2a, data from the CLES-CT ($N = 7$) suggested that the ISLE program (Phase I) was effective in terms of the degree of implementation of constructivist teaching approaches in the teachers' public/private school classrooms (Phase II) as perceived by the ISLE science teachers. To answer Research Question 2b, data from the CLES-CS ($N_{\text{ISLE}} = 445$ students in 25 classes taught by 5 ISLE science teachers; $N_{\text{Non-ISLE}} = 328$ students in 19 classes taught by 5 other science teachers) suggested that the ISLE program (Phase I) was effective in terms of the degree of implementation of constructivist teaching approaches in the teachers' public/private school classrooms (Phase II) for the ISLE science teachers, as perceived by their respective students.

Discussed in section 8.4, Research Question 3 concerned the Integrated Science Learning Environment (ISLE) university/field trip course. Data from the CLES-A ($N = 12$) documented the teachers' perceptions of the university/field trip learning environment (Research Question 3a). The results suggested that the instructors' teaching in Phase I of the ISLE program successfully modelled constructivist pedagogy for the ISLE participants, particularly for science teachers.

Data from the Teachers' Attitudes Toward Information Technology (TAT) and various qualitative methods were used to assess the effectiveness of the university/field trip course in terms of changes in teachers' attitudes toward information technology (Research Question 3b). Qualitative data from the participants' journal entries ($N = 12$) suggested that the instructors' teaching in Phase I of the ISLE program successfully modelled the seamless integration of information technology in an educational context. Pretest/posttest data from the TAT ($N = 7$)

suggest that the ISLE program facilitated a positive overall change in the science teachers' attitudes toward information technology. Additional data from the participants' journal entries (N = 12) suggested that the positive change in the teachers' attitudes toward information technology during their ISLE program experience (Phase I) had a positive impact on their public/private school classrooms (Phase II).

Qualitative data from reflective field journal entries, observations, and interviews was combined with quantitative data from concept maps, along with an individual case study, to describe the teachers' conceptual development in order to assess the effectiveness of the university/field trip course in terms of teachers' conceptual development (Research Question 3c). Specifically, data from participant-generated concept maps (N = 12) suggested that the methodology used to implement a constructivist paradigm within the ISLE program was appropriate and successful in increasing participants' conceptual understandings.

In conclusion, Chapter 9 discusses the overall results of this research study that generally investigated whether changing teachers' learning environments might affect a change in their respective students' learning environments.

Chapter 9

RECOMMENDATIONS AND CONCLUSIONS

This study evaluated the Integrated Science Learning Environment (ISLE) in terms of promoting constructivist classroom learning environments in schools, teachers' attitudes toward information technology, and teachers' conceptual development. Quantitative assessment through learning environment dimensions, attitude scales, and concept map analysis was supported by qualitative data derived from reflective field journals, interviews, and observations to suggest the impact of the emergent model.

The overall results of this study suggest that a teacher's participation in the ISLE program does lead to the teachers' implementation of constructivist pedagogy in their respective students' school classrooms – thus, accomplishing several of the goals set forth for today's science educators. ISLE program participants improved in terms of their conceptual understanding and their development of positive attitudes toward information technology. Participants also perceived their university/field trip learning environment as emphasizing constructivism.

Specifically, this study provided the following answers to the research questions asked in section 1.2:

- 1) The new versions of the Constructivist Learning Environment Survey (CLES) are valid and useful in secondary schools and graduate university courses in Texas (see section 8.2).
- 2) The ISLE university/field trip program was effective in terms of increasing the implementation of constructivist teaching approaches in the teachers' school classrooms relative to classes taught by other teachers in their school (see section 8.3).
- 3) The ISLE university/field trip program was effective in terms of improving the teachers' attitudes toward information technology and promoting the teachers' conceptual development (see section 8.4).

Although the primary sample of 12 classroom teachers and one administrator is numerically small ($N_{\text{Participants}} = 13$), it is representative of the population expected for this type of intensive professional development program. Therefore, this sample

size is acceptable for evaluating the impact of the teachers' participation in the ISLE program on their respective public/private school classrooms. These results are also supported by more than 15 years of similar field-based graduate-level science education courses and the homogeneity of the phenomena under study (Van Dalen, 1979).

The ISLE program was thorough in its content, creative in its research, and rigorous in its application. Teachers entered the program wanting to expand their knowledge base, their ways of thinking about science education, and their vision of science education. They returned to their classrooms with the knowledge that there are ways to teach that are more effective, more innovative, and more enjoyable for all. As experienced upper-level problem solvers, the ISLE teachers also realised that they can, in fact, meet the needs of a greater number of students by designing and helping others to carry out changes for the educational community. Their larger and more practical view of teaching and learning will make them particularly valuable as educational leaders who cultivate and influence an astute group of global citizens.

This concluding chapter is comprised of five main sections. The following section 9.1 recommends factors to be considered in future implementations of the ISLE program. Section 9.2 examines relationships between the scales contained in instruments used in Phase I, namely, the Teachers' Attitudes Toward Information Technology (TAT) pretest questionnaire, final teacher-generated concept maps, and the Constructivist Learning Environment Survey. The significance of the actual program design is discussed in section 9.3 based on teacher participation in pre-trip, field trip, and post-trip activities. Section 9.4 discusses the implications of the ISLE program in terms of the potential impact of and extensions to the ISLE model in Phase II. The final section of this thesis, 9.5, summarises the overall conclusions and recommendations offered in light of this study.

9.1 Recommendations for Future ISLE Programs

Based on the results of this evaluation of the first ISLE program reported in Chapter 8, this section describes four key recommendations to be considered in implementing future programs based on the ISLE model. These factors concern the instrumentation, scheduling, and administrative support of the overall program.

The first recommendation is to revise the three modified versions of the Constructivist Learning Environment Survey (CLES-CS, CLES-A, and CLES-CT)

slightly, as suggested by the data presented in sections 8.2 and 8.3. For example, the removal of four items (numbers 3, 6, 7, and 25) enhanced the reliability of the comparative student form (CLES-CS). The wording of items in each instrument could be slightly changed to better reflect the understanding of each of the different audiences, adults, teachers, and students. Recall that a wider range of scores in three scales of the adult form (CLES-A) indicated that some questions might be ambiguous or might not reflect unique factors for instance. The same changes would be repeated for the comparative teacher form (CLES-CT).

The results derived from the modified versions of the original 30-item CLES also suggest that shorter versions might be more suitable to this research design and still could accurately assess the same dimensions of the learning environment. For future implementations, the researcher would reconstruct the three CLES versions based on the CLES2(20), which was recently developed and validated by Johnson and McClure (2002).

The second recommendation also relates to data collection. The transition from a linear to non-linear structure, evidenced in the concept mapping case study (section 8.4.3.3), was critical to evaluating the change in the participants' conceptual understanding. In future implementations, the researcher would collect participants' preliminary, pre-trip, and final concept maps to assist the instructors with individual consultations and re-direct facilitation as needed.

The third recommendation involves restructuring the time allocation of the pre-trip and post-trip segments. To ensure that all participants have a solid knowledge and understanding of the basic science content expected at the post-graduate level, online self-tests with immediate feedback and further references would be added before each topic-based lesson of the pre-trip segment. Participants who were uncomfortable with terminology, for example, could learn or review the necessary information to reduce the sense of anxiety and lack of preparedness often encountered in the field environment (noted in section 4.1.1). This would allow for higher-level discussions during the actual lessons and accommodate the scheduling limitations mentioned earlier in section 7.4 and elaborated later in section 9.3.

A more structured post-trip segment would be implemented to help participants complete the final processing phase. The researcher would dedicate more time to the preparation of the virtual field trip components as an intact group. Formal presentation of individual projects would enable the participants to develop the subtle

interconnections and cross-references among their final concept maps. Thereby, the links that form the virtual field trip could be more fully developed and the participants could create a more fully integrated product.

The fourth recommendation considers administrative issues surrounding the overall effectiveness of the ISLE program. As detailed in section 7.4.3, offering university credit for three separate courses in conjunction with the university coursework and single extended field trip experience posed an unavoidable complication to this implementation. The researcher suggests that future implementations either be approached as continuing education programs that support the professional development of teachers or that all instructors directly engage in promoting the ISLE model throughout the Master of Arts in Teaching (MAT) program. Effectively, participants could thereby experience full immersion in the program, without the underlying tension of multiple and separate agendas.

This recommendation also lends support for continued funding of similar programs based on the ISLE model, along with increased district support for the participants. The importance of full participation in all program segments is detailed in section 9.3. The local administration's actions, like providing leave for program participation, have a direct impact on the effectiveness of the ISLE program. Such support can realise the opportunity for ISLE participants to extend their influence throughout their schools and can be used to send strong messages to the community as to their district's educational priorities and active involvement in lifelong learning.

9.2 Relationships Among the Instruments in Phase I

This research contributes to the field of learning environment research by evaluating a comprehensive professional development program that used information technology to initiate teacher change from the central perspective of the learning environment. As detailed in Chapter 7, a multi-method research design was used to evaluate the Integrated Science Learning Environment (ISLE) program. In order to understand the inter-relatedness of the main aspects of ISLE model (instructors' modelling of constructivist practice in the ISLE program (CLES-A), teachers' attitudes toward information technology (TAT), and teachers' conceptual development), it was decided to explore the nature of relationships between the scales of these three instruments used in Phase I (see section 1.3.1 for additional details).

Pearson correlations (Gay, 1996) were performed to relate CLES-A scales to TAT scales and concept map scores. The data from the content-based instruments (TAT pretest, described in section 7.2.1, and teacher-generated concept maps, described in section 7.2.5) correlated to specific scales within the learning environment assessment (CLES-A, described in section 7.2.2), indicating that there are statistically significant correlations between the scales of the instruments for participants with different content backgrounds. The following sections (9.2.1, 9.2.2, and 0) report and interpret the correlations for the 12 program participants, 7 science participants, and 5 non-science participants, respectively.

9.2.1 Correlations for ISLE Participants (Science and Non-Science)

For the combined sample of 12 ISLE participants (see section 8.1) represented in Table 30, Personal Relevance positively and significantly correlated with attitude to using computers in the classroom (+0.61). By modelling effective uses of information technology, including computers and computer-generated content, teachers could realise the value of such as a tool and resource, rather than yet another technical inconvenience intruded into the classroom. Emphasising the content, over the construction, of the website could minimise their apprehension of using new software and enable them to appreciate the benefits of appropriate applications.

As teachers find computer usage more involved with their lives, they see its usefulness in more situations, and transfer its use across their teaching. Personal Relevance also positively and significantly correlated with the number of levels represented on the final concept maps (+0.67). Individually developed from each participant's perspective, content that is directly related to one's unique life experiences might make more sense within her/his particular frame of reference. This correlation also could indicate that participants gained information regarding science. By focusing on a single topic of interest, participants might be able to explore it more fully and, by placing it into the broader context of the website, produce a deeper, more meaningful report.

Student Negotiation positively and significantly correlated with all but one scale of the TAT. As teachers are required to use information technology professionally, it is not surprising that Personal Productivity was not a statistically significant feature. The lack of significant associations of attitudes and concept map

scores in the areas of the Uncertainty of Science, Critical Voice, and Shared Control could be simply attributable to the fact that the sample is predominantly comprised of teachers. Teachers are often directly questioned; therefore, they accept that there is uncertainty in every answer. Teachers also tend to be teacher-pleasers; therefore, they might not readily question the leader's role. The deliberately open design of the program could have minimised the impact of each. This could also be a factor of maturity or the character of the teacher-student relationship in professional development programs (adult-adult versus adult-child).

Table 30. **Means and Simple Correlations of Constructivist Learning Environment Survey (CLES) Scales with Attitude Scales and Concept Map Scores (for Science and Non-Science Teachers Combined)**

Attitude Scale or Concept Map Score	Mean	Simple Correlation with CLES Scale				
		Personal Relevance	Uncertainty of Science	Critical Voice	Shared Control	Student Negotiation
Teacher's Attitude Toward Information Technology (TAT) Pretest						
Electronic Mail	5.58	+0.40	+0.30	+0.30	+0.22	+0.74*
World Wide Web	5.99	+0.33	+0.51	+0.22	+0.24	+0.74*
Multimedia	5.92	+0.19	+0.35	+0.30	+0.21	+0.70*
Personal Productivity	6.01	+0.16	+0.32	+0.19	+0.12	+0.50
Computers in Class	5.17	+0.61*	+0.28	+0.10	+0.31	+0.69*
Participant-Generated Concept Map Analysis						
Levels	4.50	+0.67*	+0.05	-0.18	+0.53	+0.37
Links	23.17	+0.49	-0.10	-0.03	+0.46	+0.24
Items	20.00	+0.41	-0.31	-0.13	+0.32	+0.26
Items/Links	1.12	+0.44	+0.25	+0.02	+0.42	+0.09
Links/Items	0.91	-0.50	-0.22	-0.04	-0.48	-0.04
CLES Scale Mean		4.64	3.93	4.38	4.06	4.36

* $p < 0.05$ N = 12 ISLE participants

Initial team-building exercises could encourage the teachers to share ideas and 'tricks' throughout the course. By design, participants had to work together to successfully create a coherent web-based virtual field trip product. Qualitative data

suggest that articulation and reflection can be facilitated by the use of information technology.

9.2.2 Correlations for Participants with Science Backgrounds

Interestingly, the pattern of correlations was different when the sample is stratified by content background, as shown in Table 31. As for the combined sample, Personal Relevance positively and significantly correlated with attitudes to computers in the classroom only (+0.77) for the 7 science participants (see section 8.1). Scientists expect to use function-specific devices for their work. Presenting the computer as simply another tool demonstrated its power as a dynamic resource.

Table 31. Means and Simple Correlations of Constructivist Learning Environment Survey (CLES) Scales with Attitude Scales and Concept Map Scores (for Science Teachers)

Attitude Scale or Concept Map Score	Mean	Simple Correlation with CLES Scale				
		Personal Relevance	Uncertainty of Science	Critical Voice	Shared Control	Student Negotiation
Teacher's Attitude Toward Information Technology (TAT) Pretest						
Electronic Mail	5.66	+0.54	+0.27	+0.20	-0.02	+0.76*
World Wide Web	6.13	+0.36	+0.45	+0.33	-0.17	+0.77*
Multimedia	5.99	+0.16	+0.22	+0.49	-0.15	+0.78*
Personal Productivity	6.03	+0.12	+0.32	+0.44	-0.21	+0.73
Computers in Class	5.43	+0.77*	+0.10	+0.26	+0.21	+0.73
Participant-Generated Concept Map Analysis						
Levels	4.71	+0.68	-0.40	+0.18	+0.64	+0.41
Links	23.86	+0.48	-0.34	+0.31	+0.59	+0.45
Items	21.14	+0.44	-0.51	+0.01	+0.35	+0.51
Items/Links	1.09	+0.46	+0.06	+0.72	+0.84*	+0.21
Links/Items	0.93	-0.50	-0.02	-0.70	-0.86*	-0.18
CLES Scale Mean		4.69	4.12	4.36	4.26	4.60

* $p < 0.05$ N = 7 ISLE Science participants

However, Shared Control positively and significantly correlated with links/items (+0.84) and negatively and significantly correlated with items/links

(-0.86) on the concept maps. The program goal was to support teachers in constructing their own knowledge. As the teachers assumed responsibility for their learning, they were able to make more complex representations of relevant content, indicating more meaningful learning.

Student Negotiation also positively correlated with attitudes to electronic mail (+0.76), to the World Wide Web (+0.77), and to multimedia (+0.78). Based on qualitative interpretation, it is not unreasonable to presume that the non-science participants' perspectives enriched the entire experience and offered insight into teaching science to students of different learning styles. Discussion of innovative uses of information technology inspired individual creativity and opened new possibilities for science education.

9.2.3 Correlations for Participants with Non-Science Backgrounds

As shown in Table 32, the pattern of correlations was different for the 5 ISLE participants without science backgrounds (see section 8.1). Personal Relevance positively and significantly correlated with links/items (+0.91) and negatively and significantly correlated with items/links (-0.89). Science is inherently paramount for science teachers. As science becomes more individually meaningful, these non-science participants were able to see how the concepts fit together across many categories and in more than one situation. Like the science teachers, they too were able to limit the number of topics addressed in their final projects and more precisely place each in context by identifying more inter-relationships. That the non-science teachers gained a deeper understanding of how science relates to their everyday lives is indeed important in realising a holistic approach to teaching.

Shared Control positively and significantly correlated with attitudes to the World Wide Web (+0.77) and to multimedia (+0.98), further supporting the benefit of exposure to new and different aspects of information technology. This suggests that these tools allowed for personal exploration of the topics and presentation of information in what teachers feel is an educationally sound manner.

Table 32. Means and Simple Correlations of Constructivist Learning Environment Survey (CLES) Scales with Attitude Scales and Concept Map Scores (for Non-Science Teachers)

Attitude Scale or Concept Map Score	Mean	Simple Correlation with CLES Scale				
		Personal Relevance	Uncertainty of Science	Critical Voice	Shared Control	Student Negotiation
Teacher's Attitude Toward Information Technology (TAT) Pretest						
Electronic Mail	5.46	-0.16	+0.40	+0.52	+0.84	+0.83
World Wide Web	5.79	+0.29	+0.66	+0.07	+0.97*	+0.74
Multimedia	5.82	+0.35	+0.67	+0.01	+0.98*	+0.68
Personal Productivity	5.98	+0.44	+0.42	-0.20	+0.85	+0.29
Computers in Class	4.80	+0.23	+0.55	-0.12	+0.32	+0.60
Participant-Generated Concept Map Analysis						
Levels	4.20	+0.87	+0.86	-0.74	+0.41	+0.26
Links	22.20	+0.66	+0.36	-0.66	+0.29	-0.11
Items	18.40	+0.28	-0.09	-0.37	+0.10	-0.28
Items/Links	1.17	+0.91*	+0.82	-0.79	+0.43	+0.17
Links/Items	0.89	-0.89*	-0.75	+0.82	-0.42	-0.09
CLES Scale Mean		4.57	3.67	4.40	3.77	4.03

* $p < 0.05$ N = 5 ISLE Non-science participants

Qualitative data suggest that, by encouraging the construction of knowledge based on information gathered from experts and their own actual experience, the teachers accepted responsibility for their learning and gained a sense of how to implement similar strategies with their students. By requiring an integrated concept map for the final group project, facts and figures assumed a supportive function as teachers' understanding reflected a higher level of conceptual development that could be approached from any frame of reference. By developing a transparent information technology learning environment, the deliberate re-focusing of perceptions could transform teachers' attitudes toward information technology from one of potential trepidation to personal enjoyment and professional satisfaction.

9.3 Importance of the Program Design

The Integrated Science Learning Environment was realised by merging the conceptual and logistical frameworks of the ISLE model, respectively detailed in Chapter 3 and Chapter 4. Also recall from section 6.1.3 that the revised experiential training cycle (illustrated in Figure 18) provided the scaffolding for each class, as well as the framework for each lesson within the class. The ‘big picture’ was mirrored in the repeated sequences of experience, reflection, generalisation, and application to illuminate the commonalities and inter-dependencies of each concept.

As described earlier and shown in Figure 5, the ISLE model used information technology to combine the vertical progression (↓ ↓ ↓ ↓) within the overarching conceptual framework with the horizontal progression (→ → → →) of each topic within the logistical framework: ecology, geology, humankind, and the environment. Figure 39 illustrates how the overall program design seamlessly merged theory and practice with science and education through effective applications of information technology to create a rich Integrated Science Learning Environment.

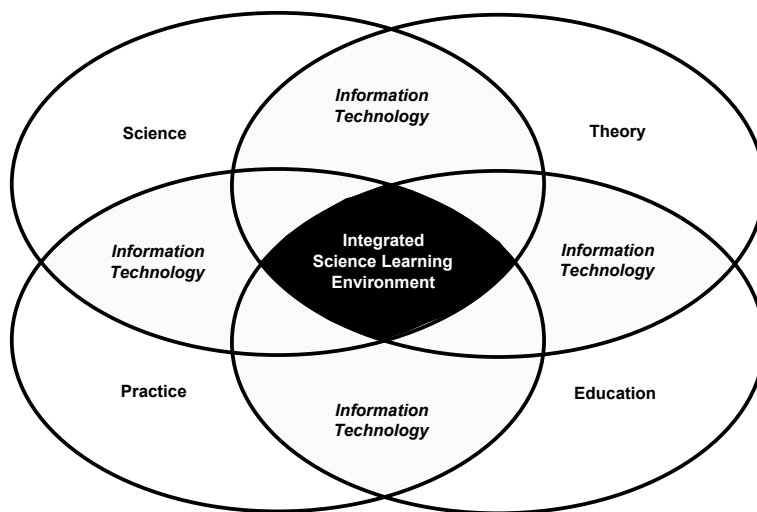


Figure 39. **The Integrated Science Learning Environment (ISLE)**

The critical importance of multiple, repeated cycles of experience, reflection, generalisation, and application is that participants are exposed to the scientific and pedagogical concepts and processes in multiple, repeated ways. Thereby, as challenged in Chapter 2, each participant is better prepared to address the unique needs of an increasingly diverse population, regardless of her/his preferred learning and teaching style.

In today's information society, adults (especially classroom teachers) lead busy lives with a broad range of commitments. Those choosing to engage in an intensive professional development program or to pursue an advanced degree are not generally full-time students. In spite of the monetary investments in tuition fees and materials, coursework cannot always be completed for many acceptable reasons. Based on prior experience with programs like ISLE, the researcher and instructors anticipated absences and complications under the best of circumstances and participant efforts. The following sections (9.3.1, 9.3.2, and 9.3.3) summarise the importance of, and report specific details concerning, participation in each phase of the ISLE program: pre-trip university classes and local day trips; required and optional activities during the extended field trip; and post-trip university classes and optional activities.

9.3.1 Pre-Trip Participation (University Classes and Local Day Trips)

The pre-trip segment was comprised of five university classes, four local day trips, and one optional seminar, as detailed in section 4.1. A tentative schedule of the pre-trip events was distributed along with program application and posted to the virtual field trip website on announcement of the program. Based on the total ISLE sample (N = 13), Figure 40 shows the percentage of participation in each main event of the pre-trip segment.

Each class meeting (summarised in Table 6) incorporated an experiential training activity associated with a related aspect of information technology, the modelling of information technology in content-based instruction, and collaborative discussion requiring peer and mentor interaction, along with individual reflection and contribution to the group as a whole. Each local day trip (summarised in Table 7) built on aspects of real-world research, allowing the teachers to become comfortable about teaching each other and learning in an outdoor environment, through the implementation of constructivist pedagogy.

As shown in Figure 40, full participation ranged from 38% for the optional seminar to 93% for two classes. Overall, the data reflects better than 60% participation in all required events.

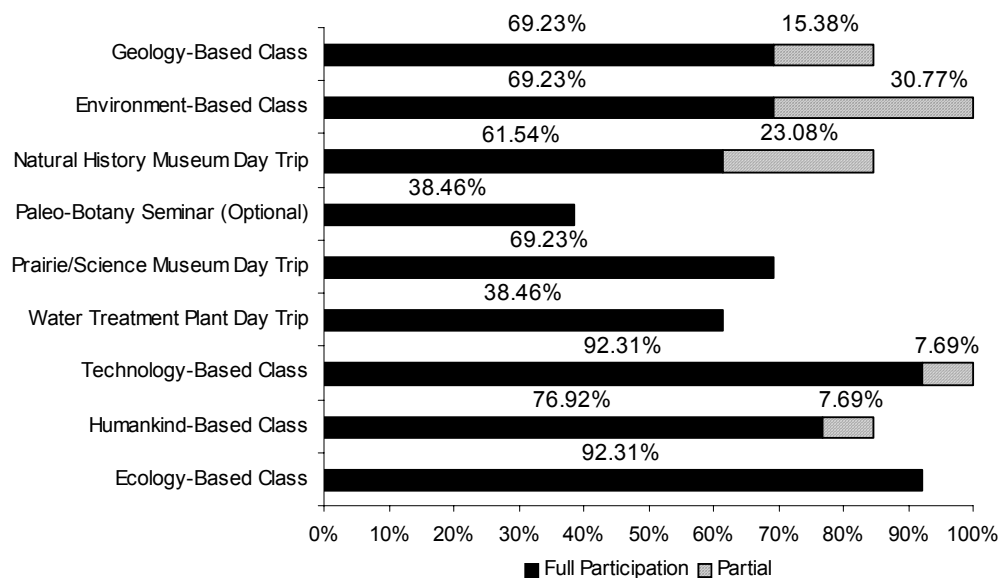


Figure 40. **Pre-Trip Participation Summary**

Surprisingly, one non-science teacher achieved nearly perfect attendance and full participation in the pre-trip phase even though she lived in another city approximately 400 km from the university. The only participant not enrolled in any of the three credit courses offered by the Science/Mathematics Education Department, missed the first activity of the last pre-trip class due to a flight delay and was unable to attend the optional seminar given the short notice. Her school principal provided substitute teachers and covered all travel-related expenses in support of her participation in the ISLE program.

All other participants lived in the metropolitan area surrounding the university and were associated with the Science/Mathematics Education Department in an on-going basis. In contrast, another non-science teacher, needing just 3 credit hours for graduation, missed 3 university classes, the optional seminar, and 2 local day trips. Her reasons varied from personal child-care issues (i.e., the babysitter did not show) to professional duties (i.e., conducting cheerleader try-outs).

Of particular importance, Student Negotiation was emphasised throughout the pre-trip segment. For example, the participants who were able to participate in certain events were encouraged to and did help those who were not able to participate by sharing class notes, field records, and summarising event details in electronic mail messages. For the benefit of all, the field ecology instructor or information technology assistant also facilitated a review of the previous meeting before starting the coursework of the following gathering.

The local tree transect activity forced teamwork and allowed each individual to experience the benefit of the collaborative design. Based on this common field experience, each participant realised that it was ‘OK’ to work together to get the job done. It showed them that they could learn as much – in fact, even more – in a cooperative environment as compared to the traditional learning environments typically fostered in their school classrooms.

9.3.2 Field Trip Participation (Required and Optional Activities)

The extended field trip segment spanned a total of seven days and a distance of over 960-kilometers, as detailed in section 4.2. A tentative schedule of the field trip events was distributed along with program application and posted to the virtual field trip website on announcement of the program. Figure 41 shows the percentage of participation in each main event of the extended field trip segment for the total ISLE sample (N = 13).

As shown in Figure 41, full participation ranged from 31% for the optional hikes to 100% for 7 activities. Overall, the data reflects better than 92% participation in all required events.

Maintaining a holistic approach to teaching and learning, 100% participation was not guaranteed even though the individuals were removed from the everyday interruptions they encountered at home. Throughout the extended field trip segment, it was important that the trip leaders, course instructors, associated assistants, and peers took care of and watched out for each other. For example, an apparently physically-fit dancer was not allowed to participate in the excursion to the dinosaur excavation site. This precaution was necessary to provide time for her to recover from the heat exhaustion she experienced on hike to the Hot Springs the day before.

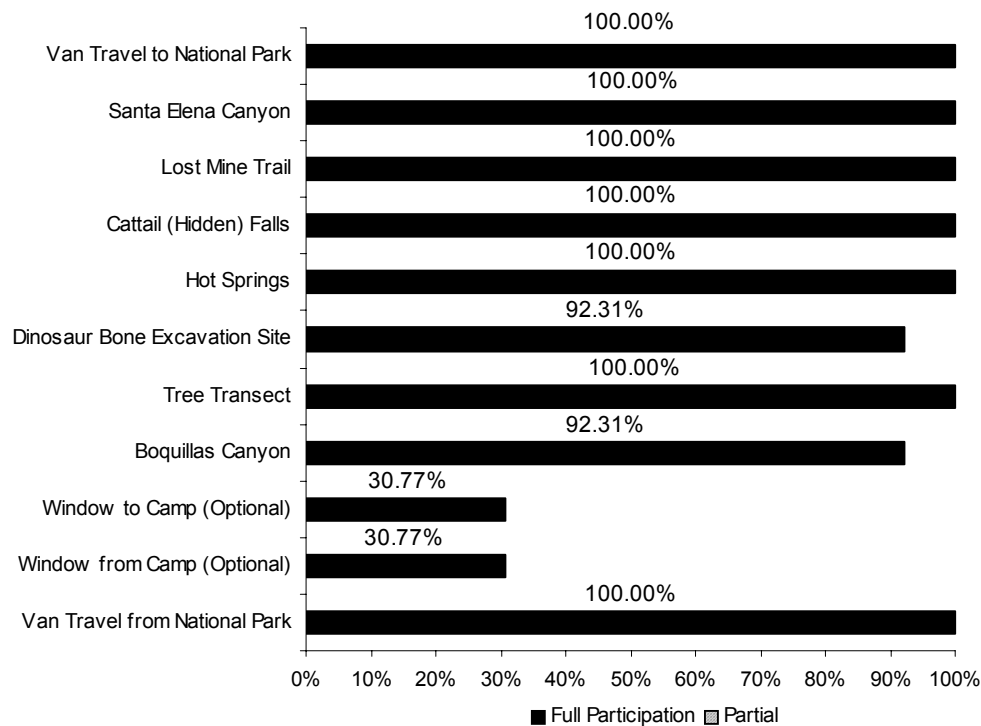


Figure 41. Extended Field Trip Participation Summary

By this point in the program, all participants realised the value of the Field Experience Questionnaire, reiterated by the field ecology instructor and researcher. A basic premise of experiential training (described in section 6.1.3) purports that if the participants felt unsafe or pressured in any way (pertaining to the physical aspect), they will not be able to fully register the experience (pertaining to the emotional aspect), and thereby, learning will be impacted on as well (pertaining to the intellectual aspect). Therefore, it was emphasised that all activities were presented in ethical context of ‘challenge by choice’.

As a result, partial participation was not negated as a weakness, but rather applauded as a critical awareness and personal intelligence. Recall the arduous Lost Mine Trail hike, described in section 4.2.1.2. The teachers’ self-imposed challenges on this first full implementation of the ISLE model surprised even the most experienced field trip veterans. For example, the demanding hike up from Hidden Falls to ‘the Window’ improved the self-efficacy of two participants who suggested the activity as they were insecure in their physical abilities. In the end, four adventurers – along with one of the university’s two-way radios to maintain contact in case of emergency – exchanged ideas on many subjects and bonded in lasting and unique ways.

The positive learning environment established in the pre-trip segment was voluntarily maintained in the group's inherent openness. A sense of team overpowered the fear of specific requirements. The teachers repeatedly surprised themselves as they also took care of each other at the historically expected expense of their own outward performance. Recall the patience, support, and concern of able-bodied participants who remained with fatigued or injured peers on the strenuous hike to the dinosaur excavation site (see section 4.2.1.4). The same behaviours were evidenced on an emotional level as well. For example, a more popular and determined science teacher stopped to talk with a frustrated and upset non-science teacher during the tree transect (see section 4.2.1.5). These two participants had not experienced extensive, direct contact prior to or following this experience, but they could relate to each other and felt the need to connect in this instance.

In each of these instances, and in many other cases in which an individual's well-being mattered more than completing a specific task, the comprehensive virtual field trip design reinforced the fact that participants could afford these unique moments as they each would be able to catch up with the group in the long run.

9.3.3 Post-Trip Participation (University Classes and Other)

The post-trip segment was comprised primarily of two informal working sessions, one off-site social gathering, and requests for additional data as detailed in section 4.3. The schedule for the post-trip events was determined by the group after development of the program. Figure 42 shows the percentage of participation in each main event of the post-trip segment, based on the total ISLE sample (N = 13).

As shown in Figure 42, full participation ranged from 54% for the optional survey administration to 100% for other activities. Overall, the data reflects better than 50% participation in all informally scheduled post-trip events. Reasons for the lower return rate on the CLES-CS surveys were mostly beyond the control of the participants, as detailed in section 8.1.2.1. Of the 8 ISLE science teachers, one had retired and two reported administrative policy restrictions for not being able to participate in that particular part of the study.

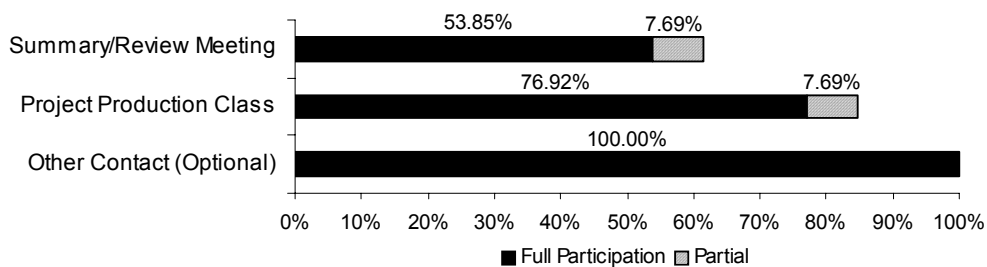


Figure 42. **Post-Trip Participation Summary**

In the post-trip segment, the field ecology instructor and information technology assistant worked individually to ensure that the teachers meaningfully internalised the coherent whole of their experience. Within a comprehensive program design, the ISLE participants gained more than just the sum of the parts. By fitting the pieces together in the virtual field trip project they learned far more than just discrete bits of facts and figures concerning the ecology, the geology, and the impact of humankind on the environment in a particular place. In realising the ‘big picture’ by creating the virtual field trip product, the teachers were enabled to transfer to this understanding their own students. This final outcome is much more meaningful than any single lesson on any single day, as suggested in the following section.

Occasional unsolicited contact was made directly and indirectly with various participants over time. Several participants were still completing the MAT program, while others reported maintaining regular personal and professional contact with their ISLE peers. The field ecology instructor and information technology assistant have heard from at least one ISLE participant nearly every week since the official calendar completion of the program through electronic mail messages, phone calls, or casual drop-in visits to the university campus when convenient.

The actual long-term impact of the ISLE program is difficult to document; however, this single implementation developed a specialised network that has remained in tact for over two years. In January 2002, for example, after describing an evening lecture presented by a palaeontologist at a local natural history museum, one non-science participant added the following personal comment in an electronic mail message to all of the university instructors.

I still can't begin to express how much fun I had on and how much I learned from the Big Bend experience! It has been a topic of conversation many times. Every time I tell the story of our group's trip to Big Bend, most people

are amazed and fascinated by my experience. Thank you for giving me and other teachers the opportunity. I would do it again in a heartbeat!

That same week, a science teacher, after lamenting the struggles of school science fairs, noted that “I am using more of my trip stuff than I ever thought I would or at least realising that I can integrate it next year. That’s been nice”. Later that summer, a brief message informed the information technology assistant of another participants’ marriage and subsequent change of address. Without a doubt, the ISLE program impacted the lives and careers of several participants. As such, the potential impact of the ISLE model is suggested in the next section.

9.4 Implications of the ISLE Model

In a speech delivered to university students and their parents, instructors, and administrators, Fraser (2001) presented “compelling evidence that the classroom environment so strongly influences student outcomes that it should not be ignored by those wishing to improve the effectiveness of schools and universities” (p. 2). Consisting of more than content and outcomes, the curriculum of schools and universities includes unexpected places and spontaneous ways in which the business of learning can take place. Fraser (2001) eloquently concluded that: “It is the quality of life lived in the classrooms that determines many of the things that we hope for from education – concern for community, concern for others, commitment to the task in hand” (p. 2). Because the ISLE instructors changed the teachers’ learning environment in Phase I, the ISLE teachers’ were able to improve each of their students’ classroom learning environments in Phase II.

In the ISLE model, a process approach to information technology (described in section 6.2.2) practically illustrated how, when combined, separate parts that typically work independently can be combined to realise effective applications in the real-world (refer back to Figure 39). The significance of this internalisation of concepts and principles was recognised in the Montgomery County Public Schools, where a change in philosophy during the last 10 years began slowly from the bottom up. “A few teachers learned about constructivist theory and began advocating restructuring of curriculum and instructional practice. Word spread. More teachers began attending conferences and workshops. As interest grew, retraining sessions

were conducted. Teachers made great changes because they wanted to, not because they were required to do so” (Matusevich, 1995, ¶ 11).

The urgency of today’s educational issues necessitates immediate reform on an impressive scale. As noted by Rillero (1993), holistic transformation can be exponentially promoted in the public/private school classroom through established teacher education programs. Table 33 projects the potential impact of ISLE-based virtual field trip products on the ultimate target, the public/private school classrooms.

Table 33. Potential Impact of ISLE-Based Virtual Field Trip Product for Public/Private School Classrooms

Big Bend Trip (2000) (1 trial, tuition-based)	Future Trip Potential (2 per year, funded)	Audience
2	2	Instructors, initially teach
12	40	Teachers (12-20 per class), who impact
1,200	4,000	Students (100 total on average), who over time gain the attention of
60	200	Colleagues (5 per department on average), who in turn influence next class of
6,000	20,000	Students, who may become teachers, but will be decision-makers and caretakers

Considering this study alone, two instructors initially taught 12 teachers. On average, these 12 teachers could impact not only 1,200 students, but also 60 colleagues. Those peers, as a whole, influence the next class of 6,000 students who also could become teachers and are the next generation of global citizens. Maximising the impact by implementing two full-scale ISLE programs per year, the same two instructors could potentially impact on 20,000 public/private school students.

Other studies suggest the possibility of realising these projections. Ramey (1999) evaluated a field-based summer teacher professional development model that was shown to be powerful in implementing change within school settings “because of its collegial nature – a fellow classroom teacher working with and supporting other teachers to bring about enhanced science teaching and learning” (¶ 4). The ENVISION professional development model successfully changed teachers practice by “shifting their pedagogy toward a more student-centered inquiry orientation” (Shepardson, 2002, p. 4). Unfortunately, however, those teachers did not integrate student-generated science research into their classrooms.

The virtual field trip product, inherently promoted in the ISLE model, was designed to provide a way for teachers to implement the constructivist teaching modelled in the actual experience at no cost and with unlimited access, as cautioned by Dickerson and Dawkins (2002). Two practical issues emerged from their research concerning field-based programs: designers of professional development programs must “remain cognizant of the physical demands of their programs” and program leaders need to “remain mindful of their participants’ abilities to secure materials necessary for the implementation of ideas gleaned from their instruction” (p. 6).

Beyond these theoretical projections, and perhaps more importantly from a practical point of view, the ISLE model also effects a cumulative impact on lifelong learning. Figure 43 illustrates how the experiences which a single teacher gains in the university classroom impacts on her/his experiences in the field. Those experiences further impact on the same teachers’ school classrooms where, ultimately, they give their students the opportunity to gain their own unique experiences.

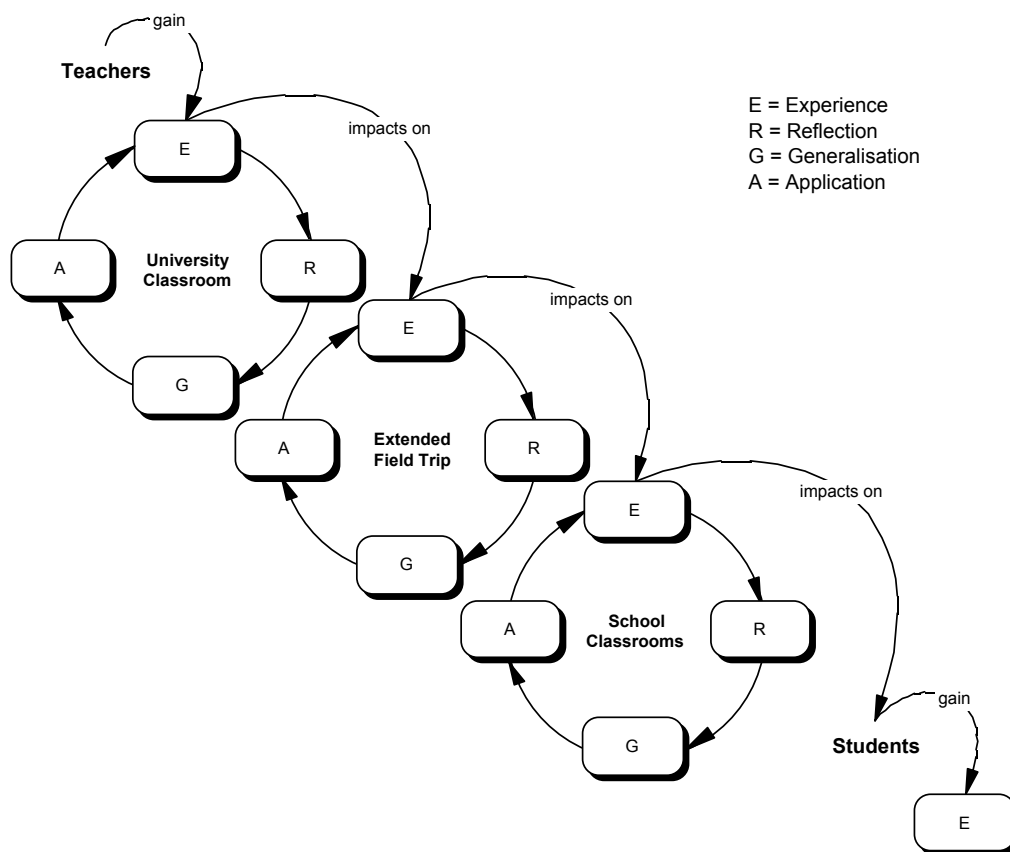


Figure 43. Cumulative Impact of ISLE Model on Lifelong Learning

The end result of incorporating actual field trips into teacher professional development programs continues to be reported as powerful and lasting (Krockover, 2002; Marlow & Wright, 2002). That the ISLE model was strategically designed to attract and accommodate a diverse audience of educators and lifelong learners is further supported by the breadth of its appeal in a variety of fields. The researcher has presented the ISLE model at international meetings for educational researchers, national conferences for geologists and geology teachers, and state and local conventions for science teachers, instructional designers, and university professionals. The open structure of the research study enabled the evaluation of a complicated program to find out what worked and how it impacted the learners. Therefore, the outcomes can be used to address teachers, researchers, funding agencies and, ultimately, the students in our classrooms.

9.5 Summary of the Recommendations and Conclusions

The ISLE model provided a catalyst for educational change. Like train-the-trainer programs, the ISLE multiplied the power of actual scientific field experience through an educationally-sound, globally-available, virtual field trip product. The actual university/field trip course enabled teachers to understand the concepts and learn the techniques of constructivism.

These skills and insights were internalised by each individual, as well as the whole team. By establishing a networked community of like-minded individuals, transfer of theory and practice is more readily implemented in the geographically separate school settings. As the ISLE teachers implement more and more constructivist learning opportunities in their classrooms, other teachers throughout the school are likely to begin to see and hear and feel the effects of such change. The virtual field trip provided a means for these second-generation ISLE teachers to implement constructivist teaching through the same foundation as the actual ISLE teachers. Thus, a true mentor relationship is formed and the community is further expanded; thereby, a single teacher might effectively influence an entire district, as this approach is transferred to other science lessons and across disciplines.

Building on fundamental coursework in science, society, and technology, participants directly interacted with renowned experts and specialists. The principles of hands-on inquiry and teacher-as-researcher transferred directly into the classroom as students observed and participated in diverse educational settings. Real-world

experience integrated the core concepts of science with the subtleties of pedagogy that sprung from allowing students to construct their own knowledge.

Virtual field trips, based on the ISLE model, enable the principles of student-centred inquiry and constructivism to be practised for the benefit of all styles and ages of learners (Galas, 1999). *Why are geology students required to complete field camp or medical students required to perform internships?* Because the real world is where theory and practice come together and science becomes relevant, making sense that leads to understanding.

Tell me... and I'll forget.

Show me... and I may not remember.

Involve me... and I'll understand.

Native American Proverb

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Appendix I

Introduction to Information Technology

The following narrative was delivered to the ISLE program participants by the researcher (also the information technology assistant) in the first university class to introduce the members of the group, while providing a metaphor for managing information overload and non-linear processing. The teacher instructions for Community Juggling were included on the Global Environmental Change website.

Welcome! We're going to start off with an activity that you can do in your classes. Let's form a large circle. Face inward about elbow width apart please.

Community Juggling is a lot of fun and many folks have enjoyed using it in a myriad of applications. There are just two rules: 1) you have to play nice and 2) you have to be polite. Let's run a quick requirements check. Everyone please cup your hands in front of you. Now do the same with your hands behind your backs. Good job!

We're going to learn a few names by establishing a pattern. Here's how it works. I'm going to first get Cynthia's attention by calling her name, 'Hey Cynthia...'. When she replies 'Yes Rebekah?', I then toss a soft object to her. Being a kind friend, she says 'Thanks Rebekah'. Now it's her turn to choose someone else to toss the object to; after you receive the object, be sure to place your hands behind your back so we know you've had it. That's all there is to it! We'll repeat the process until everyone has played and it finally returns to me. Pay close attention to the sequence of events: remember who throws the object to you and to whomever you choose to toss it. Ready?

(Perform the activity as described with one object.)

That was pretty good! Now you at least know one other person's name in the group, and hopefully will be better able to remember your own! Do you think we can do it again? Alright, let's repeat the same pattern and see how it goes. 'Hey Cynthia...'

(Perform the activity as described, but after the first object has been received and passed on to the second in the sequence, get the first person's attention again and toss another object. Repeat until all objects have been returned.)

You did it! Great job! Did anyone happen to look into the centre of the circle while all that was going on? What did it look like? What did it sound like? What did it feel like?

(Repeat responses to the group.)

Sometimes I feel like that's just the way my day goes. I'm constantly bombarded with unexpected tasks and emergencies that require my time and attention – and often wear me out! With respect to your teaching, what might these different objects represent?

(Relate responses to the group.)

Now, does life always happen the way you expect it to? Think about how you deal with things that come at you from unexpected directions. Let's see what happens when we try this in reverse! Repeat the same pattern in the opposite sequence. Okay? 'Hey Rick...'

(Perform the activity in reverse sequence with multiple objects.)

Way to go! Give yourself a round of applause! Was it easier or harder this time?

(Poll group after they stop laughing!)

What made it work did we do to accomplish the task? As an individual, what did you do that worked or didn't work? As a group, what did you all do that worked or didn't work? What happened when someone dropped the ball? How do you recover when you 'drop the ball'?

(Repeat responses to the group.)

Good. With that perspective, what can/do you do to balance your various priorities and numerous tasks in your classes? Do you think your students might be similarly overwhelmed with 'items' tossed their way from different directions during the day? What might these objects represent to them?

(Relate responses to the group and transition to information technology.)

One reason I like this activity so much is that it so aptly represents the way the web works. Perhaps the biggest hurdle we face as a result of the information explosion is information overload. How do you deal with the great numbers of options available in this information age? I heard someone mention that they couldn't remember everyone's name. Did you need to get the job done? The thing that seemed to help was focus. As we practised did you become more comfortable with the names? Eventually we got into a rhythm that made the process a lot smoother and seemingly more natural. Did you notice how many times people helped each other out with their names? That was terrific and touches on another key element you noted as the teamwork aspect.

What implications does this activity have for non-linear learning, specifically using the Internet in teaching? What if all who handled an item focused on that specific issue, taking into account the others' perspectives?

This is a particularly busy time for you at work right now. Are there any other items that make your role as a teacher easier or harder? Having successfully managed this activity, think about what you might try to better deal with those items. Not only do you have to deal with work, there are also families, friends, hobbies, and other commitments that distract you nearly everyday. By breaking the big picture into manageable 'chunks' (or individual objects), it's a whole lot easier to accomplish each task. Seeing your success in focused areas helps you keep things going until that initially overwhelming goal is achieved.

By now you're surely wondering what you've gotten yourself into! Why in the world would we chose to start this course off with such a silly activity! Think about it... It's ironic that the one constant in our society is 'change'. Technology literally advances daily. There is no way we could cover all the tools and resources available right now even. And what would be the point? Specific skills quickly become obsolete. As teachers, you are faced with different scenarios each semester. We must learn to select/apply appropriate tools and develop/adapt to relevant resources.

The main purpose of the Community Juggling experience is to help participants internalise the three key concepts critical to developing a comprehensive understanding and effective implementation of educational technology: communication, collaboration, and creativity. Throughout the program, we'll use this same approach to build the virtual field trip. Each team member will focus on a smaller piece of the whole. Even with all the things going on around you in the field, you can be confident that when we return and assemble the final project, everything will fit together and you'll be able to enjoy the big picture! Everyone will share the same benefit without being overwhelmed. There's no way you could process all the sights, sounds, and sensations you'll experience in a week in Big Bend!

You'll soon find out why this is such an important activity! Trust me, we'll come back to this one again and again. No matter how many times you 'play' these 'games', you'll always become aware of something new! Remember this particularly powerful metaphor – and use it!

Appendix II

Introduction to Concept Mapping

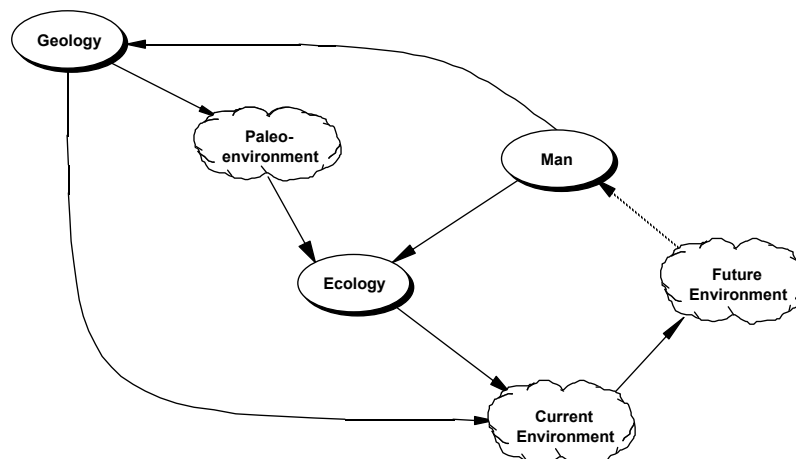
The following narrative was delivered to the ISLE program participants by the researcher (also the information technology assistant) in the university computer laboratory to model the effective use of electronic presentation tools, while providing direction for project definition and management. The complete, original, full-size graphics were included for review on the Global Environmental Change website.

Slide 1: 'Chunking' Complex Concepts: How to Develop Your Area of Focus for the Field Trip...

We've talked about information overload in a variety of contexts. We are bombarded with factoids, ploys, and gimmicks for the better part of each day. Rapid advances in technology provide exciting opportunities to venture into new realms of knowledge and experience. But our amazing minds and human bodies can only absorb so much! How do we stay 'sane' in such ever changing, exponentially expanding times?

One trick is to break things down into manageable "chunks". Research has shown that there is a critical capacity for maximum stimulation and a limit to comprehension. Concept mapping is an effective technique that can be used to address the overwhelming feelings that negatively impact learning in the university classroom, the field, and the public/private school classroom. It also caters to the needs of diverse learning styles, requiring higher-level critical thinking skills and a basic understanding of content and process. Additionally, concept maps offer an appropriate tool assessment and evaluation for this information society.

Slide 2: High-level Concept Map

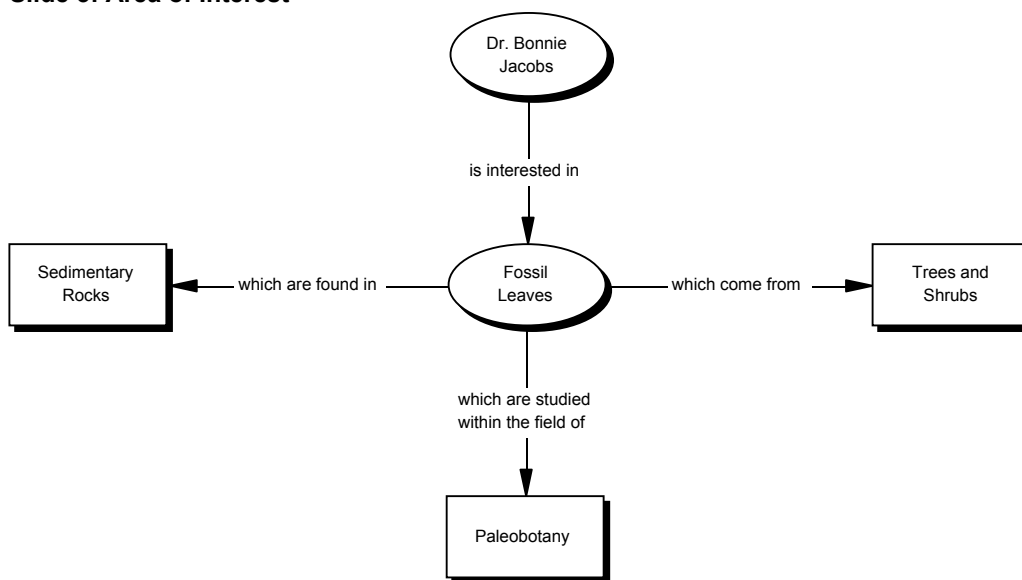


You recognise this image. It appears quite simple at first glance; however, was a tremendous challenge to create. You are faced with the same charge! Concept maps force you to actively think. They are not fancy organisation charts! Each element and link represents a complex feature that is tied into an even greater whole and can be extended in infinite directions. Clearly defining your focus is certainly not an easy task; but it is worthwhile

and incredibly rewarding. Use your experience with 'surfing the web' as a metaphor. There's an impressive list of related links on the class web site. Notice the things you like; note which pages you don't like or find confusing. What prompted your response?

We'll link our individual project 'chunks' into this basic overview to create a multi-faceted, cross-curriculum product - more importantly, to develop a rich learning environment for unlimited use. Our series of multi-level concept maps provides a metaphor for illustrating the effective use of a powerful teaching tool and resource: the World Wide Web. Look closely at each 'piece' of the image. This is the highest conceptual representation of the project. Basically, it's the home page for the content portion of our virtual field trip. Everything stems from and leads back to this idea of the direct and indirect links between ecology, geology, and man as evidenced in the past, observed in the present, and implied for future environments.

Slide 3: Area of Interest



We'll build our site with information presented from your unique perspective. This example (one of many possibilities) represents my interpretation of what Dr. Jacobs might develop. She is interested in fossil leaves that are found in sedimentary rocks, come from trees and shrubs, and are studied within the field of paleo-botany. The concept map simply places the main ideas/key elements/concepts (the pages) in a framework (the site map) held together with descriptions of the relationship (the link).

This is the type of design you need to develop before we head into the field. Explore your interests, discover your passion, consider your talents, do a little research, choose your focus area. You'll become the trip expert on that particular subject over the next few weeks. Your plan may change and will surely be revised as you look at it through new eyes within the context of the 'big picture'. This (indicated by the yellow fill in actual presentation) is as far as you need to go on your own. As a team, we'll map out the intermediate links to tie everything into the high-level map (previous image).

Slide 4: Link to Geology

This is just one dimension to show a possible pathway linking the area of interest to the high-level concept of geology. Notice the direction of the arrows. We'll build our site from the bottom up (specific to general). Visitors to the web site will approach it from the top down (general to specific). Knowing where we're headed (the high-level map) will ensure that the pieces fit together to colour the panoramic picture we'll paint.

Slide 5: Link to Ecology

You can do the same thing to show the relation to the ecology section. Eventually the pieces will be 'hot' (hyper-linked) so that all you have to do is click on the item in the map to go to the next level map or supporting pages.

Slide 6: Link to Man and the Environment

Ultimately, it all comes back to the environment and man's impact/response. This is an extremely simplified example. We all know that the real world is not so clear-cut and compartmentalised. Our final map will look like a web, with all sorts of cross-cutting angles and loops. Remember our Community Juggling circle? Relationships are indeed complex and hard to represent on a 2-dimensional sheet of paper.

Slide 7: The Big Picture

This is the possible extent of just one contribution! You can see the complexity and potential confusion in managing such information. If the chunks are too large or the relationships vaguely defined, this sort of task is impossible. No wonder it's hard to stay on task when surfing the web! With careful design, each learner can determine his/her own route and eventually navigate through the entire site, with maximum understanding.

Slide 8: Your path...

Don't worry about 'getting it right'. There is not a right or wrong answer/approach. Learning is a life-long opportunity for adventure and exploration. Field experience is the culmination of schooling and demonstrates the ultimate application of content within context. Indeed, this trip is quite real. We're taking advantage of all sorts of technology to make a virtual experience to share with your students. We'll use the Inspiration software package to develop the pieces of our puzzle in the field. Keep an open mind – and hang on to your sketches!

1. Re-focus investigations for classroom use; you can't cover everything
2. The goal is to relate practical, real-world experience (hence, 'virtual' field trip)
 - Keep it open-ended to allow for teacher customisation.
 - Define little chunks for clear links and easy navigation via multiple paths.
 - Paint the BIG picture: highlight relevancy and point out possible paths for further discovery.
3. Pick something you find interesting/curious, and
 - look for examples/evidence in the field,
 - ask questions of the experts you encounter,
 - discuss observations with your peers and co-field trippers,
 - fill in the gaps with additional research and links to detailed background,
 - figure out where it fits in the grand scheme (our initial concept map), and
 - how it relates to what the other members of the field team are investigating.
4. Clearly, the concept map is the main evaluation tool; if you can create effective concepts maps of your topic, within the basic outline, then you have learned and are able to communicate that understanding!
5. Consider the medium! Think about what you liked/disliked/would change about the web sites you've looked at in preparation for the trip or otherwise. Don't forget that your project will be delivered electronically over the World Wide Web.

Appendix III

Instruments, Scales, and Items

As described in section 7.2, six primary data collection instruments were used to support and evaluate teaching and learning within the ISLE program and its impact on the public/private classroom learning environment. This Appendix III provides details of the instrumentation, including the scales and sample items, of the Field Experience Questionnaire (FEQ) in section III.1, the Teachers' Attitudes Toward Information Technology (TAT) questionnaire in section III.2, the three forms of the Constructivist Learning Environment Survey (CLES) in section III.3, the Website Contribution Evaluation Rubric in section III.4, and the Reflective Field Journal in section III.5

III.1 Field Experience Questionnaire (FEQ)

The Field Experience Questionnaire (FEQ), described in section 7.1, contains 13 questions about general travel and outdoor science-related activities. Table 34 shows the statement and response format for each item of the FEQ.

Table 34. Items and Responses on the Field Experience Questionnaire (FEQ)

Item	Statement	Response
1**	Your name? Today's date?	Fill-in-the-Blank
2**	How many trips a year do you take that are more than 3 days long?	More than 6, 3-6, 1-2, I Don't
3**	How many trips a year do you take that are more than 50 miles away?	More than 6, 3-6, 1-2, I Don't
4**	Circle all the places you have visited.	Canada, Mexico, Caribbean, Asia, Europe, Africa, South America, Australia, Hawaii, or Alaska
5**	How many times do you <i>generally</i> camp overnight in a year?	More than 6, 3-6, 1-2, I Don't
6**	Where do you <i>prefer</i> to stay when you're exploring the outdoors?	In a Tent, In a Travel Trailer, At a Lodge or Cabin, In a Motel
7**	Where do you <i>generally</i> stay when you're exploring the outdoors?	In a Tent, In a Travel Trailer, At a Lodge or Cabin, In a Motel
8**	Do you like to travel to new and different places?	Definitely Yes, Later Maybe, It Doesn't Matter, No Not at All
9**	Rank your <i>preferred</i> modes of learning (i.e., 1, 2, 3, 4...).	Listening to Lectures, Doing Lab Activities, Working in a Group, Working in Outdoor Activities, Reading by Myself
10**	Circle the activities in which you <i>like</i> to participate.	Science Fairs, Nature Hikes, Science Clubs, Reading Science Magazines/Books, Watching Science Programs On TV, Environmental Action Projects
11**	Circle the activities in which you have <i>already</i> participated.	Science Fairs, Nature Hikes, Science Clubs, Reading Science Magazines/Books, Watching Science Programs On TV, Environmental Action Projects
12	Please note any physical, emotional, or other limitations that might influence your participation on this trip (i.e., sprained ankle last month; recent loss of loved one, etc.). THIS INFORMATION IS CONFIDENTIAL!	Short Answer
13	Please note any other comments concerning field/travel experiences that might be relevant to the upcoming trip.	Short Answer

** Items adapted from Lisowski (1987)

III.2 Teachers' Attitudes Toward Information Technology Form (TAT)

Teacher scales of the Teachers' Attitudes Toward Information Technology (TAT) questionnaire, developed by Knezek and Christensen (1997) and discussed in section 7.2.1, were adapted to assess the teachers' perceptions of information technology. The 50-item semantic-differential questionnaire repeats the 10 adjective pairs listed in Table 35 for each of the following five scales:

- 1) Electronic Mail
- 2) World Wide Web
- 3) Multimedia
- 4) Personal Productivity
- 5) Computers in the Classroom.

Table 35. **Adjective Pairs on the Teachers' Attitudes Toward Information Technology Questionnaire (TAT)**

Item	Adjective Pair	
1*	Important	Unimportant
2	Boring	Interesting
3*	Relevant	Irrelevant
4*	Exciting	Unexciting
5	Means Nothing	Means a Lot
6*	Appealing	Unappealing
7*	Fascinating	Mundane
8	Worthless	Valuable
9*	Involving	Uninvolving
10	Not Needed	Needed

Adapted from Knezek & Christensen (1997)

* Reverse-scored item

III.3 Constructivist Learning Environment Survey (CLES)

The Constructivist Learning Environment Survey (CLES) focuses on students as co-constructors of their own knowledge (see section 5.1.6), providing a measure of students' perceptions of the extent to which constructivist approaches are present in classrooms. Each of the three modified versions of the CLES developed specifically for evaluating the ISLE model – the adult form (CLES-A), comparative teacher form (CLES-CT), and comparative student form (CLES-CS) – is described in the following subsections.

For the administration of each form, subjects were directed to read each statement and indicate how often each practice occurred with a five-point frequency response scale. They were told to draw a circle around: '1' if the practice takes place almost never; '2' if the practice takes place seldom; '3' if the practice takes place sometimes; '4' if the practice takes place often; or '5' if the practice takes place almost always. They were also cautioned that some statements in the questionnaire are intentionally similar to other statements. They were reminded to give an answer for each question and to change their mind about an answer by simply crossing out the original and circling another. It was emphasised that there are no right or wrong answers as the participants' opinion was what was wanted. Items are scored a 1, 2, 3, 4, and 5, respectively, for the responses, with the exception of item 6 which is scored in reverse. Omitted or invalid responses are scored with a value of 3. The total score for each scale is obtained by adding the scores for the six items in each scale.

III.3.1 CLES – Adult Form (CLES-A)

The CLES-A, described in section 7.2.2, was specifically designed for use with adults and administered, as was the original, to assess the degree to which the principles of constructivism have been implemented in a program or course. Participants were encouraged to think about how well each statement describes what the program was like based on their individual experience ('In this program...'). Within the ISLE model, it was used to evaluate the instructor's teaching both in the university classroom and in the outdoor locales during the extended field trip. Table 36 shows the item numbers and statements in each of the five scales of the CLES-A.

Table 36. Items on the Constructivist Learning Environment Survey – Adult (CLES-A) Form, Grouped by Scale

Item	Statement
Personal Relevance Scale	
1	I learn about the world beyond my professional setting.
2	My new learning starts with problems about the world beyond my professional setting.
3	I learn how science can be part of my life beyond my professional setting.
4	I get a better understanding of the world beyond my professional setting.
5	I learn interesting things about the world beyond my professional setting.
6*	What I learn has nothing to do with life beyond my professional setting.
Uncertainty of Science Scale	
7	I learn that science cannot provide perfect answers to problems.
8	I learn that science has changed over time.
9	I learn that science is influenced by people's values and opinions.
10	I learn about the different sciences used by people in other disciplines.
11	I learn that modern science is different from the science of long ago.
12	I learn that science is about creating theories.
Critical Voice Scale	
13	It is acceptable for me to ask 'why do I have to learn this?'
14	It is acceptable for me to question the way I'm being taught.
15	It is acceptable for me to talk about activities that are confusing.
16	It is acceptable for me to talk about anything that prevents me from learning.
17	It is acceptable for me to express my opinion.
18	It is acceptable for me to speak up for my rights.
Shared Control Scale	
19	I plan what I'm going to learn.
20	I decide how well I am learning.
21	I decide which activities are best for me.
22	I decide how much time I spend on learning activities.
23	I decide which activities I do.
24	I assess my learning.
Student Negotiation Scale	
25	I have a chance to talk to other students.
26	I discuss how to solve problems with other students.
27	I explain my understandings to other students.
28	I ask other students to explain their thoughts.
29	Other students ask me to explain my ideas.
30	Other students explain their ideas to me.

Adapted from Taylor & Fraser (1991)

* Reverse-scored item

III.3.2 CLES – Comparative Teacher Form (CLES-CT)

The Constructivist Learning Environment Survey – Comparative Teacher Form (CLES-CT), described in section 7.2.3, is a slightly modified variation of the CLES-A. It was specifically designed for use with classroom teachers to assess the degree to which the principles of constructivism have been implemented in the public/private school classroom as the result of a program or course.

Two response blocks for each of the same 30 items are presented in side-by-side columns. The left, shaded area begins with ‘In my lessons BEFORE the course ...’, while the right, clear area begins with ‘In my lessons AFTER the course...’. The 60-item CLES-CT contains six statements in five scales about practices that could take place in a class or program. Grammatical changes were carefully constructed to maintain the validity of the base instrument in the new comparative format, illustrated below:

I teach about the world outside of school.									
<i>In my lessons BEFORE the course...</i>					<i>In my lessons AFTER the course...</i>				
Almost Never	Seldom	Some- times	Often	Almost Always	Almost Never	Seldom	Some- times	Often	Almost Always

Item Layout for the Constructivist Learning Environment Survey – Comparative Teacher (CLES-CT) Form

Within the ISLE model, it asks the classroom teacher to compare the degree to which s/he feels that s/he has implemented the principles of constructivism in his/her own classes following their university/field trip experience (AFTER) with previous classes that they have taught throughout their careers (BEFORE). Table 37 shows the item numbers and statements in each of the five scales of the CLES-CT.

Table 37. **Items on the Constructivist Learning Environment Survey – Comparative Teacher (CLES-CT) Form, Grouped by Scale**

Item	Statement
Personal Relevance Scale	
1	I teach about the world outside of school.
2	My teaching starts with problems about the world outside of school.
3	I teach how science can be part of students' out-of-school life.
4	My students gain a better understanding of the world outside of school.
5	I teach interesting things about the world outside of school.
6*	What I teach has nothing to do with my out-of-school life.
Uncertainty of Science Scale	
7	I teach that science cannot provide perfect answers to problems.
8	I teach that science has changed over time.
9	I teach that science is influenced by people's values and opinions.
10	I teach about the different sciences used by people in other cultures.
11	I teach that modern science is different from the science of long ago.
12	I teach that science is about creating theories.
Critical Voice Scale	
13	It's OK for students to ask me 'why do I have to learn this?'
14	It's OK for students to question the way they're being taught.
15	It's OK for students to complain about teaching activities that are confusing.
16	It's OK for students to complain about anything that prevents them from learning.
17	It's OK for students to express their opinion.
18	It's OK for students to speak up for their rights.
Shared Control Scale	
19	Students help me to plan what they're going to learn.
20	Students help me to decide how well they are learning.
21	Students help me to decide which activities are best for them.
22	Students help me to decide how much time they spend on learning activities.
23	Students help me to decide which activities they do.
24	Students help me to assess their learning.
Student Negotiation Scale	
25	I get the chance to talk to other teachers.
26	I talk with other teachers about how to solve problems.
27	I explain my understandings to other teachers.
28	I ask other teachers to explain their thoughts.
29	Other teachers ask me to explain my ideas.
30	Other teachers explain their ideas to me.

Adapted from Taylor & Fraser (1991)

* Reverse-scored item

III.3.3 CLES – Comparative Student Form (CLES-CS)

The CLES-CS (described in section 7.2.4) was specifically designed for use with secondary students and administered, as the original, to assess the degree to which the principles of constructivism are evident in a specific classroom learning environment within the broader context of the school-level environment.

Similar in format to the CLES-CT, two response blocks for each of the same 30 items are presented in side-by-side columns. The left, shaded area begins with ‘In OTHER classes...’, while the right, clear area begins with ‘In THIS class...’. The 60-item CLES-CS contains six statements in five scales about practices that could take place in a class or program in the new comparative format, illustrated below:

I learn about the world outside of school.									
<i>In OTHER classes...</i>					<i>In THIS class...</i>				
Almost Never	Seldom	Some- times	Often	Almost Always	Almost Never	Seldom	Some- times	Often	Almost Always

Item Layout for the Constructivist Learning Environment Survey – Comparative Student (CLES-CS) Form

Table 38 shows the item numbers and statements in each of the five scales of the CLES-CS.

Table 38. **Items on the Constructivist Learning Environment Survey – Comparative Student (CLES-CS) Form, Grouped by Scale**

Item	Statement
Personal Relevance Scale	
1	I learn about the world outside of school.
2	My new learning starts with problems about the world outside of school.
3	I learn how science can be part of my out-of-school life.
4	I get a better understanding of the world outside of school.
5	I learn interesting things about the world outside of school.
6*	What I learn has nothing to do with my out-of-school life.
Uncertainty of Science Scale	
7	I learn that science cannot provide perfect answers to problems.
8	I learn that science has changed over time.
9	I learn that science is influenced by people's values and opinions.
10	I learn about the different sciences used by people in other cultures.
11	I learn that modern science is different from the science of long ago.
12	I learn that science is about creating theories.
Critical Voice Scale	
13	It's OK for me to ask the teacher 'why do I have to learn this?'
14	It's OK for me to question the way I'm being taught.
15	It's OK for me to complain about teaching activities that are confusing.
16	It's OK for me to complain about anything that prevents me from learning.
17	It's OK for me to express my opinion.
18	It's OK for me to speak up for my rights.
Shared Control Scale	
19	I help the teacher to plan what I'm going to learn.
20	I help the teacher to decide how well I am learning.
21	I help the teacher to decide which activities are best for me.
22	I help the teacher to decide how much time I spend on learning activities.
23	I help the teacher to decide which activities I do.
24	I help the teacher to assess my learning.
Student Negotiation Scale	
25	I get the chance to talk to other students.
26	I talk with other students about how to solve problems.
27	I explain my understandings to other students.
28	I ask other students to explain their thoughts.
29	Other students ask me to explain my ideas.
30	Other students explain their ideas to me.

Adapted from Taylor & Fraser (1991)

* Reverse-scored item

III.4 Web Site Contribution Evaluation Rubric

The Website Contribution Evaluation Rubric, described in section 7.2.5, lists 10 critical aspects related to the Integrated Science Learning Environment project requirements. Each item is rated by the teachers, and also by the instructors, on an 11-point scale ranging from a minimum score of zero (0) for no evidence of the feature, through mediocre (5) work, to a maximum value of 10 for excellent demonstration of the feature. Summation of the scores earned results in an overall evaluation of the work based on 100 total possible points. Table 39 lists the elements contained in the rubric.

Table 39. **Elements on the Web Site Contribution Evaluation Rubric**

Item	Element
1	Integration of Data Collection
2	Evidence of Change/For Prediction
3	Relation to Geology
4	Relation to Ecology
5	Relation to Man
6	Information Organisation
7	Content Accuracy/Completeness
8	Originality of Topic
9	Relevance of Topic
10	Interdependence on Other Topics

III.5 Reflective Field Journal Requirements

The Reflective Field Journal, described in section 7.2.6, is comprised of teacher responses to a series of guiding questions. It was designed to highlight key aspects of each field-based activity throughout the program, including day trips executed as part of the university coursework and main events planned for the extended field trip. The requirements for each participants' Reflective Field Journal for the Field Ecology course implemented in the ISLE program are listed below:

Reflective Field Journal Requirements (Summer 2000)

Your field notebook is a **daily** log of your time spent in the field. It is due the last day of the trip. (Also included in this notebook are reflections from the five days prior to the trip.) Set the notebook up in the following manner:

- Title page:
 - Name
 - Date
 - Address
 - Phone number
 - Course title
- The left page (back of the previous page) contains drawings, diagrams, charts, graphs, and other pictorial data.
- The right page contains notes. Notes include:
 - Date
 - Location
 - Information about the location
 - Whatever else you want to add to jog your memory. Put an 'aha' next to things you learn that surprise and/or delight you.
 - Question section at the end of each day
 - Reflection section at the end of each day

Parkhill Prairie Field Questions

- How did the terrain change between UT-Dallas and the prairie? Why are there juniper trees in some areas and not in others? Why do the junipers appear to be growing in rows?
- What types of plants are visible now? Would these be the same plants you might have observed 100 years ago? What about 1,000 years ago? How about 100,000 years ago? And 60,000,000 years ago? How do you know?
- What is man's impact on this area, other than construction (housing, industry, etc.)?
- What surprised you most about this prairie area? Why?
- What is the relationship between the water and the prairie? From where does the water come? How do you know?
- What causes prairies and forests to form in different areas?
- Describe the ecotome between forests and prairies. Did you see one on this trip?
- Who will go home with the most interesting nickname? Back up your prediction with observations.

Water Treatment Plant Field Questions

- What left all the lakes, streams, and rivers in North Texas?
- How does the geology indicate where water was previously?
- What is the impact on the environment of making lakes/reservoirs?
- Why, geologically, are lakes/reservoirs where they are?
- What is the effect of **not** treating water? (Don't tell me that it will still be dirty! Think about the 'Big Picture'.)

- What is the effect of treating water? (Again, think about the 'Big Picture'.)
- What is the impact on the watershed of farming? How does farming impact water treatment? What has irrigating to do with this entire scenario?
- How does the ecology of an area affect the geology?
- How does the geology of an area affect the ecology?
- What does all this have to do with **your** drinking water?
- Who has a new tattoo? What is it? Where is it and how do you know?

Big Bend Questions

Day 1 (from Dallas):

- On your drive from Dallas into the park, you passed through several different biomes. What were they and how could you tell them apart? Give specific examples.
- How has man's impact affected the availability of water in West Texas? Was this area ever better for farming? How do you know?
- What part does the substrate play in the characterisation of a biome? Give specific examples.
- How have the geologic changes in these areas (from Dallas to Big Bend) changed the vegetation?
- A column of water cannot be lifted by air pressure higher than 34 feet. How does water get to the top of trees greater than 34 feet tall?
- Looking toward 'the Window', what do you see? How does this vista affect you?

Day 2 (Santa Elena and Lost Mine Trail):

- On our hikes we saw a variety of plants. How does the available water in the area affect them? How do you know?
- Draw a cross section of the areas through which we hiked. Be sure to label changes in flora and in terrain.
- Explain why plants wilt.
- Identify and sketch 15 plants. Make sure you have representatives from shrubs, herbs, cactus, and trees. Explain how turgor pressure is important to these plants and how they establish this in such a dry area.
- 'The Basin' is an extinct volcanic crater. What caused its formation? How does this affect the variety of plants in this area? How does man affect this area?
- Reflect on what you learned today. How do you FEEL about your learning?

Day 3 (Dinosaur site and Hidden Falls):

- You hiked through a variety of plants on your way to the dinosaur site. List at least 5 different adaptations to desert life they exhibited. Give specific examples.
- Trace the movement of energy through the desert system in the area near the dinosaur site.
- What is the major type of erosion in these areas? How is this related to the flora?
- On our hike, there were many kinds of plants. Why do they occur in these specific areas?
- Is an ocotillo a cactus? What about an agave? How do you know?
- What are your frustrations about learning science in the field? What are the good points?

Day 4 (Boquillas, Hot Springs and Transect near Lodge):

- What are the interactions between the plants and the geology at each of the areas we visited today?
- Do the plants in the desert form any sort of observable pattern? Explain.
- Describe the fauna you have observed. How are they adapted to live in their biome?
- Find 10 plants described in the *Medicinal Plants* book. Locate them and sketch what you see in the field. If you have already sketched them, refer back to that page in your notes. Why was each important to the human inhabitants of this area.
- Why do ecologists perform transects? How could research of this type benefit the park? How could it transfer to your classroom? How are the internal structures of herbs different from trees? How are they the same? How is helping others do a transect different from doing one? Make sure you get each group's data in your notes!

- You've travelled back in time 200 years to visit your favorite part of Big Bend. Who would you bring? Why?

Day 5 (Where ever we are that day):

- What types of flora were in this area when the dinosaurs were alive? How do you know? Describe a likely progression from those flora to current flora.
- You've observed several types of flowering plants. Describe the flowers and their probable pollinators.
- Project the impact the industrialisation of Mexico and NAFTA may have on Big Bend.
- Would you support the regulation of numbers of tourists in National Parks? Explain your position.
- Describe at least two interactions you observed today among the flora, fauna, and abiotic factors.
- Write a poem (not a limerick) about your field trip experience. You may use the following pattern if you wish:

noun
 adjective, adjective
 -ing, -ing, -ing
 adjective, adjective, adjective, adjective
 -ing, -ing, -ing
 adjective, adjective
 noun

The first and last nouns may be synonyms or antonyms. The first two adjectives in the center line refer to the first noun; the second two adjectives in the center line refer to the last noun. In the third and fifth lines, -ed words can be substituted for -ing words.

Final Reflections:

The following questions are intended to measure the information and teaching applications you acquired.

- Into what part of the curriculum you teach will you integrate what you learned today?
- How will you use hands-on activities to accomplish the integration?
- What artefacts will you use to help your students attain this knowledge or skill?
- How will you check to see if your students 'got it'?

Your reflections on **your learning** help you evaluate your own progress. Answer the following when you write your reflections:

- How do you learn best?
- What is hardest about learning science in the field? What is easiest?
- How do you feel about your learning? Are you progressing? Are you progressing in the direction you expected?
- How did your perspective about Big Bend change after this trip?
- How did your perspective about field work change after this trip?
- What do you like best about learning on field trips?

Appendix IV

Teachers' Ideas for Using the Virtual Field Trip

The following ideas, described by actual field trip participants in their journal entries, suggest starting points for Early Elementary, Upper Elementary, and Secondary class lessons for using information provided for virtual field trip visitors. The complete list was included on the Global Environmental Change website.

EARLY ELEMENTARY

General Science

Exploring maps

- Where is Big Bend National Park?
- What is the vegetation like between here and Big Bend National Park?
- What is the land like (shaded relief map) between your school and Big Bend National Park?

Desert biome

- What kinds of plants live in the desert?
- What kinds of animals live in the desert?
- How much rain falls in the desert?
- How hot or cold is it in the desert?

Man's impact

- How many people go to Big Bend National Park?
- What do they do when they get to the park?
- How do people take care of their trash in the park?

Language Arts

- Read *The Three Little Javelinas* and tie it to the wildlife in the park.
- Read *Stellaluna* and tie it to the pollination of the Century Plants.

Art

- Design and create a desert diorama.
- Use various media to make desert animals.
- Use various media to create desert plants.

Math

- Count the number of plants seen in a slide from the virtual field trip.
- Count the number of animals seen in slides from the virtual field trip.
- Record in a chart or graph the number of flower petals or leaves.

Geography/History

- Locate the Texas/Mexico border in Big Bend on a map.
- Locate your town on the map and draw a straight line to Big Bend. Relate this to the distance you are from the park.
- Who lives in Big Bend now?
- Who lives nearest Big Bend?
- Which Indians lived in Big Bend?

UPPER ELEMENTARY

General Science

Exploring maps

- Where is Big Bend National Park and what route could we take to get there?
- What is the vegetation like between here and Big Bend National Park?
- What is the land like (shaded relief map) between here and Big Bend National Park?
- What is the elevation (topographic map) of some of the mountains in Big Bend?
- What is the weather (weather map) like in Big Bend National Park?

Life Science (Desert Biome)

- What kinds of plants and animals live in the desert?
- How do the plants and animals interact?
- How much rain falls in the desert and how does it affect the plants and animals?
- How does the temperature of the desert affect plants and animals?
- How does the soil affect plants and animals?
- How have plants and animals adapted to arid conditions?

Man's impact

- How many people go to Big Bend National Park? How does this impact the environment of the park?
- What do people do when they get to the park and how does this impact the environment?
- How do people preserve and protect the plants, animals, and land in the park?
- How has the industrialisation around the park changed the ecology of the area?
- How has agriculture impacted the area in and around the park?

Earth Science

- What kinds of landforms are found in the park?
- What kinds of rocks are found in the park?
- What forms of erosion and weathering are at work in the park?
- How is soil formed in this area? Are there different types of soil in different areas of the park?
- What kinds of fossils are found in the park?
- What do these fossils tell us about their environment?

Physical Science

- What chemicals are in the water of the Rio Grande River?
- What is the pH of Rio Grande river water?
- How is the chemistry of the Rio Grande water related to the geology and to man's impact on the area?

Language Arts

- Read and write poetry about the desert.
- Read and write short stories about the desert.

Art

- Design and create a desert diorama.
- Use various media to make desert animals.
- Use various media to create desert plants.
- Use authentic materials to create adobe bricks.

Math

- Measure the distance from your town to Big Bend National Park on a road map.
- Measure the circumference of trees using the metric system.
- Record in a chart or graph the number and type of plants around your school.
- Measure the mass of rocks using the metric system.

Geography/History

- Locate the Texas/Mexico border in Big Bend on a map.
- Locate your town on the map and draw a straight line to Big Bend. Relate this to the distance you are from the park.
- When was Big Bend established as a National Park?
- What part in the history of the United States has the Rio Grande River played?
- Which Indians lived in Big Bend?

SECONDARY

General Science

- The teacher sets up a series of laboratory stations that only work if each student group 'leaves no trace'. Students relate this to leaving no trace in the national parks.
- Students design investigations of their local environment including the geology, ecology and man's impact on the area.
- Students design methods for interacting with national parks without impacting the geology and ecology.
- Students analyse the data in the 'Data Archives'.
- Students manage the data in the 'Data Archives' by creating graphs and charts.
- Students determine how earth, life, and physical science are integral aspects of Big Bend National Park.

Earth Science

- Students relate the geologic history of the area to the current landforms, rock types, and stratigraphy of the park.
- Students relate the current climatic conditions to erosion, weathering, and soil formation in the park.
- Students use a variety of maps to predict areas of greater or lesser impact of tourism and the resulting weathering.
- Students relate volcanism to the current environment in Big Bend.

Life Science

- Students use field guides to identify plants and animals from the Big Bend area.
- Students use field guides to identify plants and animals from their own areas.

- Students collect water for microscopic analysis. This water should come from healthy as well as less than healthy areas.
- Students describe a desert food chain/web and relate the similarities and differences to food chains/webs active in their areas.
- Students show how the biotic and abiotic portions of the desert biome are similar to and different from the biome in which they live.
- Students explore the adaptations of desert dwellers.
- Students research the medicinal uses of desert plants.
- Students determine how man has impacted the environment of Big Bend over the last 100 years (both preservation and destruction).
- Students map the vegetation of the area from their town to Big Bend.
- Students perform transects (actual or a model).
- Students determine the impact of plants and animals on the rocks and soil of Big Bend.

Physical Science

- Students determine the chemical processes at work in weathering.
- Students test water for various chemicals, pH, and pollutants.
- Students determine the relationship between mechanical weathering and gravity.
- Students determine the relationship between soil chemistry and plant variety/growth in Big Bend.

Math

- Students use maps to make distance/time calculations.
- Students relate miles per gallon rates to distances travelled to the price of gasoline.
- Students prepare a food budget.
- Students prepare a lodging/camping budget.
- Students use statistics to analyse transect data.

Political Science

- What is the political history of Big Bend prior to and during its becoming a national park?
- What is the impact of politics/laws on the environment of Big Bend?
- How does NAFTA affect the park?
- How does tourism affect economy of the park? How is the park's economy balanced against the environmental impact of tourists?