

CHAPTER ONE

Introduction

A. Background To The Problem

Society demands computer literacy in every field. It is no longer a question of whether computers should be used in education but rather how? For the last six years, the Technology Enhanced Secondary Science Instruction (TESSI) project has demonstrated the effectiveness to which computers can address learning needs.

Innovation in teaching practices and in approaches to learning seems to be a constant occurrence in the teaching profession. New and recycled strategies ranging from Cooperative Learning to Outcome Based Education (O.B.E.) entice the teaching profession to “engage in on-going professional development”. However, unless teachers see the need for such innovation and have the belief that it is the right thing to improve student learning, then the innovation may be less than successful, or worse yet, doomed for failure. “Educational change depends on what teachers do and think - it’s as simple and as complex as that” (Fullan, 1991, p. 117). It is important that the teacher be particularly interested in some aspect of their own practice and want to make changes. Fullan (1991, pp. 127-128) asserts that teachers “buy into” progressive innovations if they feel that the change meets four criteria:

1. Does the change address a need? (e.g., do students learn better?);
2. How clear is the change in terms of what the teacher has to do?;
3. How will the change affect the teacher personally in terms of time, energy, new skill, sense of excitement, and competence, and interference with existing priorities?; and
4. How rewarding will the experience be in terms of interaction with peers and others?

It would be a rare teacher who would not recognize that innovation in the art and the science of teaching is a common phenomenon. In fact, a large number of professional

development activities are offered to and by teachers annually¹. It appears that teachers have an innate interest and willingness to learn, experiment, re-frame and improve their practice in order to create more engaging student centered classroom environments.

The author of this study is a Chemistry teacher in a middle-class, suburban high school in British Columbia who was interested in computer technology and the use of computers in science classrooms. The teacher became aware of an innovative project called Technology Enhanced Secondary Science Instruction (TESSI) in 1995 during a professional development presentation. After meeting with the project coordinator at the University of British Columbia in 1996 and explaining his interest in integrating computers into his science teaching, the teacher was invited to join the TESSI project team. The teacher's role in the TESSI project was to be that of a developer of Chemistry relevant TESSI resources, particularly in the creation of study guides which infuse available computer-based activities into the British Columbia curriculum for Senior Chemistry in a workbook-like format.

During the early involvement in the TESSI project, computer hardware and software resources were gathered and set up to create a mini-computer lab in the teacher's Chemistry classroom. All equipment was initially provided by the project funding. The acquisition of eight computers, eight sets of microcomputer based laboratory probes, one laser printer, and several software packages formed the equipment that permitted the start of Technology Enhanced Instruction (TEI) in the teacher's Chemistry 11 and 12 classes. It was cutting edge, new and exciting. The TESSI model, however, had not been applied to the Chemistry classroom prior to this time. There was no template or model to follow.

The creation of the TESSI Chemistry classroom was (and continues to be) an evolving process. More equipment, such as a TV and VCR, were purchased through a technology grant that the teacher received from the school district thus completing the acquisition requirements. Unfortunately, the equipment did not all arrive at the same time. Several key ingredients of the

¹ Teacher negotiated contracts in British Columbia mandate a specific number of professional development days for teachers to engage in professional development.

lab remained incomplete (i.e., the computer network and minor, but essential, room renovations). The latter components were still not completed during the study period.

For the first year of involvement in the TESSI project, the teacher's goal was to become familiar with the operation of the equipment and software packages. And, as TESSI study guides or other support materials did not exist, the style of teaching used differed somewhat from the guidelines² of the TESSI model (Woodrow, Mayer-Smith & Pedretti, 1996, 1997). The teacher began utilizing the computers to teach Chemistry 11 and 12 at an appropriate point in the curriculum in October, 1996. To get the students immersed quickly, work with simulations was initiated early on in the project, before any exploration and orientation into the use of computers in the Chemistry classroom was introduced. (As it turned out later, this may have had some negative ramifications). Later, other software packages were introduced for other kinds of activities (e.g., for data acquisition in experiments and for testing). Together, the students and the teacher began to learn how to use the computers in Chemistry through mutual sharing and testing of software packages.

With time and experience, it became evident that the introduction to this new medium of learning on such a large scale would have significant impact upon the students, the teacher and the pedagogical process. As a result, the teacher decided that a study should be made to document the issues that a teacher faces in the use of computer-based activities while working as a developer of the TESSI pedagogical model for the Chemistry 11 and 12 classroom.

² Much of this author's information regarding TESSI structures and approaches to learning was gained in project meetings and in discussions with TESSI project members.

B. Statement of the Problem

This study presents a teacher-researcher action research study of the issues that a teacher faces while incorporating the use of computer-based activities in the Chemistry 11 and Chemistry 12 classroom while working as a developer of the Technology Enhanced Secondary Science Instruction pedagogical model. Specifically, the teacher-researcher of the study intended to examine the following research question:

- What are some of the issues that arise for a teacher as computer-based instructional activities are used in the Chemistry 11 and 12 Technology Enhanced Secondary Science Instruction classroom?

Additional questions of interest to the researcher at the outset of this study included:

- What changes occur in the teacher's practice while incorporating elements of the Technology Enhanced Secondary Science Instruction model into the Chemistry classroom?
- What are some of the influences that impact a teacher's attempts to adopt Technology Enhanced Instruction practices?
- What are some of the effects of new technology on teacher-student interactions from the teacher's perspective?

C. Definitions Of Terms

Computer technology, like the fields of education and research, has unique language and terms that apply specific meaning to tools, methods and concepts that are significant for shared understanding amongst practitioners and lay people. In this section, various terms are operationally defined to clarify their meaning for use in this study.

Action research: a genre of qualitative research methodology in which systematic scientific inquiry is undertaken by practitioners with the goal of improving practice.

Hub: a device which connects a group of devices (e.g., computer or printer) to a central network through ethernet cables.

Microcomputer-based laboratory (MBL): a laboratory activity in which electronic probes are used to input experimental data directly into a computer program.

MBL interface: a device that connects an MBL probe to the computer often converting signals from one device to the other.

Multimedia: computer software incorporating text, sound, pictures, movies and animations displayed on a computer screen. Multimedia is hypertext-based in which the user is able to click on text or graphics to “jump from page to page” of information in a non-sequential, user-directed fashion.

Network: the interconnection of computers and peripheral devices that allow for exchange of data from one device to another.

Probe/probeware: an electronic device that converts a change in some physical parameter (e.g., change in temperature) into electronic signals that may be input into a computer program.

Simulation: a software modeling program that displays a phenomenon in which a user can alter parameters and control features.

Teacher-researcher: a teacher who uses action research methodology to examine phenomena in school settings, often the teacher's own classroom.

Technology Enhanced Instruction (TEI): the use of computers, computer software, multimedia and other electronic devices and resources for classroom learning and instruction.

Technology Enhanced Secondary Science Instruction (TESSI): a TEI pedagogical model initiated in British Columbia in which computers, multimedia technology, and related resources are incorporated into the secondary science classroom and used as teaching and learning tools.

D. Significance Of The Study

Much of the research conducted on computer-assisted instruction has focused on how students interact with a specific technology (e.g., pH meter-computer interface probeware) in the classroom by measuring student knowledge gains made and student attitudes towards the particular approach to learning specific subject content. However, there appears to be little research regarding the issues, both personal and pedagogical, that teachers deal with when implementing new technological approaches into their classroom practice. The teacher's understanding of computers and associated technology and their personal attitude, effort, and desire to bring this type of innovation to their praxis are important factors in successful implementation. This study documents the personal and practical issues, including technological and pedagogical issues, that a teacher has to deal with when applying the principles of the TESSI model. This study extends knowledge about teachers and their teaching practices, while illuminating some of the issues that teachers and others have to address prior to or during the incorporation of technology into pedagogical practices as we enter the "information-age" of the twenty-first century.

CHAPTER TWO

Literature Review

The literature review is divided into two main divisions. The first sections (A through D) lay out the groundwork for the technology aspects of this study by presenting a sample of research studies investigating the integration of computer technology into instructional practices. This part of the review defines computer technology as it is used in this study, describes some of the topics that have been researched and provides some background on a new pedagogical model which utilizes computer technology in science classrooms. The second major division (E through G), outlines a general profile of a genre of action research commonly referred to as teacher-research or practitioner-research. In this part, the purposes of action research and the types of studies that are carried out in this genre of investigation in the area of science education are described. The latter section also builds the case for a self study on the implementation of technology into the Chemistry classroom using the teacher-researcher framework.

A. The Role of Research in the Classroom

One important purpose of research into teaching and classrooms should be to provide practitioners (i.e., teachers) with information that leads to improved practice within the profession. Among other objectives, research should yield a better understanding of the applications of cognitive theory, the factors that affect student learning and the use of innovative techniques that may improve instructional practices.

Traditionally, research in education is directed by university investigators or individuals from independent research agencies. Although ideal from the perspective of objectivity, this form of research may limit the practical impact of the research findings for several reasons. The researchers are only able to examine a small slice of the reality of the phenomenon studied, even when using ethnographic methods. Relying upon multiple interpretations, those of participants and researcher, critical events may be distilled to the point at which practical considerations lose

significance. While the results may satisfy the academic world, educational professionals such as classroom teachers may ignore their results or treat them with little regard. Some teachers may believe that objective research examines cases in the “ideal setting” and that the results are irrelevant to the practicing professional. In a comment on researchers’ efforts, Day (1991, p. 538) states that “however well meaning, in a very real sense the knowledge they produce is, from a teacher’s viewpoint, decontextualized because such knowledge is not under their control”. For research to translate into change in the classroom, teachers need to have ownership of the knowledge that is generated. Therefore, to increase the impact of research findings, it may be useful to encourage teacher research at the school and district levels. As Day (1991) points out, change in teaching practice requires a trinity of components: a willing teacher, an appropriate guiding force (e.g., a university researcher or a school principal) and an appropriate vehicle through which change can be achieved. The vehicle can be a new approach, such as an instructional strategy, or the adoption of a new pedagogical model. Teacher research is one way to include teachers in the research process and to foster reflective and innovative practices.

B. Technology Enhanced Instruction

In a recent edition of a popular science magazine, Saddy (1996) re-examined Marshall McLuhan’s assertion that “we shape our tools and thereafter our tools shape us” (p. 54). As the modern world is entering the so-called information age, the computer has become one of the tools that seems to be shaping human activity. The role of the computer originally was that of a “number crunching” device, a glorified calculator that was able to store and manipulate data. Now, computers are an integral part of modern existence. Automobiles, for example, use computers to monitor and maximize fuel economy by making carburetor adjustments as the vehicle is driven. Automatic teller machines permit routine banking transactions to proceed at any hour of the day. It appears that computers and related technologies have penetrated nearly every human activity and have started to shape the way people work, communicate and entertain.

Computer technology is also changing the way that many professionals deliver their services. For example, architects and engineers use computers to design new structures prior to building prototypes; doctors use computers to better diagnose patients. In education, computer-based tools are beginning to shape new instructional practices, providing teachers with the means to respond to the needs of their students with more efficient, interesting and engaging methods.

The most common term applied to the use of computer technology in classrooms is Computer-Assisted Instruction (CAI). Computer assisted instruction is an expression that includes virtually all aspects of computer use in classrooms, from instructional aids to mastery learning software programs. CAI approaches to learning traditionally promote knowledge acquisition in a sequenced, small step incremental pattern (Walker, 1996). Often characterized as a “drill and kill” approach, CAI emphasizes learning in small steps with repetition, frequent practice, immediate knowledge of results and reinforcement. Many students have been successful using CAI approaches and many school districts within British Columbia have adopted Integrated Learning Systems programs, a modern version of CAI. These approaches have been successful in generating better standardized test scores, but some critics argue that there is an emphasis on rote or low-level learning at the expense of higher-order thinking (e.g., classifying and analyzing). Walker (1996) notes that students may find the CAI experience less than satisfying. Indeed, as McCluskey (1994) warns, some uses of technology may even cause “lower-order thought processes to drive higher-order thought processes out of circulation”, citing the widely held belief that the calculator has caused a deterioration of computational skills. The computer used with a CAI approach has had mixed success rates and has an unclear future.

The 1990s have seen rapid improvements in computer interface design and a diversification of approaches used in software products, particularly in the fields of education and entertainment. Multimedia, for example, has created a new approach to learning and entertainment with interactive characteristics. Hypertext has turned traditional textual structures

into “user defined” experiences where the user can navigate through texts and graphics with multiple directions possible. Users can search for and manipulate information in a sequence that suits their interests or needs.

In the last six years, a pedagogical model has been developed around the integrated use of computer technology in science classrooms. In this approach, often referred to as Technology Enhanced Instruction (TEI), computer technologies are applied as tools intended to enhance learning and thinking activities (Woodrow, Mayer-Smith, & Pedretti, 1996, 1997; Woodrow, 1994). Within the TEI model, a teacher uses available technologies to model concepts that are abstract, to input data into a form that allows for manipulation (e.g., graphs), and to promote collaborative cooperative teamwork. The TEI teacher uses computer-based activities to broaden and enhance student learning experiences in a manner that moves beyond what is possible in most traditional classes. In such classrooms, the computer becomes a seamless addition to the pedagogy, and students and teachers come to view it as an everyday device needed for the exploration of concepts and the analysis of data. The teacher’s instruction is augmented by technology, expanded by a greater variety of methods to illustrate concepts. Although the computer is the heart of TEI, other devices such as CD-ROMs, microcomputer-based laboratory (MBL) probeware, laser disc players, VCRs, video cameras, and various software packages form the peripheral components of the approach. Woodrow et al. (1994) point out that TEI can free the student from some lower level tasks and allow for greater time to be spent on the understanding of relationships and interconnections of phenomena.

Technology Enhanced Secondary Science Instruction (TESSI) is a working pedagogical model in which computers, multimedia technology, and related resources are incorporated into the secondary science classroom and used as teaching and learning tools (Woodrow, Mayer-Smith, & Pedretti, 1996, 1997). TESSI teachers use a variety of available technologies, not as a substitute for the teacher, nor as an “add-on” to the curriculum but as enabling tools to enhance teaching and learning. In TESSI classrooms, students use computer based activities to explore and analyze scientific phenomena. For example, a CD-ROM may be used by a teacher

to model a science concept like a three-dimensional representation of an orbital proposed in the quantum mechanical model of the atom. Students may use computers to investigate simulations of phenomena, such as chemical equilibrium, where they can manipulate variables and examine subsequent changes to a system. Students are encouraged to ask “what if” type questions, to explore and to immerse themselves into the phenomenon studied. According to Woodrow et al. (1996), three principles guided the TESSI model design:

- hardware/software must function within a model which produces measurable enrichment of learning;
- communication amongst participating classroom teachers and researchers must be frequent, and implementation must be sustained; and
- students must perceive their teacher’s and their use of technology as integral parts of the normal classroom, rather than as an “add-on” feature.

The TESSI classroom is student-centered and incorporates non-technology related outcomes. For example, in a TESSI classroom students complete a large amount of their tasks in collaborative situations, generally with groups of three students working together at each computer station. Students are encouraged and provided opportunities to set goals and to evaluate themselves as they attempt to reach those goals. TESSI also promotes the ideal that the ownership of learning belongs to students. For instance, students are given a choice of learning activities within a unit of study whenever possible. Students leave these classrooms with new views of what it means to learn. Affective domain outcomes, such as collaborative group skills and independent goal setting, are also enabled by the effective use of the classroom-based technology.

Technology enhanced instruction, like any pedagogical practice, can be effectively incorporated into classroom practice if teachers have proper preparation, experience and knowledge, access to resources, and have a willingness to take risks that are associated with

innovating practice. Woodrow, Mayer-Smith, and Pedretti (1997) point out that there is a fundamental shift in the role of the classroom teacher and the practices used.

Fundamental to the success of implementing educational technology are the teaching strategies employed by teachers. Rather than trying to adapt new technology into standard teaching practices, teachers must learn how to adapt their teaching strategies to accommodate the benefits made possible by technology. Using technology to simply present better classroom lectures in a teacher-centered format is not the best pedagogical use of technology. (Woodrow, Mayer-Smith, and Pedretti, 1997).

To date, the TESSI research has primarily focused on the application of the model to the Physics classroom in the project called Technology Enhanced Physics Instruction or TEPI. Studies on this application of the TESSI model have been conducted in British Columbia schools, examining several different aspects of the project.

Mayer-Smith, Pedretti, and Woodrow (1998a, in press) interviewed TESSI project teachers and described the essential ingredients of the success of the TESSI project: an equal partnership between project teachers and university researchers with a shared vision, a strong backing by school administrators providing support and resources, and constant opportunities for communication between teacher and students. One key theme was that strong lines of communication between all stakeholder groups within the project builds the teamwork necessary to make the project a success. Mayer-Smith, Pedretti, and Woodrow (1998b, in press) also examined the collaborative process used in the TESSI project, and found that successful collaboration required a number of other components including a willingness by teachers to explore and inquire into their pedagogical practices.

Pedretti, Mayer-Smith, and Woodrow (1998) studied student views about the uses of technology in the TESSI Physics classroom. The majority of students favored the use of technology and were able to describe its strengths and weaknesses from their perspectives. Students recognized that changes in their roles and the teacher's role were evident in the TESSI classroom. They acknowledged that TESSI approaches fostered student independence, self-pacing and collaborative work. TESSI students were also aware that they had learned more than

just Physics in the Physics classroom. Many TESSI students were able to talk about “learning to learn”, issues such as learning responsibility, independence, self-reliance, and problem solving. These outcomes that went beyond learning the Physics curriculum were regarded as important “cognitive keepsakes” by the researchers.

A study carried out by Eichorn (1997) on the application of the TESSI model in the Biology 12 classroom determined that students performed at least as well on unit tests when instructed in the TESSI classroom as compared to the traditional classroom. Eichorn found that the TESSI students he studied also exhibited collaborative behaviors, increased engagement, and self-pacing abilities. The behaviors he described were not regularly manifested in the classroom prior to adopting TESSI pedagogical practices.

C. Computer Technology In Classrooms

There is a growing body of literature about the use of computers in education with respect to pedagogical strategies, students’ attitudes, and student achievement. Many studies focus on the implementation of specific computer software programs and microcomputer-based labs. Other studies examine effects of technology on students. This section will lay out a representative sample of the types of studies undertaken.

Micro-pieces of Technology

There is a wide assortment of articles published that describe the virtues of MBL probes (Thompson, Seligmann, & Cava, 1993; Stringfield, 1994), interactive computer simulations (Lewis, Stern, & Linn, 1993; Snir, Smith, & Grosslight, 1993), or video disc use (Duhrkopf & Kramer, 1991). Typically, these reports are descriptive and explain possible application and the benefits of implementing each kind of technology. Authors cite benefits such as the creation of more constructivist activities in science (Richards, Barowy, & Levin, 1992; Snir, Smith, & Grosslight, 1993) or the improvement of learning by building more stimulating environments (Lewis, Stern, and Linn, 1993). While these studies provide information about technological

devices, how they operate, and their uses in the classroom, no studies offer a clear pedagogical approach for the application of technology. In contrast, TESSI provides a holistic pedagogical approach and does not simply deal with micro-pieces of technology. In the TESSI classroom technological devices represent the tools rather than the methods used.

Effects of Technology on Student Learning and Achievement

Some studies have attempted to determine the effect of computer-assisted instruction on learning. For example, Nicholls, Merkel, and Cordts (1995) conducted a comparative study to determine the instructional effectiveness of animated hypertext linked computer tutorials in a university level microbiology class. Students were given the opportunity to choose to participate in either textual-based or computer animation-based tutorials developed by the researchers. The same content material was presented in both formats. Item analysis of test results as they related to participation in the particular tutorial mode suggested that viewing visual animated tutorial modules had a significant effect on improving learning. Although it is hard to argue away the Hawthorn Effect and self-selection bias, Nicholls et al. contend that computer-assisted approaches may have impact on student's cognitive understanding.

In a quantitative study on the use of a simulated frog dissection using video disc technology, Kinzie, Strauss, and Foss (1993), determined that some learning gains can be made by students. The video disc simulation alone appeared to be at least as effective as actual dissection in promoting learning about frog anatomy and dissection procedures. The use of the simulation as a preparatory activity prior to a real dissection, however, seemed to improve student test scores and dissection abilities. This result implies that the coupling of the two approaches is the best tool for the job (i.e., technology applications can enhance learning when blended with traditional practice).

Effects of Technology on Student Attitudes

Some studies focus on the affective domain of inquiry by asking students about the use of computers in classrooms. Woodrow (1994) used questionnaires to measure the computer-

related attitudes of grade 8 and grade 11 students. Her study correlated student attitudes towards computer utilization in school with various student characteristics (e.g., gender, computer training, computer experience, and availability of home computer) to provide guidelines for the development of effective computer implementation programs. Woodrow stated that these results are consistent with related studies that show gender differences in use, experience, and attitude towards computers. For example, she notes that male students had more favorable attitudes towards utilization of computers than females, although both gender groups expressed equality of ability to use computers. Woodrow further suggests that there is a link between computer experience and positive attitudes towards computers. Woodrow advises that care is needed when developing programs in which computers will be implemented; it appears that students develop positive attitudes towards computers and will master various computer skills when they do it “for a purpose - one that is immediate and obvious” (p. 334). Students see the computer as a tool that is useful to solve problems or enhance understanding of particular phenomenon.

CAI has expanded into many areas of instruction. Ester (1995) compared the effectiveness of computer-assisted instruction and lecture approaches in vocal anatomy and function to university students with different learning styles. Placing students into different treatment groups, he found that concrete learners learned well under both lecture and CAI approaches, whereas abstract learners seemed to prefer lecture methods. Ester grants that more work in this area is needed since it counters similar research of other studies. That some students may enjoy computer-assisted instruction more than traditional practices suggests computers may serve as a motivation tool.

Effects of Technology on Student Interactions

Studies to gain an understanding of how discourse plays a role in the use of computers in small group settings have also been carried out. Focusing on the development of shared meanings of language in Physics, Roth (1995) examined teacher-student and student-student interactions while students worked with a simulation package. His study was conducted with grade 11 students in a private high school. Students explored a Physics simulation package and engaged in “science talk”. Roth provides sample excerpts to illustrate the kind of discussions that occurred between the students and teacher while focusing on Physics concepts in the simulation. Roth indicates that the technology provided opportunities to replay the learning events over again to ensure shared understanding between media and participants. He suggests that multimedia CD-ROMs can set the stage for interactive discourse in which learning is enhanced and common meanings developed. As students engaged in vector analysis of a moving object, the computer was the tool that promoted meaningful actions. Students become encultured into the language of Physics while using the computer as a learning tool. The article contends that the power of the computer’s interactive and graphical qualities provide a new platform from which learning can proceed, particularly in group settings, where discussion can flourish.

Technology in Chemistry Classrooms

An example of research on the use of TEI in Chemistry is the study by Williamson and Abraham (1995). Their work was based upon the general notions held by Chemistry instructors that many Chemistry students do not have the ability to visualize particulate behavior very well and have developed inaccurate or incomplete mental models when compared with experts’ understandings. Using a quasi-experimental posttest control-group design with college students as subjects, Williamson and Abraham found that treatment groups who interactively operated with animated sequences scored significantly better on the evaluation constructed for their study, than did their traditionally instructed counterparts. Conceptual understanding was

measured by asking students to make drawings, explain answers, and answer multiple choice items explaining chemical phenomena. Drawings and explanations were judged and codified by an expert panel. Their findings suggest that computer-assisted instruction does help students to develop conceptual models similar to those held by experts, and that students held fewer misconceptions when applying the particulate model to chemical principles. This study suggests that if traditional verbal, written, and static graphical representations used by Chemistry teachers are inadequate to help students develop more scientifically accurate conceptions, technology enhanced instruction may provide a tool for students to develop deeper and richer understandings of complex and abstract concepts.

D. Summary of Technology Studies

The future classroom may operate in different ways than in the past, with the impact of computers felt in many classroom activities. Teachers aim to have students engage with curriculum and, at the same time, teachers interact with students. Technology offers the vehicle that links these two. There is a large and growing body of knowledge about the use of computers and related technologies in the classroom and its effects upon students. However, there appears to be little published research into the effects of computer use on teachers particularly Chemistry instructors, who incorporate computer technologies into their pedagogical practice. The introduction of the TESSI model, which has been successfully used in Physics classrooms, to a Chemistry classroom provides an ideal setting for studying the experiences of a Chemistry teacher incorporating technology into his professional practice. Such a study will also contribute valuable knowledge since at this time there are no published studies that deal with the efforts and issues of the teacher who incorporates the TESSI or similar model.

E. Practical Knowledge

Practical knowledge, the knowledge that practitioners possess and apply in their day to day practice, encompasses the skills and knowledge obtained through years of practicing in the context of real situations (Schön, 1983). The practitioner examines all cases and evaluates each one on the basis of theoretical knowledge and experience.

There is a high, hard ground where practitioners can make effective use of research-based theory and technique, and there is a swampy lowland where situations are confusing messes incapable of technical solutions.
(Schön, 1983, p. 42).

Schön's analogy of "rigor or relevance" illustrates the separation of knowledge generated from theory as compared to the knowledge produced from practice. Theoretical knowledge exists in a refined form, such as a set of principles or concepts. It is gleaned from many examples, distilled to yield pure relationships that may be generalizable to other situations.

Schön suggests that practical knowledge is less clear cut than theoretical knowledge, rough, and embedded in unique and context dependent situations. Practitioners, such as teachers, are involved in a realm where problems do not necessarily match those cases examined in formal professional training. Such problems don't have limiting examples or neatly defined parameters. They are real life problems that require practical solutions, that are often developed on the spot. Practitioners use less tangible methods to solve such practical problems. "They speak of experience, trial and error, intuition, and muddling through" (Schön, 1983, p. 43).

An example of the division of knowledge is found with the questioning practices of teachers. Teachers spend much of their time posing and responding to questions in classroom interactions with students. Teachers build a repertoire of questioning skills that are suitable to a wide variety of different situations. Question types can be classified into neat categories such as knowledge, understanding, or application using Bloom's taxonomy. The taxonomy represents the theoretical principles upon which teacher questioning is constructed, knowledge based upon

theory distilled from thousands of observations, pure and refined. However, the 'art' of questioning is in the domain of practical knowledge. Knowing what questions to ask and when to ask them, and whom to ask, are experiential skills developed over many cases and self-corrective fine tuning. Tacit knowledge or intuition takes over in the day-to-day practice. Experienced teachers seize the opportunity to ask thought-provoking questions often without conscious forethought, an interaction for the moment. In addition, teachers phrase their questions using words and tone fitting a particular target audience, with the choice of questioning level appropriate for the individual called upon. Other examples of practical knowledge could be found in teachers' disciplining procedures and in their decisions related to the organization and presentation of course content.

F. Action Research

Good ideas without action don't accomplish much.
(author unknown)

The debate about the epistemology of positivist research methodology has churned over and over again in the last half of this century. The inherent view in quantitative methodology, that all knowledge can be quantified and experimentally reduced to smaller elements, has had great use in the natural sciences like Chemistry. Quantitative methods, however, have disregarded possible data sources in the humanities and education as unquantifiable. The descriptions of events in a contextualized case, for example, do not fit neatly into quantitative schemes of collection. A variety of qualitative methods have been developed to fill this void.

One goal of qualitative research is to understand the social phenomenon from the participants' perspective (Schumacher & McMillan, 1993). Under this approach, phenomena are studied in their natural settings, using a wider range of data sources including interviews, narratives, and ethnographic means. Data collection is characterized by thick, rich descriptions of events and participant narratives. One genre of qualitative methodology is action research.

The term action research integrates two words: action and research. Both of these words bring forth specific meanings. Action suggests that something is to be done, while research indicates an inquiry. Bound together, these words evoke the meaning of a systematic study of an action being carried out. Many authors have defined action research in such terms. For example, Elliot (as cited in McKernan, 1991, pp. 3-4) has defined action research as “the study of a social situation with a view to improving the quality of action in it”. Although a wide variety of other definitions exist, McKernan (1991) encapsulates many of these into a useful and simple form: “action research is a systematic self-reflective scientific inquiry by practitioners to improve practice” (p. 5). This conception embodies the idea that action research is appropriate for studying problems encountered in real life situations, the ‘messes’ in Schön’s swampy lowland.

In action research there is a deliberate attempt to intervene in practical situations to improve practice. It is different than applied research in that it involves intervention with the intent to modify the treatment after implementation. Calhoun (1993) describes three approaches to action research: individual teacher research carried out by a single teacher, collaborative action research conducted by a volunteer group working with a university professor, and school-wide action research conducted by an entire faculty. In each approach the focus of studies center on the practitioners and their practice.

Generally, there are cycles embedded in the structure of an action research study. In describing action research models, McKernan (1991) illustrates the cycles of action-observation-reflection-planning that are characteristic of action research. Action research begins with an idea of interest, an action requiring improvement. After defining the problem, hypothesizing solutions, an action plan is developed and implemented. Participants observe, reflect upon their observations and then evaluate the action. Decisions of how to continue are made based upon reflection, explanation, and understanding of the original action. The problem is then redefined, if necessary, and the cycle begins again. Each cycle of action-to-reflection

revises and improves the quality of the action initiated. This can be thought of as a spiraling cycle of action and reflection. A sample of action research studies follow in this section.

The PEEL Project is an example of a collaborative action research project that has collated and generated a large set of learning strategies (called classroom procedures) such as *concept mapping*, *predict-observe-explain*, and *what's my rule* (Mitchell & Mitchell, 1992). This project is set up as a large sharing group of experienced teachers in which participants develop, discuss, share, use, and compare strategies. The various classroom procedures were created by PEEL teachers as responses to specific problems with students' learning. Some procedures, like concept mapping, were refined from their original state to more closely match project teacher needs. As an action research group, PEEL teachers have progressively developed new variations of adopted procedures, as teachers of different subjects develop new ways of using them. The PEEL project shares its results in published newsletters and books.

A science specific action research group was organized and facilitated by Feldman (1994, 1996). The group was composed of Physics teachers who wished to study and improve their practice. As part of his study, Feldman examined the ways that teacher knowledge is generated and shared in a social milieu. Meeting every three weeks in a social setting, this group talked about their teaching, their knowledge of Physics, and engaged in systematic inquiry into their teaching. Feldman (1994) describes participants' concerns regarding the validity of teacher-research and action research in his study of the action research group. Like many science teachers, qualitative methodology is an alien approach. The Physics Teachers Action Research Group (Feldman, 1996) continued to use research notebooks of their observations, reflections, and hypotheses. Gradually, the role of facilitator was rotated through the eight participants as their study progressed and they took greater charge of their own research agenda of improvement to practice. Feldman notes that by describing and analyzing their practice, Physics teachers can enhance their normal practice and develop a critical inquiry into what they were doing in the classroom by sharing with the action research group.

G. Using Action Research To Study TESSI In The Chemistry Classroom

The Technology Enhanced Secondary Science Instruction (TESSI) model is an integrated approach that employs the use of available technology in the science classroom to enhance and extend student learning (Woodrow, Mayer-Smith, & Pedretti, 1996, 1997). The TESSI research project has evolved over the past six years but it has focused on the application of computer technology to the Physics classroom and curriculum. The model has only recently been introduced into Biology and Chemistry classrooms. However, the unique nature of these disciplines means that the TESSI approaches used in Chemistry and Biology will vary somewhat from those used in the Physics class. In view of the differing situation, it is anticipated that Chemistry and Biology TESSI teachers may encounter many new and different implementation problems. For example, high school level Biology is much more descriptive than Physics and some technologies used in Physics may not suit the needs of Biology instruction or learning. For example, Physics makes extensive use of simulations. In Biology there has been limited use of simulations whereas video clips and animations have been successfully used to illustrate biological concepts³.

Chemistry is also different from Physics and Biology. Chemistry is an untidy science where lab results often do not correspond to the expected results nor do they neatly follow mathematical models. Chemistry deals with colors, smells and relative comparisons of reactivity. Problem solving in Chemistry requires students to combine both the qualitative and quantitative aspects of a problem (e.g., predicting an equation from reactants, balancing it and then mathematically determining the product yield). In addition, the equipment and chemicals

³ Informal information on Biology computer-based activities used was gathered in TESSI project meetings and e-mail correspondence with the two Biology teachers involved in the project.

that are used in the Chemistry lab entail safety issues that will need to be considered. The differences between the science disciplines may change the structure of the TESSI model and its application in Chemistry. For example, safety concerns may limit the multi-activity classroom approach that formed the foundation of the TESSI platform in the Physics classroom. The TESSI Chemistry teacher faces an uncertain implementation process. There is a need to explore the issues that a teacher faces when implementing computer-based activities into the Chemistry classroom to provide teachers with information that may ease the transition of technology into instructional praxis in Science classrooms throughout British Columbia. Action research provides an appropriate means for conducting such explorations.

CHAPTER THREE

Methodology

The purpose of this study was to determine some of the issues that arise for a teacher as computer-based instructional activities are used in the Chemistry 11 and 12 Technology Enhanced Secondary Science Instruction classroom. The study was conducted over a four month period, from September 1997 to December 1997, at a secondary school in British Columbia. For this study, the author assumed the role of teacher-researcher and kept an anecdotal journal of daily activities including log entries of events, reflections of daily activities, and other pertinent written documents (e.g., e-mail correspondence related to acquisition and use of computer technology or software in the classroom). To gain insight into the perspectives of students regarding the applications of technology in the classroom as part of their learning environment, the author also collected student exit slips from all the Chemistry 11 and 12 students enrolled in the author's classes at the school for Semester 1 of the 1997/98 school year. In addition, the author audio taped and transcribed five Chemistry classes in which computer technologies were introduced and then used by students. The multiple data sources were analyzed to determine relevant themes that represent the experiences of the author as he worked to implement technology in the classroom.

A. Teachers Studying Their Own Practice - The Teacher-Researcher

Teachers, as a group of professionals, possess a broad knowledge base that includes knowledge of content, general pedagogy, curricula, personal understandings of learners and their characteristics. They possess knowledge of educational contexts and classroom dynamics, knowledge of community, and knowledge of educational ends, purposes, and values and their philosophical and historical grounds (Shulman, 1986, 1987, 1988). There is a great deal of research in which teachers have served as the research subjects, with studies focusing upon just about every aspect of teachers' professional lives. The least well documented aspect of the teacher's life, however, is their wisdom of practice and their practical knowledge.

Teaching begins with an act or reason, continues with a process of reasoning, culminates in performances of imparting, eliciting, involving, or enticing, and is then thought about some more until the process can begin again. (Shulman, 1986, p. 13).

In a typical working day, many of the creations of teachers, (e.g., the substance of interactive discussions with students) are conducted without an audience of peers. The reflective interplay that goes on in the teacher's mind, the thoughts of changes for next time, the little modifications introduced into the next class in the rotation schedule are elusive and situation dependent components of the practitioner's practice. Unfortunately, the information generated from an outsider's perspective leaves much of this tacit knowledge untapped, and a field of study underdeveloped. Until recently, little attention has been given to the roles that teachers might play in generating a knowledge base. Furthermore, there has been no formal way for the practical knowledge of classroom teachers to become part of the literature on teaching. This has changed as teachers have begun to assume the role of researcher in their own classrooms.

Teacher-research is systematic, intentional inquiry carried out by teachers about their own school and classroom work (Cochran-Smith & Lytle, 1993). Teacher-research is a form of action research and provides a framework for practicing teachers to examine practical problems of interest. As researchers, teachers identify their own questions, document their own observations, analyze and interpret data in light of their current theories, and share their results primarily with other teachers. Research questions emerge from discrepancies between what is intended and what occurs (e.g., student progress, classroom routine problems, conflict or tension between students, or new instructional approaches). Through their research, teachers can strengthen their judgments, improve their practices, and share their findings with other practitioners and the academic world (Cochran-Smith & Lytle, 1993). Results may not generalize to other contexts, but may evoke a reader "resonance" with the intended audience. Cochran-Smith and Lytle (1993) characterize teacher research as "an approximation of university-based research; a more grass-roots phenomenon that has its own internal standards

of logic, consistency and clarity; it is a reflective or reflexive process that is for the benefit of the individual and a dialectical process of action and reflection aimed at social change” (p. 9).

Teacher-researchers can examine a wide variety of documents or artifacts that support the case they are examining. Collected evidence includes such things as field notes about classroom interactions, interviews with students and teachers, classroom documents, examples of student writing and drawing, test scores, teaching plans and handouts, extensive written journals, audio or video tape discussions, classroom presentations (Cochran-Smith & Lytle, 1993; Altrichter, Posch, & Somekh, 1993).

Teacher-research is recently gaining acceptance in academic literature. Typically, teacher-researchers report their findings to others through professional journals and books. The styles vary with the epistemological tendencies of authors but tend to be generally qualitative in design. For example, Awbrey (1989) carried out a year long study on her use of writing strategies with kindergarten students. Using a narrative approach, she describes her thoughts leading up to the first day of school and the first writing activity her students were assigned. She describes in detail the setting of the school, backgrounds of her students, her classroom, and her typical day in detail to provide the reader with a sense of the context of the study. She then tells a story of the year with her innovative experiment of having her kindergarten students writing, through a wide variety of means. She inserts samples of student work with interpretive translations for the reader to gain an understanding. Her reflections and thoughts are interspersed between her methods and the children’s’ comments. Using simple language she clearly lays out the events that occurred. Awbrey ends with her reflections on the year, her “observations and insights”, and she offers a set of conclusions regarding her writing journey to other practitioners.

Billington (1994) describes an action research study he carried out in his elementary level mathematics classes as part of a larger collaborative action research project. He cites a twofold purpose: to provide teachers with research findings that would benefit them in their

classroom, and to encourage teachers to act as researchers, thereby promoting teachers to view their role as more than that of classroom instructor.

B. The Teacher's Roles

In this teacher-research study the teacher was not only a researcher but also a participant-observer (Schumacher & McMillan, 1993). A participant-observer is an interactive research role assumed when a researcher has a role in the site he or she intends to study. Because the framework for this study involved practical action (i.e., the incorporation of technological activities into practice, as an integral part of research) the teacher-researcher was able to participate, examine his practice, and search for recurrent and unique themes that represented the issues that a teacher faces in incorporating technology enhanced instruction.

C. Site Selection

The formal phase of this study was conducted in the author's classroom in a secondary school in British Columbia from September 1997 to December 1997. Several reasons existed for the site selection. This site was chosen since the teacher-researcher had worked at the school as a full time staff member for the past eleven years and had complete access to the site. The school principal and district senior administration were amenable to research studies carried out within their facilities and their approval was obtained easily. The teacher-researcher's Science classroom at the school where he worked was the specific classroom in which the study took place. It had been outfitted with eight computers for student use during the piloting phase of the study. Each computer was the base of one student workstation and included several software packages appropriate for teaching and learning in Chemistry, as well as, one set of microcomputer-based laboratory equipment (interface and probes). All of the equipment used by students was made available to the classroom by the TESSI project as part of the author's on-going involvement as a developer of TESSI Chemistry related resources.

D. Description Of Site

The site school services a population of about 1200 students from a variety of socioeconomic, racial and ethnic backgrounds. The classroom in which the study was conducted is a windowless general Science classroom located on the upper hallway of the inner core of the school. This room is equipped with standard science equipment such as glassware, sinks, gas lines, and dissection equipment. Student tables are arranged in five rows across the room with sinks and gas tap attachments nearby. To create a TEI classroom, an array of technologies were added. At the front of the room there was a multimedia center composed of a Power Macintosh 6500/AV computer connected to the school district's WAN (wide area network) and the Internet, a 31 inch large screen TV connected to the computer and a video cassette recorder. The TV and VCR were on a moveable trolley and positioned to the right of the teacher's desk. Nine computer workstations (six Macintosh LCIIIs, two Macintosh Performa 5200, and one Macintosh Performa 6360) were spread throughout the classroom for student use. Six computers were placed on the right side and back countertops of the classroom while three were positioned on student tables in the middle of the room, one per row of student tables. Eight of the computers, and all the sets of MBL equipment were furnished by TESSI project funds, with the remaining equipment purchased through a technology grant at the district level that the researcher had applied for in the previous school year. Due to room renovation and network completion problems that occurred during the study period, the computers were not networked.

Each student computer contained several software packages including *At Ease*TM (for computer hard drive security), *Science Workshop*TM (for MBL experiments), *Clarisworks*TM (for word processing), and *LXR*TM *Student Interactive* (for testing purposes). In addition, each computer contained *CHEMedia*TM, a set of simulations that focused on ten different topics in Chemistry such as thermodynamics and electrochemistry. *Saunders*TM *Interactive Chemistry* CD-ROM was used for some presentations of course material. An array of MBL equipment (including pH, pressure, voltage, temperature, and colorimeter probes with a PASCOTM 300

Interface) was available for use in experiments, but was kept in cupboards until needed due to space and security concerns. Typical resources such as student texts, *Heath Chemistry* for Chemistry 11 and *Nelson Chemistry* for Chemistry 12, and the associated teacher's resource packages were also available for use by the teacher.

E. The Participants

The participants of this study were the teacher-researcher and the students of his Grade 11 and 12 Chemistry classes during semester one of the 1997-1998 school year. The students⁴ were assigned to these classes at the beginning of the school year by a schedule making program at the school office. There was no attempt to select students for these classes by the researcher. The Chemistry 12 class had 24 students (17 females and 7 males) and the two classes of Chemistry 11 had a total of 55 students (33 female and 22 male). Informed consent of all participants and their parents was obtained during the first week of classes in September 1997⁵. Prior to commencement of the study, permission to conduct the research was obtained from the University of British Columbia, the District Deputy Superintendent and school principal.

⁴ Pseudonyms have been used throughout this study when reference to participants has been included in the descriptions or discussions.

⁵ The Letter Of Consent underwent several revisions prior to approval by the Ethics Review Committee at the University of British Columbia due to policy changes regarding teacher-researcher studies (see Appendix A for Letter of Consent).

F. Sources Of Data And Collection Methods

To track the experiences and events that took place during the period of study, data was collected through detailed journal entries augmented by other collected documents including e-mail correspondence, student exit slips (small open ended surveys), and audio tapes of lessons. Each of these will be described in this section.

In order to establish a descriptive context for this study, the teacher-researcher kept a daily detailed research journal following the suggestions put forth by Holly (1989) and Altrichter, Posch, and Somekh (1993). According to these authors, research journals should be written on a daily basis in a private reflective time and should include the researcher's thoughts, reflections, feelings, emotions, and opinions.

During the 1996/1997 school year, the research journal was piloted as a means to gain experience with the process of writing a journal and to gather preliminary data around which to focus the research. As Altrichter et al. (1993) recommend, it is useful to structure the research journal around headings and subheadings. To organize the journal for this study, the teacher-researcher developed and used five general domains under which to record experiences. These domains were: teacher issues, technological issues, pedagogical issues, student issues and other. The category "other" was included to provide a place to record pertinent observations and reflective comments that did not seem appropriate for any of the other categories. The journal was piloted for approximately seven months. The pilot categorizations seemed to work well for organizing thoughts and for the reflective analysis that followed later; thus these were retained and used in the formal study. The teacher-researcher used a reflexive, free-form style of writing to record his thoughts as they occurred. These written passages were, for the most part, descriptive sequences containing accounts of activities, descriptions of events, and reconstructions of dialogues (see Altrichter et al., 1993). After reading what was written, the researcher would expand and elaborate on the thoughts described, edit to correct meaning, and later add interpretative writings. The interpretative sequences allowed the teacher-researcher to express feelings, speculations, explanations, and reflections upon the writings. At each journal

writing session, grammar, sentence structure, and spelling were checked but the researcher's primary goal was to ensure the integrity of the written thoughts (i.e., since the journal was considered to be a private document there was no attempt to remove thoughts or ideas). Samples of several journal entries appear in Appendix B.

To supplement the daily journal, the teacher-researcher collected other artifacts including electronic mail (e-mail) correspondence that was related to classroom activities or the involvement with the TESSI project, project proposals that the researcher wrote, presentations to stakeholder groups (e.g., the Parent Advisory Committee of the school), and letters to the principal of the school. Since these documents were already in a word processor form, they were simply "cut and pasted" electronically into the appropriate portions of the journal (see Appendix C for examples of other associated artifacts).

To help with the analysis of the journal and associated other documents, the teacher-researcher enlisted the aid of a "critical friend". Altrichter et al. (1993) recommend that an action researcher read sequences of a journal to a colleague or research partner. The authors suggest that the conversation about experiences can provide deeper insights into "the fine texture of educational situations" (p. 15). The teacher-researcher asked one colleague who was also involved in the TESSI project to read and critique several journal entries that spanned approximately one month of the study period. Afterwards, comments were shared back and forth.

As part of this study, the teacher-researcher audio-taped five of his lessons during classes where technological activities were introduced and used by students. Conversations between teacher and students as well as student-student interactions were recorded. The recorder was turned off once when requested by students in a small group setting. Audio tapes were then transcribed verbatim directly into a word processed format. Appendix D provides a sample transcript.

The teacher-researcher also used two small, open-ended student surveys to gather data on students' perspectives regarding the use of technology-based activities in the classroom. A

pilot of the survey questions was carried out in late October, 1997. The formal survey data used in this study was collected in December, 1997. All students present in the three classes of Chemistry 11 and 12 in which computer-based activities were used were surveyed. The surveys consisted of several open-ended questions that asked students to describe their thoughts about each of the computer technologies or activities that they had used. The surveys provided an opportunity for students to express their feelings and beliefs anonymously. Appendix E contains the two formal surveys completed in December, 1997.

G. Methods of Data Analysis

Human beings look for meaning. We are often quick to ascribe meaning to chaotic events: this is one of our most important abilities. It helps us to see the world as a network of interrelationships, coherent and predictable. The more we refine this ability, the more we feel at home in our environment. (Altrichter, Posch, & Somekh, 1993, p. 119)

Journal entries and associated artifacts, open-ended student surveys and transcripts of audio-tapes of lessons were examined for emergent issues. To analyze the data gathered in this study, several methods of data analysis were employed.

In this study, the researcher used coding methodology described by Altrichter et al. (1993) to analyze the data. Coding is a method in which data is sorted into categories that are created by a researcher as the analysis proceeds. In the initial stages of this study, for example, the teacher-researcher deductively created a journal format during the piloting phase of the project. The format seemed logical given that the apparent issues focused around the teacher, students, technology, and pedagogy concerns.

Later, after reading the gathered data, the teacher-researcher used inductive coding methods in which categories were derived from the data sources. The journal and transcribed audio-tapes were analyzed by reading the text and highlighting passages that seemed important in relation to the research question. The text was read a second time, looking at marked passages and a category was created for each unique passage of text. In analyzing the whole

data set, similar categories were grouped together and more general categories were created. In addition, the teacher-researcher looked for patterns that were relevant to the research question during the coding process. A descriptor for each coding category was selected to provide meaning of each category independent of the data. The coded data under descriptors was shared with a critical friend who was able to help the teacher-researcher become aware of any “blind spots” or missed coding opportunities.

The student surveys were coded in a similar way to the journal and audio-tapes transcripts but additional collection and analysis methods were used. All survey responses collected were transcribed as written by the participating students. The responses from each survey sheet were collated such that all responses to each survey question were placed within separate sections in a word-processed document (using each survey question as a heading to separate collated sections). The responses were numbered according to the order in which they were recorded. For example, the second response after each question in the transcript was gathered from the same student survey response sheet written by one student. As the survey responses were read, categories of student responses emerged from the data. After the categories were generated, the researcher recorded the frequency of each response within the category in order to develop a sense of the general perspectives of the entire group of students in the class. Many students responded with more than one codable comment within a particular question. Thus, some categories of comments contained more responses than students. The frequency of comments provided information about the level of concern by students regarding a particular event. Excerpts of journals, audio-tape transcripts and tables showing categories and frequency of response obtained from the student surveys appear in Chapter Four and in Appendices B to F.

H. Summary Of Procedures Followed

The purpose of this study was to determine some of the issues that face a teacher in the implementation of technology enhanced instructional activities in the Chemistry classroom. The teacher-researcher used computer-based activities as instructional and learning tools in his classes of Chemistry 11 and Chemistry 12 during a four month study period. The teacher-researcher kept a daily research journal that outlined the day's activities and incorporated reflective comments. Other written artifacts were collected, such as e-mail correspondence, that supported and augmented the journal entries. Student surveys were conducted at two intervals to gather information on the perspectives of students. In addition, five classes were audio-taped and transcribed verbatim. The collected data was then analyzed using coding methods discussed in this chapter and are presented in Chapter Four.

CHAPTER FOUR

Re-creating the Teacher's Story

The purpose of this study was to determine some of the issues facing a teacher who incorporates computer-based technologies into instructional activities in the grade 11 and grade 12 Chemistry classroom. The qualitative data (i.e., the journal and collected artifacts obtained during the study period) was analyzed for patterns relevant to the research question set out in Chapter One. The presentation of the data is divided into two main sections. In Section A, the results of this study are presented in the form of a story that reconstructs the events that occurred during the study period. In Section B, the researcher presents emergent issues and themes with supporting data from journal excerpts, collected artifacts, audio taped classroom activities, and student survey results. The reader should view these two sections together as a case study. As this is a teacher-researcher self-study investigating the changes that occur in practice, this chapter is written in the first person to describe experiences that occurred and issues that emerged.

A. The Story Of A Teacher Undergoing Changes

To gain admission to the Faculty of Graduate Studies at the University of British Columbia in 1995, I wrote a letter called a Statement of Intent as part of the registration process. In this letter, I expressed a vague desire to broaden my understanding of teaching methods in science and to explore the use of computers and computer-based activities in the science classroom. The final sentence in the letter stated, "I hope to bring new techniques and knowledge back into my classroom to enhance the learning atmosphere". For whatever intrinsic reasons, I felt the need to re-energize my practice and to meld my interest in computers into some practical approaches in my classroom instruction.

At the end of the first year of my Masters program at U.B.C., I was trying to determine just how to undertake a study about the use of technology in my classroom that had personal meaning and utility. I had contacted the deputy superintendent in my school district about

possible funding for a TESSI-like project in my classroom. I had already been experimenting with TV-computer presentations of several CD-ROMs and was excited about the possibilities of using computers as instructional and learning tools. It wasn't until I had completed all required course work for the Master's Degree and, in particular a course titled Computer-Based Science Education (SCED 412), that my ideas finally converged. The SCED 412 instructor, Dr. Janice Woodrow, who had been my faculty advisor during my student teaching practicum in 1985, was the originator and project coordinator of TESSI. I worked through her SCED 412 course with due diligence and expressed interest in the TESSI project. At the end of August 1996, she phoned to invite me to join her project team and to begin work on TESSI Chemistry development (e.g. study guides that would integrate the British Columbia Chemistry curriculum with traditional and technological activities). It was a chance of a lifetime! I could hardly contain my excitement!

With much anticipation of the up-coming year, I phoned and spoke at length with the principal of the school to ensure that bringing TESSI into the school would meet with his approval. He was excited as I was but expressed concern over the amount of money that the school might have to "kick in" to get a TESSI lab set up and running. Apparently, the principal had inherited a budget deficit from the previous administration and the district had adopted a school based scheme in which over-expenditures would have to be removed from the next budget allocation. Money would be tight. He granted his approval and Dr. Woodrow made four student computers available to begin the TESSI lab in my classroom. There was, however, one component that I would need to provide - a teacher computer/presentation center. The principal promised that he would be able to acquire this for me to use and it would represent the school's contribution to the formation of the TESSI lab. It was an exciting start to the school 1996/1997 year, filled with promise of new innovation to my classes and to me personally.

Most of the 1996/1997 school year was involved in the acquisition and testing of hardware and software resources. The principal had left it within my charge to determine what my needs were for the teacher computer/presentation center and to establish what models of

equipment I would need. Dr. Woodrow suggested a higher end model such as a Power Mac 7600 with AV capability so I began my consultations with various people (e.g., district technology staff and salespeople through letters and e-mail correspondence).

The district was about to receive a sum of \$600 000 in technology grant money from the provincial government as part of a catch up plan to infuse more technology into B.C. schools. Their plan required that districts spend this cash in the 1996/1997 school year. The District Technology Committee stated that it would disperse funds in the following way: 60% to schools based upon population, 30% for individual initiatives, and 10% for the Information Technology Center and their needs. This was my chance. I consulted with the vice-principal and found out the requirements to tap into these funds. A technology proposal was all that was needed. After spending a few hours putting one together, I felt that I had fulfilled the requirements fully, asking for approximately \$15 000. The vice-principal hand delivered it to the powers that be in charge and later in the month my project received \$11 400. It was the largest single disbursement for an individual project initiative in our district. By May of 1997, I was permitted access to these funds to order the computer equipment that I wanted as well as the TV and VCR that play such an important part of the teacher computer/presentation system.

I immersed myself in the use of various pieces of software and hardware and, in the process, became a bit of a “techie”⁶. This was both a blessing and a curse. I learned how to network my room using phone net connectors and how to secure the computers and printer in my classroom using a desktop system called *At Ease*TM. However, as I gained experience in troubleshooting, I received many requests for help. My role in the school expanded from classroom teacher to technology helping teacher. It seemed that nearly every day I was called upon by other staff members to fix some computer glitch or establish their network connection. I was asked to provide inservice workshops after school on the use of the local computer

⁶ A common definition of a “techie” would be a person who has more than the average knowledge of how computers operate and can effectively troubleshoot or fix the majority of computer related problems.

bulletin board for teachers operated by the school district. In addition, I became the resident expert on a marks record keeping program that all teachers were required to use to submit student marks to the office. Frequently, my school day was filled with teaching while lunch and after school time was filled with solving other teachers' computer problems. It was overwhelming in terms of time and energy, especially since I was so involved in trying to get my own TESSI lab up and running.

In much of the first year of journal entries, I described the various successes and failures that I experienced with the learning activities I assigned the students in my Chemistry classes. It was all trial and error, with me learning along with the students. There were many negatives to overcome and positives seemed few and far between. My enthusiasm for technology was tested many times due to hitting brick walls with regard to the development of my lab and the "new" role I seemed to be adopting at the school. However, I maintained my interest in developing the TESSI lab and trying to adopt at least parts of the TESSI model since I believed (and still believe) that computer literacy and familiarity with computers are essential skills in today's world. The TESSI model also combines many elements of what I think are important lifelong learning and technical skills. For example, students are provided opportunities and are encouraged to work in collaboration with others, to set and strive to reach goals, to use computers as tools for accessing and manipulating information, and to read and to understand technical documents. Yet, I did not feel that I had altered my practice enough to call myself a TESSI teacher.

The formal study phase of my journey into technology began at the start of my second year of involvement with TESSI. By this time I had acquired all of the equipment I needed to establish the basic TESSI lab. Networking and the room alterations that I was requesting throughout the previous school year still had not been done, and it became apparent after consultation with the school administration that these would not be met until much later in the year, if at all. I was ready to begin the new school year with a fresh, energized attitude but the same nagging frustrations cropped up at the outset. However, I felt that there was a lack of

administrative support since my initiatives were not expedited. As it turned out, the administrative support was definitely present but my eagerness to progress on my TESSI plan had blinded me. No project of the magnitude of TESSI could possibly be successfully incorporated into the school without leadership and vision. My school's administrative team was most certainly interested in completing the lab renovations and networking. The time line was just too slow for me. I took solace in a comment that was written by the principal to me in a letter: "The wheels of education may turn slowly, but they do turn." (letter from principal, October 24, 1997).

Since I had gained experience with many aspects of the computer-based activities that the students were using, by year two, technological problems were being reduced. Having spent one year playing with simulations I now understood better what problems students would encounter and could proactively steer students out of the pitfalls, such as the relationship between icons on the student worksheet and the computer screens they had to use. MBL activities ran much more smoothly since I now understood the calibration process a lot better myself. Experience with the computer technology and how the software packages worked helped me to overcome many technical issues that had plagued me in year one and undermined student confidence in my teaching ability. I now started to think more about how to best incorporate the computer-based activities rather than about surviving them. The CD-ROM presentations were adequately representing the abstract concepts and the interactive testing was going well, despite the glitches that were present in many of the questions that formed the question bank that I was using. These problems were minor and could be corrected and students for the most part seemed to like the approach because it was fresh and they could get instant results⁷. CD-ROM presentations were short and to the point, providing visual interpretations of the concepts discussed in class. MBL activities were reasonably well received by students, albeit for a few glitches experienced in trying to get used to the calibration

⁷ Test items were scored right away while students were on-line. Appropriate feedback was received while students marked their test items. Students claimed that effective use of review time was made due to capacity of the software to facilitate self- corrective action.

procedure and the inflexibility of the software program to allow for correction of inputted data if that happened. Students worked very well with the computer technology and the associated activities but, as with any instructional methodology, there were minor complaints and a sense of feeling overwhelmed at some points. I shared that feeling, too.

The problem of how to best use the Chemistry simulations became a real issue for me over the next few months. When I originally used the simulations in year one of my technology initiation, I tried them as introductory activities and then later as learning activities. Students did not follow the instruction sets as well as I had anticipated. It seemed that students were unable to work independently through the concepts presented in the simulation. I ran from student workstation to workstation throughout the entire class troubleshooting problems as quickly as possible. Once I arrived at one workstation I would be summoned to the next. Student frustration was evident many times during these lessons. I feel that I am fairly sensitive to the needs of the students and have prided myself on keeping a classroom atmosphere in which students enjoy learning. So I was bothered by the student frustration in regards to using the simulations. I was quite concerned about maintaining the positive classroom atmosphere which I had developed through years of experience. At times during the study period, I led students through computer-based activities with a great deal of teacher direction, much more than I desired. I wanted to ensure that the students felt like they had been successful with the activity. I tried to maintain a balance of traditional “hands-on” lab activities with the computer-based activities such that students did not feel overwhelmed with computers, counter to my interests in using the machines more. In essence, I navigated around TEI trying to implement computer-based activities only when I believed that students would experience a high degree of success and a minimum of frustration.

In looking back on the four month study period of this research project and further back to the beginning of my role in the TESSI project, I see myself as having gained an incredible wealth of experience and knowledge about the use of computer-based activities under the TESSI model. I learned how to better use and to troubleshoot hardware and software problems

encountered both in my lab and by others, how to better promote myself as a computer using teacher and to model the use of technology, and I came to better understand the role of computer-based activities in the Chemistry classroom. While I felt that the progress was slow, the successes were many. A quote I reflected upon from a conference I attended a couple of years prior to this study aptly summed up my dilemma: “Inch by inch, it’s a cinch. Yard by yard it’s hard”. I wanted to progress by leaps and bounds, but had to settle for incremental changes. I had learned to accept that the changes I wanted to make in my practice would not occur overnight. There were many obstacles to overcome, only some of which were related to my practices in the classroom.

There were several troubling moments when I felt that I had no time to do an adequate job at any one of my commitments, neither professional nor personal. Emotional bursts of my frustration spilled over into my reflective times and journal writing. My energy and motivation levels dropped and rose like a roller coaster. At times I thought that I could no longer continue keeping up the pace of innovating and maintaining all of my regular duties. I felt physically drained. Eventually, over the course of realigning priorities, I was able to bring balance into my life. I realized that I could not do it overnight. The incorporation of technology into my classroom activities took time, effort, reflection, planning, and evaluation. My growing understanding of the role of a computer-using educator, along with my beliefs regarding the uses of technology in the classroom, carried me forward through the school year. Perhaps my experiences are not too dissimilar to other people who try to do something out of the ordinary in their classroom or change their pedagogy. Perhaps the other TESSI developers felt the same way. The sense of being overwhelmed, excited, frightened, and frustrated were among a few emotional states that occurred almost simultaneously. The four months chronicled in this study represent a time in which many changes occurred and many issues surfaced. There have been certain issues that have arisen on more than one occasion. The next section outlines some of the major issues that affected my pedagogical practices as I worked to adopt computer-based activities in my Chemistry classroom.

B. Emergent Issues, Themes And Critical Events

If teaching is an art form, then the teacher is the artist. A new canvas is created at the bell that signals the start of each class. A planned activity such as a computer simulation or MBL activity is directed by the teacher and engaged in by students learning some new concept. Together, the teacher and students construct a portrait of understanding through their shared interaction and meaningful activity. It is the teacher that constructs the studio for learning ensuring that students receive a meaningful educational experience. This is why I undertook this study and why I wanted to determine what impact computer-based technologies would have on my instructional practice and interactions with students.

Teacher issues formed my main research question in this study. As I revisit my research questions over and over again, I find it easy to think about issues that have significantly affected me both personally and professionally. However, these issues were not the direct type of factors that I expected at the outset of this study. I expected that I would be able to document a measure of change in the way that I actually delivered instructional services to my students. I feel that I can describe many changes that occurred in my professional life as a result of my melding of instruction and computers, some of which I did not fully expect. What follows is an examination of the issues I felt have impacted me the most over the past two years particularly those that are manifest in the four month period that passed as I began the transformation of my teaching.

Throughout this chapter I have separated issues that have affected my practice as I have incorporated computer-based technologies into the instructional activities I used in my grade 11 and grade 12 Chemistry classroom. The reader should bear in mind that these issues have been distilled from a reconstructed experience as detailed in the research journal kept and from the artifacts collected during the study period. To support emergent issues, I used data from journal excerpts, collected artifacts, audio-tape transcripts, and coded student survey responses. As I had set out to do in my journal, I have clustered the discussion that follows around the domains of teacher issues, technological issues, pedagogical issues, and student issues as logical starting

points. It is within these confines that I wrote my reflective thoughts and reconstructed experiences and I feel at the time of writing this thesis that these domains still seem to be the best way of sharing my findings.

Teacher Issues:

There always seemed to be many diverse events going on in my classroom, in the school, and in my involvement with the TESSI project. As a teacher I immersed myself in these events and the technology, spending time using computers and creating my vision of a TESSI classroom in Chemistry, but the balance between personal and professional life proved difficult to manage at times. Thus, after reading my journal entries, it appeared that many issues that I had to deal with related more to me as a person than as a teacher. Time, energy and emotional issues were the most common themes in my writing.

The emotional issues that pervaded many entries were the result of several impinging factors. I felt that there was an inadequate amount of time for planning and implementing computer-based activities. As well, variable levels of administrative support at the school and district levels, a lack of progress in completing the networked lab, and some negative student perspectives about computer-based activities in the Chemistry classroom led to frustration and concerns. As a TESSI developer, I was in “uncharted territory” with no reference frame from which to work. Like a roller coaster ride up and down, there were times I felt that I was alone in my approach to using computers. At a later time, I would be riding the “high” of success experienced when students would say “that was cool” or “I learned a lot”.

Although I was feeling sick today, I felt that I needed to be at school today. It was too important to miss - with Gerald coming in to set up the server and with introducing the Chemistry 11 students to the use of computers in science class. I've been feeling very burned out and lacking energy lately... kind of beaten down by the constant battles to get things done to complete my TESSI classroom, particularly with the networking aspect of the lab. Colleagues are asking for help from me very often so I spend some time running around at lunch or before/after school. The time at school gets sucked up at a faster rate than I can ever remember. Too much to do with too little time. Anyway, having the spare during October is helping to get some of the paperwork out of the way during the day. I'm almost caught up with the marking load but seem to be constantly collecting more. I need to develop some better paper management scheme. I am up to date with marks entry so I can print interims tomorrow and get them home to parents this week. I didn't have time to follow the procedure the office had set out, however, it will get done.

(Journal Entry, October 8, 1997)

The time issues were particularly troublesome for me. Since I was interested in fast tracking myself into the TESSI environment, I spent countless hours playing with software and asking myself when and where in the curriculum should I attempt to place an activity. Obviously, I stole time from other places such as family, social life, and my regular teaching obligations. My planning was sufficiently well thought out and, since I had taught the courses in previous years, did not require as much time. However, each time I would prepare to introduce or use a new computer-based activity there would be an accompanying expenditure of time. My goal was to get as many computer-based activities into use in my classroom as possible and I suffered guilt if the computers were left idle. There was a need for me to balance that feeling of guilt with the amount of time I needed to spend to prepare some of the activities.

I spent at least an hour and a half modifying Mike's lab instruction sheet. I simply added several graphics from Science Workshop windows and then made the text more appropriate for the MBL set up. Considering that I didn't have to do this from scratch, it appears that many modifications will take several years to develop. I don't have the time to devote to that much word processing - it is, however, an essential requirement for the TESSI model to write these in a readable yet thorough way so that students can be successful, not overwhelmed.

(Journal Entry, October 14, 1997)

This excerpt describes the time required to modify a pre-existing word-processed text file that was approximately four pages. The hour and a half did not include the time for me to have a trial run through the laboratory experiment, prepare solutions, or set up the required

equipment. The next day, after the run through, I discovered that I needed to revise the activity further. Once the students did it, I saw the need for more work. Even what appeared to be straight forward step by step instruction sets needed me to run through them. In the use of some simulations, for example, certain peculiarities were discovered when I ran through the simulation. The time spent was a benefit for me since I was able to proactively steer the students through the peculiar section before a million hands went up in the class. All of this took a large amount of time and energy making me again feel that I was a first year teacher.

Throughout the first year of my involvement with TESSI, my journal entries described how I experienced some frustration about the lack of progress that I was making to establish a computer network in my classroom. Initially, this line of reflection centered on the trouble I had in the acquisition of a teacher computer-presentation center. It took about nine months of lobbying, letter writing, and comparison shopping to finally purchase and obtain the equipment that I wanted, particularly the teacher computer/presentation system that formed the heart of my classroom. The money for this equipment came out of a proposal I submitted to the District Technology Committee during the piloting phase of the study. Later, during the four month formal study period, the delays associated with networking the room and performing the necessary room alterations to my classroom became another source of frustration.

As I look back to those moments, I now feel that the administrative teams within the school and district had just as frustrating a time as I did. They were also (and still are) learning about technology, becoming computer literate, and trying to conceive of ways to incorporate technology into the district's schools. Administrators, such as school principals and senior district staff, deal with the "big picture" items such as the network infrastructure for a school or of the whole district rather than the individual classroom. The cost of technology is enormous and the task of planning how best to place technology into the hands of classroom teachers can be daunting, especially since at present so few educators feel comfortable enough with computers to use them as instructional tools. For the sake of all of us in education, administrators need time to learn the fundamentals of the language and capabilities of computer

technology in order that they may make informed decisions about the use of technology. Like myself, the school administration seemed to understand the computer and related technology in isolation, for specific needs like word processing, but were struggling to find its role in education.

Money or the school's lack of extra cash available for my project was the principal's biggest problem. He said, "These projects never go as quickly as we want, but the key is to keep pushing. For my part I will continue to support you" (letter from principal, October 24, 1997). Despite this, during the time that I maintained my research journal, I frequently mention what I perceived to be a lack of administrative support, both at the school and the district level. When I tried to be the squeaky wheel, I felt that I was ineffective or shut down, or simply "banging my head against the wall". When I remained silent, nothing happened and I felt angry. Progress was at a snail's pace, unacceptably slow for me. TESSI provided one approach for the use of technology in the classroom - a shining example. I wanted TESSI to be a working reality in my classroom overnight! The conflicts of purpose (i.e., the principal's purposes versus mine) left me feeling hollow in view of the apparent lack of administrative support.

I now realize that the moral support from the principal was there, but so much time passed that I found it hard to believe that my project was a high priority. As I re-examined these feelings I understand that I was embroiled in the "nuts and bolts" issues of the day. I was on the front line using the equipment and feeling the direct impact of the slow rate of progress I was making towards my goals. The administration at the school had bigger items to deal with such as the completion of the network in the school, the establishment of an Integrated Learning System for ESL students, and trying to provide a computer on every teacher's desk for use in record keeping and communications. Their view was more global than mine, but nevertheless, I felt let down. Although I write in a very negative tone throughout my journal about the feelings I had regarding the progress that was being made in my lab, I now know that there was indeed support from administration.

Another issue that I was unprepared for was my role as advocate of technology use in the classroom. The promotion of the TESSI program and my involvement as a TESSI project teacher, forced me out of the comfort zone I had created for myself through my teaching career. The principal expected me to explain the TESSI project, its features and, more importantly, my vision of where I would be in five years, what my future professional direction would be and how I fit into the TESSI classroom that I was yearning to create. This was a reasonable expectation. Once he was satisfied with the approach and approved the school's involvement with TESSI, equipment arrived.

I then experienced an unanticipated consequence as a result of my efforts to establish a TESSI classroom. Throughout my career, I remained a quiet piece in the educational jigsaw puzzle. I went in to the school and taught my students. I successfully avoided duties requiring leadership. I had rarely spoken in front of groups of teachers prior to my involvement in TESSI, even during staff meetings. Now, as a TESSI teacher, I was frequently asked to speak to school officials and other teachers to describe the uses of technology and the TESSI model. I willingly adopted and adapted to the role of spokesperson or public promoter of the use of technology in classrooms. In the morning, for example, I might receive a phone call from the school principal with a request to drop by my lab with some school dignitary such as a trustee or senior administrator to demonstrate an example of computers in action. He would always phone to ensure that I would be doing computer-based activity with students. I would set up a CD-ROM presentation on the TV and also have the students engaged in a simulation or an MBL activity. He would then show the guest to the room, explain the project from his perspective and then allow them to ask a few questions. After the guests left, I felt that I had put on a show to display our abilities. Because of the lack of network and insufficient development time, the display did not truly reflect what occurred in the lab on a regular basis but rather what I expected it to be like in the future after I had gained more experience.

I was also asked to make presentations to other teachers (e.g., Science Department members from another school) and to the Parent Advisory Council of my school. Each

presentation was an opportunity to promote the school's involvement in TESSI and the uses of technology in Science classrooms. In the district's inaugural Computer Using Educators meeting, I ended up being the sole demonstrator.

Friday, October 10, 1997 9:45:00 AM

Message

From: Roy Young

Subject: CUE Meeting

To: Brad Hutchinson

Hi Brad, hope things are zooming along for you! I was wondering if you are planning to attend the Computer Using Educators (CUE) meeting on Oct. 20th. It'll be held at your school in the theater from 4 to 6 P.M. There's a Trainer of Trainers meeting that will be held right before it (3:30).

If you are planning to attend, can I ask you to do a small demo of what you're doing in your classroom? I want teachers to see snippets of things teachers are doing around the district. I have Barry doing something with HyperStudio™ and possibly one other person doing something with digital cameras. It doesn't have to be long, maybe 15 minutes or so. I know you've been doing some neat stuff with U.B.C. so it'd be nice for others to see this.

Let me know what you think.

(E-mail Correspondence, October 10, 1997)

The publicity of the TESSI project and my role within the project became a necessary and important new duty. Furthermore, informing others about the uses and functions of computer-based activities was a part of my growing responsibility in my new role as computer-using educator.

Probably the biggest change in my professional life came about by my increase in knowledge about computers. During the study period, I inadvertently assumed the role of school "techie", the person who ends up troubleshooting other staff members computer-related problems. I became a Mr. Fix-it . Once word of mouth spread amongst the staff that I knew something about fixing computers, I was inundated with requests for help. I set up accounts on the district's local bulletin board for many staff members, installed ethernet cards, established network connections, installed software, connected hardware, and advised staff on the features of programs. Troubleshooting computers or installing equipment, such as ethernet cards,

requires time, frequently as much as one hour. Some problems take much longer to solve. But, having accepted the title “computer using educator”, I became the technology expert that others relied upon. I found it difficult to say “no” to anyone, even those people who had *suddenly* become my friend. Occasionally, I received some reward for the time involvement such as a thank you gift of cookies, but for the most part, much of my free time was used to assist those around me. An ironic thing happened when the school’s computer science teacher took leave for a one year sabbatical. I suddenly became the school’s expert on Macintosh computers. I ended up helping the new computer science teacher set up his lab with the new Macintosh computers that arrived. He was familiar with computers using an IBM platform, so I provided him with information on software features and techniques specific to the Macintosh environment (e.g., At Ease security system) and assisted him in installing equipment in his room. Being dubbed the techie was an incidental and unexpected effect of my use of computer-based activities. I had a lab and seemed knowledgeable about computers and, because of my disposition, my colleagues relied on me often. An example of the sort of requests that I received began on the first day of school.

On my way out of my classroom, a teacher grabbed me in the hallway, showed me a package and said “Is this the modem card I need for my LCIII?”. I told him that it looked like it and we went back to his room to install it. After we get the thing installed, which is fairly easy (especially after I learned how when last year’s ITM class did it for me) he wanted me to set up his e-mail account. Another 10 minutes goes by and I’m thinking about the hell I’m going to catch at home cause it was already after 4:00 and my daughter had to be a piano lesson at 5:00. Anyway, I got it working for him and he was excited. I showed him how to set up an address book and how to send e-mail locally and through the Internet.

It occurred to me on the way home that I have spent a heckuva lot of time in the past helping people out of their computer problems. Last year I probably spent 30 to 40 hours on the Science Department computers throughout the year ... updating, running Norton's to fix little problems, fixing printer problems ... you name it. I don't consider myself to be a computer expert by any means. I've learned enough to satisfy my needs. I guess I've played around a lot on computers, customizing my desktop and features so that it tweaked just right for me. But I don't think that I know that much about them ... perhaps it is just relative to other novice users? Anyway, I do get some satisfaction from helping others. After all isn't that why I went into teaching in the first place? I wonder how much my role has changed over the last year. It seems that I am more involved with other staff members, teachers I rarely saw outside of the hallways and staffroom. They invite me in for help and we chat ... it kind of seems that I'm a more prominent staff member now ... not as invisible as I once was. I'm not sure if this is a good thing or not. All I know is that I'm a lot busier.
(Journal Entry, September 2, 1997)

Technology Issues:

The new role of a computer-using educator that I was adopting placed me in the position of requiring assistance from others. I had learned a great deal about my computer and was assisting other, less experienced staff members as much as I could, but I had entered a new realm in which I was no longer an expert. I was charged with ordering the right computer equipment for my lab and was trying to set up a network of computers. I had to do comparison shopping for a TV and VCR at a local shop and then set up this equipment as a computer/presentation system⁸. I was no longer dealing with my one isolated computer without the peripherals and I was no longer working within a zone of comfort. I felt that my computer experience was too limited.

I had purchased an S-Video cable from Radio Shack over the summer and I was going to try to fit it into the TV and connect it to the computer (my 6500). As it turns out, the TV doesn't have the port. Great, this is one of those things that I've been dying to try out for the last four weeks and now I can't even connect! I didn't expect to encounter this problem when I bought the cable...I just assumed! ... So much time must be invested in determining what equipment you need and then what will work with what ... damn frustrating. Sometimes I wonder if I'm in over my head. I'm a science teacher not a technology wizard (geek!).
(Journal Entry, September, 5, 1997)

⁸ The computer/presentation system consisted of a TV and VCR on a trolley that was connected to the AV card output on a computer such that the image on the TV displayed the same image as on the computer monitor.

The need for advice and support could be as basic as getting advice when I was trying to establish a network. I had ordered and acquired a hub to network the student computers in my classroom. I set up the hub, connected various computers, and then connected it to the school's ethernet. I then connected my teacher computer to the hub using the patch cables I ordered. But, it didn't work; my computer did not "recognize" that it was on a network. As it turned out, after I contacted the right person at the Maintenance department, the solution was simple.

I called Dusty at ITC and Balraj and even sent e-mail to track them down and try to determine why my Asante hub is not working. No returned messages. I finally called maintenance and Len was able to tell me that I may need a crossover cable but it is likely that there is a switch on the hub that I need to flip and the wall port (ethernet) to hub connection should work with the basic connecting cable from port to hub in my classroom. Sure enough, he was right and after I flipped it ... when I opened the Chooser everything on the network was there just as it was when I had my computer connected directly to the ethernet port.
(Journal Entry, September, 19, 1997)

Much of the success that I achieved came about because of help I had received from those who had lead the charge of TESSI before I joined the project. I had another TESSI colleague drop by and set up, with explanations, a classroom server that would serve the computer science lab and, eventually, my lab. He set up the software for us and we played with it for a little while. About one week later, I logged onto the computer in my room and was surprised at how long it took to start up the network connections. Something was wrong. I went to see the new computer science teacher in his lab and asked what the problem was. He had no idea how to solve the problem. Trying as many different things as I knew, I continually met with failure in my troubleshooting attempts. Fortunately, the previous computer science teacher who was on leave came by for a visit later in the day. After I told him of my problem, he went over to the server and corrected the situation in a few seconds with a couple "clicks of the mouse".

No matter how much I learned about computers, networking or software, I was acutely aware that there was still much more to know. The fact is that even the "techie" on staff requires assistance from other technology support services. Their service comes in the form of advice, simple tricks to help the troubleshooting process, suggestions about how to set up

equipment, etc. The need for critical support from other computer-using educators and technical support staff became apparent in several situations. Lacking that support, the computer using educator meets with a lot of frustration and wastes much time. Without available technology support an educator trying to learn to use computers will feel alone or abandoned.

Support can come, surprisingly enough, from students. My school established a course called ITM (Information Technology Management) two years prior to the study. The ITM class was composed of students who were required to solve computer related problems, plan and establish networks, and perform other computer related tasks. Through the first year of my involvement with TESSI, these students had physically set up my class set of computers while I taught lessons, installed software packages such as *At Ease*TM, and installed ethernet cards and RAM chips when necessary. In fact, I learned a great deal about these processes as I watched them work. Additionally, I began to see the need for a classroom assistant who could help me sort out smaller problems and save me time with more tedious tasks such as loading software onto each of the stand alone computers in my room.

I was starting to load a practice test on moles for the Chem. 11s onto each machine as I am now prepared to use the interactive testing with the 11s too - at least for practice tests. Anyway, I got to the first machine and a student came by and asked if I needed any help. Brainstorm! "Larry, how would you like to be a lab assistant?" I showed him how to load the file and then to modify the *At Ease* set up (I gave him the password) and then had him do one for me. He mastered the techniques and so I had him finish up the rest of the machines (as I went to the staff meeting). He did a great job and I think that I was stupid for not enlisting the help of one of the Chem. 11/12 students before.
(Journal Entry, October 16, 1997)

Support from others was a large issue for me. Without the various sources of help I received, I would not be able to have completed many tasks and maintained my regular teaching functions. As others solved problems, I learned information that later I could apply in different situations when I was called upon to assist others.

One final set of technology issues that had to be dealt was that of errors in content of simulations and the very rigid design in the MBL software. These errors caused me great concern for they undermined the credibility of the use of computer-based activities. As an

example, just after I gave a lecture to students on the scientific ways of handling measured quantities, a method referred to as “determining significant figures”, we completed a simulation on mole conversions which involved many numerical calculations. The program did not use correct significant figures in its calculations, leaving the students questioning which authority to believe, the teacher or the computer. Similarly, methods of how to arrive at solutions to mathematical calculations in Chemistry (i.e., the unit analysis calculation method) were clumsy and poorly presented on the software compared to what I had taught and students expected. This was both a technical issue as well as a pedagogical one.

Students were also quick to point out that the simulation was inconsistent in its application of significant digits rules and that they could make it better by forcing the person operating the simulation to calculate the molar mass of the chemicals used in calculations since this was not found to be necessary in their work and it appeared that moles “magically” were transformed to mass, etc. One thought was to set up a unit analysis structure for the calculations and have students fill in the required numbers to verify their calculations. Great ideas on how to improve this simulation.
(Journal Entry, October 8, 1997)

The lack of ability to correct errors in some software programs resulted in a lot of frustration by users who had inadvertently typed in the wrong value or wished to go back and fix something that they had done earlier. During an MBL titration experiment, for example, students were required to input numerical values for the volume of a solution into the computer via the keyboard (called keyboard sampling) as they measured the pH. Although this task was not difficult for the students, poor software design prevented students from correcting mistakes made in data entry without losing all of their collected data. The method they had to use was also more time consuming than a traditional hands-on method, but ultimately did produce an excellent graph of the results (a titration curve). When equipment malfunctioned in a couple of stations, student frustration at those stations hit a peak since all of their gathered data was rendered useless and 20 minutes of lab time was lost!

I had two groups lose all of their useful data as the stopcock fell out of the bottom of the burette. Frustration levels were high with these two groups because this lab had required them to enter burette readings as they added NaOH and raised the pH level. The problem was that they had to start again but it took a lot of time to collect the data so they were upset. Since a regular titration is a lot simpler, they could run the titration a lot faster and have 4 or 5 trials without problems associated with time. One group had a loosely fitting stopcock and their solution to the problem was to push it back into place, so they had several readings in which the volume added was less than the previous reading so they obtained data that left the graph fluctuating up and down rather than a smooth curve. I will need to instruct the students better about this problem next time. Overall, students seemed to enjoy this activity and viewed it as a good exercise but trouble spots need to be corrected. I had to allow several groups to use other group's data so that they could continue the analysis.

(Journal Entry, December 5, 1997)

There were a couple of glitches in the BC ARC data bank. The interactive test that I prepared on the moles had two questions where answers were incorrect. I understand that the bank of questions is still being developed but my concern with this problem is that it undermines student confidence in the testing procedure. I could give bonus marks for students who catch these mistakes but since it is a published bank of questions, other teachers are having to go through the same corrections. On the other hand, the Chem. 11 students were quite happy with the feedback aspect of the interactive ... in that they could figure out they were wrong for a given question. This was a real plus on the day.

(Journal Entry, October 17, 1997)

A teacher can correct for these shortcomings of the software as best as possible, remembering that in the large scheme of pedagogy it is the illustration of the principle or concept that is important. However, student faith in the computer-based activity and credibility of the teacher is severely undermined and questioned when such things happen. The teacher who uses these activities can also become uncertain about the value of their use.

Pedagogical Issues:

The question of how best to use computer-based activities was another issue that emerged from my journal writing. Computer-based activities seemed to be useful in extending thought. A simulation, for example, allows for some manipulation of the parameters that affect an equilibrium like effects of changing pressure, adding a catalyst or changing the concentration of reactants. Microcomputer-based laboratory activities allow for the input of experimental data directly into the computer and will display data graphically thus speeding up analysis. Interactive testing allows for corrective feedback and self-analysis. CD-ROM presentations can allow for improved illustrations of concepts. Each technology seems to have a role in the TESSI classroom, but there is difficulty in determining the best place for some of these.

The role and timing of simulations were among the most difficult pedagogical problems to address. The MBL activities simply extended existing hands-on labs when they were used. CD-ROMs added to lecture at appropriate points. The interactive testing supplemented the review process. Simulations were an enigma for me. I had tried them as an introductory activity designed to pre-teach a concept, a verification activity used after all theory had been espoused, and as an exploration of a concept that fit into the theory of the day. I corresponded with my TESSI colleagues about the best use of these technologies via e-mail.

I just thought that I would add a comment regarding simulations and their appropriate place in Chemistry 11 and 12. Having tried several times, unsuccessfully, to use simulations as introductory activities, I've come to the conclusion that this is not their best use (I speak only about the CHEMedia simulations at this point in time). From my observations it appears that students quickly lose sight of the forest for the trees when working with the simulations. It seems to lack the ability to connect the dots between each successive question that they answer, either from the on-screen or print varieties, or see the relevance of all the information that is presented e.g. graphs, model window, and digital. As well, they get bogged down in the details of the instructions and don't have a clear idea of what the simulation was all about at the end - i.e. there is no summary or thing that ties it altogether. You may say that is the job of the teacher, but this then leaves us on shaky ground if we have multiple activity TEI Chemistry classrooms.

Using the CHEMedia simulations is like watching a movie that has no "final scene", something that brings closure to what students are supposed to be learning. They become immersed in completing the associated worksheet as if it were a pencil and paper exercise removed from the principles developed in the simulation. (I have used the worksheets for the most part to guide student work through the simulation, but during

the last simulation). I tried using George's suggestion of having students create a one page summary of the simulation concepts to help bridge that visual manipulation of the parameters with the theoretical - rules derived/constructed from their perspective. This did improve student focus on what they had to achieve and learn (thanks George!!). Without this kind of focal point for their thinking, student understanding of the conceptual connections appear weak as they move from one screen to the next through the simulation. Students do spend much more time wading through simulations to collect the nuggets of insight and information that we as lecturers could provide quickly, but without the simulation they lack a mental picture from which to further develop their thinking. My current approach to use the CHEMedia simulations is to teach part of the curriculum that the simulation covers e.g. three quarters of the material and then allow the students to explore the parameters of the phenomena. I'm still not sure if this is the best approach but I've seen far fewer students with confused faces or high levels of anxiety. My view is that the CHEMedia simulations broaden and enhance understanding taking the theoretical and making it practical (in a virtual sense).

Part of the TESSI experience for students is to be able to use available technology to enhance their learning experience. Students need to be made aware of their ownership in the learning process. My recent thoughts have centered on training students to view the simulation as a learning task, similar to a hands-on lab - an application of concepts - but a lot better in some ways since they can potentially do much more to help construct mental images and develop conceptual connections. I'm really not sure how to go about that effectively but it seems that too many of my students arrived at my classroom door with "feed me" signs and are quite happy to passively receive content. I'm not prepared to let them leave with that sign on!!

(Excerpt of e-mail correspondence with TESSI colleagues, October 4, 1997)

Much debate about simulations was discussed by the TESSI members. The most appropriate uses of simulations were not agreed upon but the general consensus was that they do not serve the students well as introductory activities. As another TESSI colleague stated, "So my theory on simulations is that they are most powerful when the students have some understanding of the concepts involved and then extend or revise their understanding based on their experiences with the simulation. I have not seen a Biology simulation that would be useful for concept introduction - at least not so far". The support and dialogue such as this made it possible to better understand the role of simulations. In writing some thoughts to myself:

A couple notes regarding the use of simulations. It is now clear to me that the majority of the simulations I have used with the Chemistry 11 must be used as either review, like the one I employed today, to tie together the concepts covered in lecture. Some, mainly those used in Chem. 12 can be used as introductory but only after enough information has been built up to allow students to go that one step further. With the simulation 6B used with the Chem. 12s, they had worked through Le Chatelier's Principle and could determine equilibrium shifts due to applied stresses. They had constructed some equilibrium graphs and examined how shifts to an equilibrium affect the shapes of the

graph. These allowed the students to bridge to the next concept of K_{eq} calculations since this was only one step from where they were at already. This is typical thinking in terms of effective teaching but what I failed to see the first time I used the simulations was that students could not make the jump of lecture to model. Thinking back to the simulations I started the Chem. 11s with last year, it is no wonder that they had no idea what was going on - they simply didn't have enough of an idea of how the content of the simulation fit into the concepts they had to learn about and manipulate. Stronger introductory remarks and instructions were needed and so was more background material - slightly tailored towards the simulation's content i.e., I think that I'm teaching the material differently than in the past preparing students better for activities like the simulations. I think that I need to reflect further on this.

As a final note here, there is no way that students could use this as an introductory simulation, nor was it very exploratory. It provided a means for direct and instant feedback to students and allowed them to focus on easy content while learning the simulation's structure (and this was my intended goal - to start with some material that students were quite familiar with and allow them to gain an understanding of the simulation itself).

(Journal Entry, October 8, 1997)

The perspectives of students (dealt with in the next section) had an impact on my wonderings about the use of some activities, particularly the simulations.

Perhaps the students comments made in the Chem. 12 survey had more impact on me than I originally thought. I decided, in response to students, to spend more time on lecture and worksheet practice at the first portion of the new unit in Chem. 12 and then implement some tech activities afterward. Through that approach I hope to provide more background information to students in order for simulations to be meaningful to them and be more successful as learning tools. On the flip side of this issue, I worry that if I teach too much prior to using the simulations, I will reduce the effectiveness of the learning experience. If students get too much information before the simulation, the simulation will appear to be a trivial or redundant exercise that they have to go through. They may have already learned all about the relationships that the simulation expects them to explore and, therefore, they feel that they are not learning anything new. What would then be the point of doing the simulation? I personally really like the simulations but I know that I just haven't found the right place for them and with student dislike for the simulations prominent in their responses to my survey, where and how do I use them if they are to become a part of my pedagogical practice? Or do I use them at all? It seems that this may be a question that I should pose to the rest of the TESSI group and even my Chem. 12 students.

(Journal Entry, October 21, 1997)

Throughout the study, I tried to ensure that there was a good match between any computer-based activity used and the prescribed curriculum. From my experience, there is little free time in either Chemistry 11 or 12 to experiment with activities without a direct educational

purpose clearly in alignment with the course intended learning outcomes (ILOs). For example, an interactive test used as practice in preparation for an exam, fit into the curriculum very nicely as a way to guarantee that all of the intended learning outcomes were taught and provided the students with a way to determine their strengths and weaknesses.

Practice tests on the computers seem to provide an excellent review opportunity for students. They can work collaboratively or independently and can self monitor their progress, identifying weaknesses and strengths. Students often write out hard questions and come over for extra help as needed. Most of all, I've let it be known that their real tests will be of similar structure and question types as the practice so they clearly know what to expect on the test date - there are no real surprises. One issue of contention has been the lack of a hard copy that they can take home - my only response is that I save trees and paper costs but as the system is improved to become more interactive, I think that it will be more appropriate to do tests on-line this way since corrective feedback can be given at each stage of the test. It seems that remedial questions could be added as part of the design of the test so that similar questions could be used if a student chooses to try a different one of the same type after failing to get the correct answer the first time.
(Journal Entry, November 17, 1997)

There were some times that the use of an activity covered multiple intended learning outcomes prescribed in the curriculum document. An example can be found with the use of MBL probes. I had the students do one experiment which gave them experience in manipulating the probe, measuring pH, and determining the rate of a reaction.

Students are gaining experience with the basic operation of the probes, how to calibrate the probes and how data gets imported into the computer from the probes. They were able to produce real time graphs and will, tomorrow, analyze the data. The lab does relate nicely back to reaction rates!! This lab, I think, also reminds students of the fact that an antacid will neutralize an acid and, therefore, cause the pH to be raised. It does these things very well. My intent is for the students to use the pH probe so that we all get some experience before we do titration curves and stoichiometric titration, but this lab covers a lot more than just that.
(Journal Entry, November 20, 1997)

Perhaps continued development of Chemistry simulation software will help to rectify the difficulties I encountered, by improving design and functionality of the simulation structure. Certainly, Interactive Physics™ has provided a solid simulation process in the Physics portion of TESSI and it is expected that Chemistry simulations will improve. One theme that remained

in the forefront of my mind is that the teacher still must help the student to “connect the dots from point A to B”. Thus, as with any pedagogical strategy, even when computer-based activities are used, the teacher is charged with guiding the student from one point to another through the curriculum. Without the teacher to guide events, simulations would be of limited use for promoting learning.

I tried to incorporate the Simulation 2D as a discovery type activity, as it fit fairly well into the section on trends in the periodic table of the Chemistry 11 ILOs. I had to leave out electron configurations this year because of semester system and shortened down the whole Atomic Theory section, so I was happy that I could still use a simulation from this section. For the most part there is good coverage of the trends but no explanations are provided - only student generated hypotheses are asked for. This seems to be one deficit of the simulation itself - it doesn't provide an explanation for the observed trends and is, therefore, not a stand alone item. A teacher must intervene with information to fill out the required background that students need to understand why the trends occur.
(Journal Entry, December 12, 1997)

In the TESSI classroom, the teacher retains the role of expert who summarizes and embellishes key items of information, troubleshoots student difficulties, answers questions, and probes for understanding.

The computer-based activities used during this study were effective in specific situations. However, no one type of technology was capable of satisfying all curricular and learning needs. The computer-based activities have utility when they are used to gather and analyze data from experiments (MBL), to evaluate and provide review (Interactive Testing), to supplement presentations (CD-ROM) and to explore and enhance thinking while manipulating information (simulations). The placement of each computer-based activity into the classroom curriculum must be established by the teacher. This is straight forward for all but simulations. The role of simulations in the development of the TESSI Chemistry resources remains unclear. The teacher's role, nevertheless, still remains the same. They must guide the student through the appropriate activities so that students will learn what is required of them.

Student Issues:

I have always felt very sensitive to the needs of students. Throughout my career, I've adopted the philosophy that while students were in my class, I would encourage them as much as I possibly could. I believe that every student who enters my class can be successful. Some students have said to me in the past that they didn't care for the material discussed in class but they really enjoyed the classroom atmosphere and me as a teacher. This gave me a great deal of satisfaction and pride, something I did not want to change or have affected by my desire to use computer-based activities. Thus, student perspectives weighed heavily on my mind as I used computer-based activities more frequently and asked my students to change the way that they learned Chemistry.

For all their years of schooling, the Science students had come to expect the teacher to lecture and then provide some activity to do in order that the students would practice and master the material that they were to learn. I had, in fact, taught in that way throughout my teaching career. However, as I became a computer-using educator, the traditional presentation/activity-engagement format was not occurring in my class with the same regularity any longer. As I began to change my perspective on student learning, I began to expect students to learn in a different way than they were used to. In my TESSI classroom, I was not going to "spoon feed" students as much as I had in the past. I started to develop a more student-centered inquiry approach.

I felt that students deserved and required a rationalization every time a new technology was introduced. I thought that I should explain the purposes for the computer-based activity, explain my expectations, and then demonstrate its use. This was really no different than any other teaching strategy, that is, fundamental and sound procedures of teaching apply in TEI classrooms. My early attempts at immersing students into technology without proper orientation were fraught with difficulties. By the start of this study, I had gained enough experience to know that students needed more guidance than I had originally anticipated to get them started with the new technology. The navigation through the security system and how to access the appropriate activity was an initial concern since many students had difficulty locating

the required files and programs. I found that few students felt comfortable with the computer so I demonstrated how to get started when I introduced a new computer-based activity.

This is our very first attempt at a simulation guys. And what we're going to be trying to do is change the way that we are doing some of our learning in this Chemistry class. What I'm going to be asking you to do is to use the computers as an alternative way of learning some of the material that we're trying to cover in the class. Now, if you go through the simulation sheet that is being passed out to you right now you'll actually see that this one is about a concept that we've covered quite a bit about. But, what I want to use this for, is a way to broaden your understanding of the calculations that we've been working on. When you're doing the simulation today, you'll need to have your calculator with you. You'll need to have a periodic table, and you want to have your pen and pencil. I suggest, actually, that you work in pencil just in case you decide to erase anything. And what I've given you is a simulation worksheet or guide to help you go through the simulation. Okay? Now, what you're going to need to know is how to get into the simulation and that is what my little TV presentation at the beginning of this class is all about. When you turn on the computers in this classroom, you'll always come up to a screen that is ... well, we refer to it as an At Ease screen. This is our security system on the computers and you'll see here that there is a variety of set-ups: Administration, Chemistry 11, Chemistry 12, Science 10. Okay? Administration is for me ... it allows me to have full access to the desktop. But, of course, you need to have the right password to get into it. What you want is, obviously, your course ... Chemistry 11. And then you'll see a name select come up. In this case, I've got my name there, as well as, "Student". You will use the student set up. And just click on start. Okay, what comes up is like a folder of the different programs that you have access to. This one has the At Ease items, these are the actual programs or files that you have access to. (Excerpt from Audio Taped Transcript, October 8, 1997)

Using this technique I was able to proactively point out areas of trouble and student concern. The students had never used computers in a science class before and many had never worked on computers except in a word processing module in the Grade 8 year. Some students expressed dislike or fear of computers. It was necessary to detail each step in the initial parts of the simulations to give students the idea of how to start the program and how to proceed. This was usually done by demonstration and explanation of the computer-based activity. When the same technology was used a second time, I opted to give oral instructions rather than thoroughly demonstrate again. The majority of students had gained enough experience through the first time use of the technology to be proficient at the computer-based activity the next time that activity was used. Students were successful at mastering the techniques of operating the technology after direct demonstration and some hands-on time. But, more importantly, the

students seemed to undergo a transition after two or three opportunities to use a particular computer-based activity. After learning how the specific technology operated, students were then prepared to use the computer-based activity to learn new Chemistry concepts. The technology tools need to be understood before the student can move to the next level (i.e., use the computer for learning). As the students gained experience with the computers, the focus of skill development and knowledge acquisition changed from learning the “technology skills” to learning Chemistry concepts. As the semester progressed, the students came to view the classroom technology as learning tools and they became more and more adept in using the machines to extract information and manipulate data.

The Chem. 12 students were marvelous in working on their simulation today. I gave them brief instructions at the beginning of the class regarding the things to look out for in the simulation and they eagerly worked on it. It was funny to see some of the same students who absolutely hated the simulations when they were in Chem. 11 get down to work quickly and were quite happy about the whole simulation. I felt that they had used the activity as a learning activity - working independently in collaborative groups and understanding that the task was not to be simply completed as a worksheet but they were to learn new content from this. Perhaps I found the right words in my introduction or perhaps they can see some benefit from working through the simulations. In any case, they appeared to have turned the corner on the issue of the worth of simulations as part of their learning environment.
(Journal Entry, October 8, 1997)

At some points it seemed that the amount of paper that was passing from teacher to students would lead to “technology-obstructed” rather than technology enhanced instruction. Students required a fair amount of instruction in the form of lab worksheets and fill-in-the-blank materials to be somewhat self guided.

The biggest concern I have with MBL activities is that students were getting lost in the mountain of instructions of the lab manual (Chemistry Labs with Computers - PASCO) last year. I hope that my modified instruction sheet helps the students focus more on the reason that they are doing the lab. There seems to be a fine line in MBL experiments where students have too little information or guidance to sustain their individual efforts versus where they are overwhelmed by an onslaught of instructions that detracts from the purposes of the lab. In order to effectively use the technology students must use reference material such as the instructional package but if it becomes too cumbersome the instructions will become less relevant to achieving the goal of the lab and the TESSI model (i.e., I want to see the students become more self reliant in the learning environment and to gain computer skills in an authentic environment). The last goal of mine is unlikely to be achieved if we turn off students from technology. (Will the students' have VCRs that blink 12:00 like many of their parents?)
(Journal Entry, October 14, 1997)

Many times during the informal conversation that accompanied their working through some activity, students would express their approval or disapproval of the activity and the value that they attached to each. The simulations, for example, were the activities that students seemed to dislike intensely. Thus, near the end of the study period I conducted a short open ended survey to try to determine student perspectives on learning with technology. The survey exposed student concerns about some of the computer-based activities that I could not ignore. Chemistry 12 students' responses to two of the survey questions are summarized in TABLES 1 through 4.

TABLE 1

What do you LIKE about doing practice tests on computers?

Chemistry 12 Coded Survey Responses

Comment Category	Frequency
Preparation For Test/Question Types	9
See Expectations Of Real Test	7
Useful/Helpful	6
Indication Of Weakness/Already Known	4
Immediate Feedback	2
Gets Students Used To Wording Of Questions	2
Good Review Of Content	1
Tests Current Ability	1
Easy To Use	1
Enough Time Given	1

TABLE 2

What do you NOT LIKE about doing practice tests on computers?Chemistry 12 Coded Survey Responses

Comment Category	Frequency
Errors In Question Bank/Confusion That Results	10
Not Matching Real Test	6
Nothing or No Response	3
Wasting Time On Errors	1
Some Were Too Long	1
No Explanation Of Mistakes	1
Enjoy/Helpful	1
Too Easy	1

Clearly some computer-based activities were more appreciated than others. Practice tests met with a fair amount of acceptance while simulations were passionately disliked by students. The reasons for the dislike of simulations most probably rests on the difficult transition that students must make in order to use simulations as learning tools. I seemed unable to convince students of the utility of the simulations during the study period. I recognize that once more experience is gained in teaching with simulations, I may be better able to provide pre and post simulation instruction. In using all computer-based activities, I felt the obligation to respond to the needs and feelings of students. The students are my clientele and, as such, deserve some measure of voice in how the activities should be used in the classroom. A classroom where

students do not like what they are doing is not a conducive or healthy learning environment. It was important for me to see students enjoying their experiences with the computers so at times I felt uneasy about using a computer-based approach.

In years past, I have provided written review materials in the form of question worksheets as part of the review process at the end of each unit of study in Chemistry 11 and 12. Now, in the TESSI classroom, I was also able to provide interactive testing opportunities. The interactive (on-line) tests are designed to assess learning of all aspects of each unit and are “written” on the computer. Students would be presented with a multiple choice question, select an answer and then would have the program to mark it for them. The correct answer would be indicated (along with corrective solutions or explanations if available) and the program recorded the number of correct student responses. Using on-line tests as practice tests, students were able to gauge their mastery of the course content with questions that they would meet in formal test situations and obtain immediate feedback. Students really liked the interactive testing approach since it provided a meaningful review of content, a chance to self-evaluate, and provided some remedial help. The question bank that was used, however, had many errors that undermined student confidence in the process.

TABLE 3

What do you LIKE about simulations?

Chemistry 12 Coded Survey Responses

Comment Category	Frequency
Nothing/Very Little/No Response	7
Helps Understanding Of New Concepts	5
No Thinking Required	2
Takes Up Class Time	2
No Lab Clean Up	2
Easy/Good Marks	2
Long	1
Makes You Think	1
Get To Use Computers	1
Good Visuals	1
No Calculations	1

TABLE 4

What do you NOT LIKE about simulations?

Chemistry 12 Coded Survey Responses

Comment Category	Frequency
Don't Learn/Teach Anything	8
Not Enough Time/Rushed/ Too Long	7
Hard To Understand/Confusing	2
Don't Like Computers	2
Repetitious	1
Uncertain Outcome	1
Instruction Set Is Poor	1
Lack Interaction	1
Too Much Paperwork	1
Slow	1
Poor Graphics	1
No Response	1

Simulations, on the other hand, seemed to be a nemesis for students and, by default, me. Although I saw much value in the content they discovered and parameters of phenomena they were able to manipulate in the simulations, students saw very little point in these activities. In fact, the majority of the students expressed a high degree of dissatisfaction with simulations as a

learning tool. The perception of students was that simulations lacked an instructional purpose. The Chemistry students still viewed traditional activities (e.g., hands-on labs) as more applicable to a Science class and more fun to do.

It doesn't seem that I'm fighting their opposition to the use of technology rather I'm fighting twelve years of training in a system that has required them to be empty vessels to be filled!! I don't think that, with the right software and graphical interface that leads to greater interaction between user and computer, students will be opposed to learning with computers. But, being realistic, it is perceived to be more work than having me lecture full time and assign a worksheet or questions from the book. I hate this - are they learning anything from that approach that will be a useful skill in the future? It's hard to say. That is still the approach that is used in university classrooms! Maybe my vision of TESSI isn't doing any better, at least not at the moment. I guess that begs me to ask the question about how I feel about keeping this approach going. It's not easy for salmon to swim upstream but that's where the spawning ground is! It seems that the tide is turned against me and my approach at this time - I mean, kids still like my classroom and the atmosphere is really good, but as soon as I mention that a simulation will be done, well, I sense that students are not happy with that!
(Journal Entry, October 29, 1997)

I think that there are several reasons why student perceptions of simulations were negative in contrast with their positive view of interactive testing. The interactive tests were something that was not far out of the normal routine activity to which the students were accustomed to. Interactive tests were made up of multiple choice questions that were the norm for many testing situations. Equally important, however, students saw utility in the testing approach as it was directly measuring their progress and better preparing them for the exam. Students viewed simulations as lacking clarity and as taking a long time to extract important nuggets of information or principles that I could directly teach in a shorter period of time. They apparently could not process all of the data, questions, graphs, and relationships at the same time. Student comments and their perspectives left me wondering a great deal about the use of simulations and how they may fit into the TESSI model. I think that all reflective teachers question what they are doing in the classroom, and desire an environment that is both satisfying and engaging for students. As a developer of the application of the TESSI model to the Chemistry classroom, I clearly did not have all of the answers. I was learning how to fit

activities into my classroom curriculum and asking students to change the way that they were used to learning in Science classrooms.

There must be a middle ground to satisfy all of the students' needs as well as my pedagogical philosophy. Basically, students in Chem. 12 don't like simulations since they don't feel they learn much from them and are simply filling in worksheets full of useless data. They said that they find the simulations "boring, confusing, repetitive, and dumb". What I'm not really clear on is why this is the case:

- Is it that the simulation requires the student to change the way that they usually do business in school (i.e. lecture, practice, regurgitate)?
- Is my timing wrong? Have I found the right place for the simulation? Is that causing their problems?
- Are the simulations not engaging enough for students? Where can they be improved? Should I continue to use the support materials e.g. worksheets?
- Should I pre-teach all of the concepts prior using the simulation or continue to "give part of the theory and content and have students explore to determine the rest"?
- Why is it that some students feel that they get nothing out of a simulation and feel that they are only "copying down numbers that appear to be meaningless"?

Clearly, the simulations are easy to set up and manage but the impact of what they do for students is quite unclear. I personally think that the students like hands on labs because they get to, as one student put it, "play with chemicals". Hands on labs, however, have caused this same group to groan out loud when we start talking about the lab report that must follow. If lectures and worksheet practice is what they want then why do they resent so many notes and worksheets being used (as noted on days where this may happen)?

(Journal Entry, October 19, 1997)

It is difficult not to consider the students' perspective about the use of computer-based activities in the Chemistry classroom, after all, they are the end user and the primary purpose for the educational system. During the course of classes that involved the use of computers, student-teacher dialogue covered a wide range of topics including opinions about the use of computers. A short conversation I had with one student was an important reminder to me about the purposes of education, and the types of worries that students may have with regard to computers. I never wanted the use of computer-based activities to interfere with the human relationships which I develop with my students in my class. This has been a constant worry and one that I think is echoed by some students as well. The following excerpt is from an audio taped conversation and illustrates these concerns about technology.

Student: I think that it would be a shame though if the future held a world where we worked all on computers and didn't do hands-on experiments. Cause I really

enjoy it, like, mixing the chemicals and doing everything. Like what we did the other day with the Bunsen burners. Actually be able to do what we were doing. That's why I like science.

Teacher: I understand what you're saying. And that's actually one of concerns for me with technology. You can't use it 100% of the time because you miss out on those things you're talking about.

Student: It's good because it doesn't have the error and it has better results probably more, you know ... you don't have to worry about over measuring something on a balance beam or heating it for too long, but it's more fun, you know.

Teacher: Yeah, that's a very good point. That's something to keep in mind. Because I think that just like in life we need to have a balance in what we do, so I think, do some of these [*simulation*], some hands on labs, some lecture, some probe labs, some a little of everything.

Student: I'm sure that this is much better for scientists who are actually working because it gets better results. Like, if you're actually working at a university. It would be really useful. Otherwise, I'd rather do it by hand.

Teacher: Right. You know what, the other thing is that some people just don't like computers all that much. We use computers so they don't feel intimidated by them or shy about them. But that's part of the reason why we're trying to put computers into school or into the classroom is to say, okay, "look, it's just a tool, right. Don't be afraid of it and just use it for those purposes".

Student: And it could probably let you do experiments that you just couldn't do in the classroom.

(From an audio taped session involving Chemistry 11 student, October 8, 1997)

What was the impact of this conversation on me? The student is the *raison d'être* of education, the teacher's reason for being a teacher. I believe that successful education means that students must enjoy the experiences that they are engaged in to some extent. The resistance that I felt made me question what I was doing many times. Ultimately, I see the need for balance in all aspects of teaching and in student learning. Students come to a class with a certain set of expectations about a course and a teacher. In a Chemistry laboratory situation, there are the sights and smells of science that students look forward to experiencing. A teacher who uses technology and computer-based activities cannot ignore these expectations. The role of the computer-related activities and other computer technology needs to be finely balanced with the traditional activities. No one technology can do it all. There must be a balance. As a final thought:

I have used up far more time in creating tests, MBL activities, and marking the simulations than I would have two years ago in my traditional classroom. The benefits hmm ... I'm not sure what benefits there have been. The computers are still seen by students as an outside influence in the "life of the classroom" ... an entity parachuted into the activities that makes things more complicated and difficult to get through. Students don't see the computer as truly beneficial except perhaps in the on-line testing and exam preparation. This is the one area of the applications of software where I see them come into my room and spend extra time.
(Journal Entry, December 16, 1997)

C. Summary

The purpose of this study was to determine some of the issues facing a teacher who incorporates computer-based technologies into instructional activities in the grade 11 and grade 12 Chemistry classroom. The emergent issues were clustered around four logical domains: teacher issues, technology issues, pedagogical issues, and student issues. Each domain was analyzed separately to illustrate emergent issues and factors that affected the teacher and his role in the classroom. The issues are summarized in the following paragraphs.

The teacher issues focused on several prevalent themes. The time and energy that a TESSI teacher must maintain in order to develop and implement computer-based activities was significant. The issues of support were very important as the expectations regarding what was appropriate support differed between the teacher and administration. As a computer-using educator, the teacher often becomes a learner in the classroom. In addition, the teacher's role expands to include teacher-as-advocate, adopting a leadership position as a computer-using educator and becoming a public advocate for the use of technology in classrooms.

Several technological issues were encountered in the study period. The obvious need for ongoing available support systems to deal with technological problems was apparent. Support comes from expected sources such as district technology personnel and from unexpected sources, such as students. Some technical issues were the result of software problems that affected the credibility and effectiveness of computer-based activities.

Pedagogical issues focused around issues of implementation. For example, a primary issue was the determination of the appropriate use of computer-based activities (i.e., the timing, curriculum match and placement of computer-based activities within curriculum). The role of

simulations was of significant issue that was not resolved. Through the study period it was more and more apparent that the TESSI teacher retains the responsibility to identify and summarize key points and help the student to make conceptual connections. In addition to traditional teaching duties, the TESSI teacher must rationalize the purposes of computer-based activities, as well as, introduce and demonstrate their operation. The teacher is clearly an essential ingredient in a TEI classroom.

Lastly, student issues also impacted on the teacher. Student issues centered on student perspectives and preferences about the computer-based activities used. Although not all computer-based activities used in this study met with a high degree of student satisfaction, most were considered to be good learning tools. A balance of techniques seemed appropriate since traditional activities such as lab experiments are considered enjoyable learning experiences by students. Fundamental to the success of any program, including TESSI, the teacher remains a vital link between student and content. There is more to the classroom experience than technology-related or traditional activities. The communication between humans, the teacher as a person dealing with students, is an indispensable component of education.

CHAPTER FIVE

Summary of Results, Recommendations, and Conclusions

This study has attempted to document some of the issues facing a teacher who incorporates computer-based instructional activities in grade 11 and grade 12 Chemistry classes. The study was conducted as an action research project in which the teacher-researcher kept daily journal entries and collected related written artifacts that related to his experiences in using computer-based activities. Other supporting data included audio taped transcripts of five lessons and surveys of students' perspectives concerning the computer-based activities used in their Chemistry 11 and 12 classes. The study was conducted over a four month period from September to December, 1997, after a pilot phase from September 1996 to June, 1997. This chapter summarizes the results of the study, discusses some implications of these findings, suggests limitations of the study's findings and methodology, and offers suggestions for further research.

A. Summary Of Results

This study indicates a wide range of issues can affect a teacher who incorporates computer-based technologies into instructional activities in grade 11 and grade 12 Chemistry classes. These issues have been categorized into one or more of four domains and are summarized below:

Teacher issues focused on professional and personal issues:

- Integrating technology fully in one's science teaching practices requires significant investment in terms of time and energy.
- Becoming a computer-using educator requires the teacher to become a learner of technology in the TEI classroom.

- Bringing technology into the classroom may lead to tensions if the teacher and the school administration have different expectations regarding what constitutes appropriate support for the TEI classroom. The expectations of all involved in the innovation need to be clearly established, communicated, and negotiated on an ongoing basis.
- A computer-using teacher's responsibilities may extend beyond the classroom. Additional responsibilities could include school technology expert, and teacher-as-advocate for the use of technology in classrooms.

Technological Issues dealt with issues of technical support and software design:

- There is a need for on-going and readily available support systems to immediately deal with technological problems with hardware and software that emerge on a day-to-day basis.
- Technical support will come from expected sources such as district technology personnel, but also from unexpected sources, such as students.
- Technical software problems can limit the effectiveness of computer-based activities and affect the credibility of the technology innovation process.

Pedagogical Issues focused around issues of implementation:

- The teacher is an essential ingredient in a TEI classroom.
- The computer-using teacher must introduce and demonstrate the operation of each computer-based activity and provide a rationale for its use.
- The teacher remains central to the learning process in a TEI classroom. He/she must retain the responsibility for helping students to make conceptual connections.
- The timing, curricular match and placement of computer-based activities within curriculum are very important considerations.

- The role of simulations in the TESSI Chemistry classroom was a significant issue that was not resolved during the study period.

Student Issues focused on the following:

- Student perspectives and preferences about computer-based activities used in the TEI classroom may affect the effectiveness of the technology.
- A balance of traditional and computer-based activities should be used in a TEI Chemistry classroom to ensure that laboratory process skills are learned and that a rich, varied set of learning experiences are offered to students.
- In a TEI classroom, the teacher remains a vital link between the student and the content of a course.
- The interactive communication between the teacher and students is an indispensable component of education even in technology-rich classroom environments.

The remainder of this chapter offers elaboration and further discussion of these findings, suggests recommendations in view of these issues, and describes limitations of the study.

B. Issues That Impact On A Teacher Using Computer-Based Activities

This study has generated a knowledge base about the issues that a teacher faces when initially incorporating computer-based technologies into instructional activities in the grade 11 and grade 12 Chemistry classroom. The variety of issues that impacted the practices of the teacher-researcher's pedagogical praxis are explicated in this section.

As a TESSI teacher, I learned that teaching with technology is exciting and challenging for both the teacher and students. Students have expanded opportunities to master course content and gain valuable experience with available technology. The teacher has a broader repertoire of strategies to draw upon in structuring learning activities than in traditional

classroom settings. The TESSI teacher has an opportunity to take on a leadership role to demonstrate the efficacy of computers in the classroom to the educational community.

In addition to these opportunities, there were many issues that I faced as I became a computer-using educator and a TESSI teacher. I learned that implementing technology changes the teacher's roles and responsibilities as well as their pedagogical practice. Structured computer-based activities require that learners acquire additional process skills (e.g., other higher-level thinking skills that may include exploration and prediction) and technological skills (e.g., using an MBL probe to acquire data). The TESSI teacher, like any computer-using educator, must provide instruction in these additional skills. Curricular expectations may need to be altered in order for the TEI teacher to include the additional skills as part of their practices.

The amount of time that it takes to plan, implement, reflect upon and evaluate the use of computer-based activities was enormous. Many times I felt overwhelmed by how much time was needed to maintain and upgrade the hardware, to learn how to use the software, to troubleshoot the many difficulties I encountered and to plan the implementation of computer-based activities. At various points throughout the study period I experienced low energy levels, a loss of momentum, or expressed the feeling of being tired or worn out.

Emotional turmoil was prevalent during the pilot and formal study periods. The incorporation of the computer-based activities was accompanied by a whole host of emotions that are typical of a teacher who attempts any innovative strategy. These emotions ranged from the 'highs' of elation when things went according to plan and students had a high degree of success, to the depths of despondency when it seemed like everything was going wrong or falling apart. One nagging concern was related to the apparent lack of student appreciation for simulations, and the tensions I felt whenever these were used. My journal entries also describe the sense of frustration about the apparent lack of progress in completing the laboratory equipment acquisition or room alterations throughout this study. Emotional statements were a dominant component of the reflective writing process chronicling.

The innovating teacher is in need of support from school administration including parent advisory committees, district administration, and the technology staff from the district. The teacher experiences many frustrating incidents that prevent forward motion or stall activities on a specific day. If the teacher is involved in the setting up of a computer network and the technical infrastructure for the classroom, additional technical advice and assistance may be needed. To meet all the demands of integrating technology, the innovating teacher should be encouraged to enlist the services of people who can provide support on an on-going basis, such as classroom assistants or students who may wish to volunteer to help. These people need to be acknowledged and, if appropriate, compensated.

The innovating teacher should be prepared and able to adapt to role changes. The teacher will become an advocate for the use of technology and should expect to assume a leadership role. Administration in need of support for school programs may regard the innovative classroom as a means of raising the profile of the school within the community. While this may require that the teacher take on additional responsibilities and a technology-advocacy role, it may also attract financial support for the ongoing innovation. The promotion of myself as a computer-using educator and the promotion of the TESSI project became important issues, and led to new responsibilities for me as a teacher in the school and district.

One of the most fundamental changes that occurred through my involvement in this project was my transformation to become the technology support person within the school. As the teacher gains technological knowledge and skills they become an expert in troubleshooting software and hardware problems. The teacher will be able to network computers and administer that network effectively. These skills represent a valuable resource for others on staff, and the technology-using teacher is regarded as a consultant that can be called upon for help in solving their computer problems.

The teacher issues that emerged in this study are similar to findings from other studies. Sandholtz and Ringstaff (1996) describe the experiences of teachers involved in the ACOT (Apple Classrooms Of Tomorrow) project, noting similar issues surfaced, such as changes in

beliefs, teachers concerns, classroom management, use of instructional strategies, and changes in student assessment. They write that regardless of years of experience, teachers in technology-rich learning environments need high levels of support. The support sources seem to shift over time from technological support and training to support in activity development. The findings of the present study, suggest that much of this support may need to be provided from a district or school team and coordinated by administrative staff such as the school principal. In addition, being involved with a project group like the team of teachers that work together on TESSI, seems to be an integral component of the support network that the computer using educator requires.

As I reflect back upon my original views about the role of the teacher in the classroom, I recognize I entered teaching with the belief that the teacher occupies the central position in the classroom - bridging the gap between student and curriculum. I felt that the success of student learning hinged upon the learning environment that the teacher created. The teacher facilitated the learning process, acting as a mediator between student and curriculum through the teacher's pedagogy and practices. My experiences as a computer-using educator fortified these beliefs. The teacher's role remains central to the success of student learning. However, when a teacher incorporates computer-based activities, their role is broader than in traditional classrooms. There is an additional component involved in the interplay between the teacher's pedagogy, students and the curriculum, that is the computer technology. Far from being eliminated, as proponents of CAI or Integrated Learning Systems may postulate, the basic role of the teacher must be expanded in guiding students through their educational experience. The computer and its associated technologies may be seen as advanced tools that assist students towards achieving curricular goals - but the teacher remains essential.

To incorporate technology in a pedagogically meaningful way, the teacher will need to shift the way in which they deliver their services and their pedagogical practices. For example, I shifted from using my direct teaching strategies to more inquiry-based, open-ended exploratory approaches. It is difficult to say whether this was an inevitable, personal shift towards a

constructivist approach to learning activities, or whether the presence of technology enabled that change. Regardless, I learned that the teacher always plays a central role in what actually occurs in the classroom. With or without technology, the teacher helps students to “connect the dots”. In this regard, however, the role of the teacher using computer-based activities in the classroom is little different from the role of teachers in traditional classrooms. The teacher remains the fundamental link between the student and the curriculum. In the TESSI classroom, the teacher also must forge links between students and technology as well as technology and curriculum. Thus, the teacher’s role is expanded. Students need the teacher to guide them through the curriculum and technology, just as they do in traditional settings.

C. Limitations of the Study

The teacher-researcher methodology applied in this study proved to be useful since it allowed for exploration of experiences and issues from the perspective of the innovating teacher. Although the data collection procedures resulted in detailed descriptions that could be analyzed for insights, several limitations exist for this study.

The study attempts to describe and detail the role of the researcher and participants in the study, the social context in which the study took place, and the data collection and analysis strategies that were used. At all times, the researcher tried to remain open to all possibilities in describing and reflecting upon experiences when writing journal entries. Nevertheless, remaining objective proved to be quite difficult since some journal entries were clouded by emotional issues that surfaced during the reflective writing process. Clearly, as this was a qualitative action research project, the findings of this study are intimately tied to the context of the study (i.e. the experiences of a Chemistry 11 and 12 teacher implementing technology into classroom practice). Application of the findings of this study to other cases should be done with caution. It is hoped, however, that by including sufficient detail, this study will provide “reader resonance” for other professionals undertaking the challenge of changing their practices by

implementing technology, and that the reader will find emergent issues and themes that resonate with their own situation.

Drawing upon multiple data sources can enhance the reliability of qualitative research. In this study an effort was made to gather data in multiple forms, with the reflective journal forming the main data source. Audio tapes of classroom instruction, student surveys, and other collected artifacts supported the journal and assisted in its analysis. As in any study, the researcher analyzed data with the goal of addressing the original research questions. By necessity this narrows the focus of a study and may cause the researcher to miss possible emergent themes. In this study, a journal recording scheme that focused on four domains was developed during a piloting phase. The analytical scheme used later was structured along the same lines of thought. This may have prevented other possible issues from emerging, by biasing the reflective thoughts of the researcher. To minimize the problem, the researcher called upon the assistance of a critical friend to provide some inter-observer reliability. Although this individual did help to clarify issues and focus the investigation, possible themes or issues may still be missed. Furthermore, a critical friend may also have biases that influence their ability to assist or they may hold back comment if they think it may offend. Thus, while the critical friend's role was useful and may have yielded some additional thoughts for reflection, their role is also limited by their own personal lens and biases.

The teacher-researcher framework places the researcher in the dual role of having to carry out normal professional activities and, at the same time, carry out a research project. This duality of role can cause a great deal of tension. It is, and always should be, the primary responsibility of the teacher to teach students. Abrogation of this responsibility is, at a minimum, unethical. Therefore, the researcher is compelled to apply a research method only when it is not harming student learning or classroom functioning. The immediacy of research ideas, reflective thoughts, or research observations may have to be placed on hold while students' immediate needs are met. The role of teacher-researcher then is aptly framed, with the word "teacher" being placed first and "researcher" second. With this fact in mind, the reader

should consider that the researcher role in a teacher-researcher situation is perhaps more difficult to adopt than in other research methodologies. Because the researcher reflectively rebuilds the experience outside of the immediate situation, details that seem unimportant at the time may be lost from descriptions. The opportunity to research the situation through direct and immediate observations may be lost. As Wong (1995) describes, action researchers have to struggle with their dual purposes. In addition, the researcher's emotional state at the time of reflection and writing may be quite different from that in the actual situation that is being reflected upon. The researcher may be unable to recapture the original state, and depth of those feelings. Descriptions of one situation may be subject to interference from later observations. They become clouded by opinion and retrospective thoughts that did not occur until much later after the situation occurred, an example of reflection-about-action rather than reflection-in-action (Schön, 1983). Hindsight and the experience itself may confuse the description or cause omission of pertinent detail. Like many studies, judgments about the research process and analysis of data may occur throughout the reflective process. This may have caused the researcher to miss important descriptions and, possibly, issues through later data collection. Personal biases flavor and limit the case being studied. The teacher-researcher framework posits that the teacher's perspective will be illuminated through this sort of action research project. The data obtained and analyzed in this study must be considered as the personal description of a set of experiences filtered through the perspective of the researching teacher. Given the exploratory nature of this study, the teacher-researcher framework was both suitable and useful. However, the above limitations suggest that further or more in-depth study on changing teacher practice in the area of the use of computer-based activities may be enhanced if outside observers triangulate data.

The internal validity of this study is strengthened by the length of the data collection period and the use of participants' actual language in the natural setting. However, there are several issues regarding internal validity of this study that need to be explored. Since the knowledge gained by the teacher-researcher was constantly improving and changing with regard

to the use of computer-based activities, it was virtually impossible to develop base-line data. The approach used in this study was to document experiences over time and to share the experiences through journal writing. Thus, the issues that the teacher faced evolved and changed throughout the study with some issues being solved and others not, as these were deemed unimportant as the study progressed. The issues summarized, therefore, do not necessarily represent the issues that a teacher faces all at once, but are likely to face over time as they begin to set up a networked lab, implement computer-based activities into their classroom, or utilize the TESSI model.

Probably the most difficult issue of validity to resolve in a teacher-researcher action research study of the classroom, is the issue pertaining to participation of students in the study. Regardless of the teacher's intentions or purposes, when the teacher has adopted the teacher-researcher framework and is attempting to study their own classroom, the students who become part of the case studied are a captive group. They may provide consent, as in this study, but they may only be consenting because they feel obliged to participate since their teacher also structures the learning environment and evaluates their progress. During the study period in which data is collected, students may temper their feelings about the phenomenon, and be less than honest or forthcoming with their perspectives, in order to avoid losing status in the class or being perceived by the teacher as a problem. Students are quite aware of the importance of the study to the teacher and this may have unforeseen effects. To minimize this effect, this study was carried out over a lengthy period of time, and the researcher tried to maintain the normalcy of the classroom functioning during the data collection phase (i.e., not to make "too big of an issue" about the fact the study was progressing). However, the study had to be undertaken openly, and with the awareness and consent of the students.

D. Implications and Recommendations

This study illustrates the need for a broad level of support by district and school administrators for any teacher who attempts to incorporate computer-based technologies. The support needs to be provided to help alleviate time constraints associated with extra responsibilities experienced by the teacher. In addition, it is recommended that there is evident administrative support to expedite project initiatives such as equipment purchases and room renovations as they are needed. Communication is also critical. Administrators need to illustrate commitment and clearly convey to innovative teachers how the project needs will be met. Without this level of support, project teachers may feel isolated, despondent, and reluctant to proceed with any innovative effort.

The teacher who undertakes the challenge of using computers and related technologies in their classroom repertoire requires time to plan, implement, reflect, and evaluate the use of computer-based activities. There is no obvious position or placement of some activities such as simulations into the teacher's curriculum and pedagogy. Teachers need time to develop the appropriate teaching strategies to integrate these activities into their instructional repertoire. Release time and opportunities for connecting with colleagues who share similar interests and responsibilities need to be provided. In addition, because innovative educators may feel quite isolated at times, more staff development may be required if these teachers are expected to generate and apply ideas about the use of computer-based activities in classrooms across all curricular areas.

Sharing of technical responsibilities will lighten the burden of the innovating teacher. Structures should be in place to ensure that technical support is readily available. Many problems encountered in the operation of computer networks, software and hardware could be solved quickly if more technical resource personnel were available on staff. For a staff of seventy-five (the number of teachers at the school site in this study) there needs to be at least one or two people who have intimate knowledge of software and hardware troubleshooting procedures. These people may or may not be teaching staff, but their role should be to provide

direct assistance to teachers working with computers. I experienced a lot of instances in which assisting other teachers interfered with classroom instruction and learning. The classroom teacher should not have to spend countless hours troubleshooting computers used by other teachers and should be able to rely on an in-staff technology expert to solve their problems. It is too difficult for one teacher to solve computer problems throughout the school and still maintain a classroom focus with time to properly implement computer-based activities. In addition, district-based technology personnel should further assist teachers in the purchasing of equipment and share this responsibility with the teacher who is attempting new strategies or the incorporation of a new instructional model. In the case of technology purchases, district uniformity may help to reduce the range of technological problems.

Teachers who use computer-based activities also need to be concerned not only with the transitions that they themselves experience in their pedagogy but also consider the transitions that students experience. Currently, the use of computer-based activities in classrooms across British Columbia is sporadic at best. Students entering a TESSI-like classroom where there is a technologically rich environment may arrive from traditional classrooms where instruction and teacher expectations are entirely different. This can create tensions for the student as they are expected to think and act differently than they are used to in the traditional mode of instruction. Exploration and inquiry may be more prominent in a technology enhanced classroom than in traditional lecture based classes. Students may not feel comfortable with this new approach. It is important and necessary that teachers develop strategies to aid students through the transitions into the TEI classroom. The students, and the teacher, may experience many tensions as they work to master each type of technology. This is normal and expected. But the teacher needs to be sensitive to the changes that students are undergoing and maintain a high level of encouragement and support. Students need to be made aware of the uses of technology and the potential of the computer as a tool for learning.

E. Recommendations for Further Research

This study illustrates that the teacher's professional and personal lives are affected a great deal as they attempt to change their practice by incorporating computer-based activities into the student learning environment. The findings of this exploratory study suggest that further research studies should be considered. While this study looked at the spectrum of factors that affect the teacher, future studies should focus more specifically on questions such as: what are the strategies that allow the teacher to cope with the changes in their practice, and what are the long term implications of changing practice? How does the teacher resolve the pedagogical issues that affect their practice? What methods does the teacher use to introduce students to technological activities to clearly define purpose and function of the technology? How do students cope with the changes that affect them as they are using computer-based activities in the TESSI model?

Other areas that I feel need further exploration are in the areas of staff development and support. How does an administration set up a suitable support system for the computer-using educator? What models of support are useful in practice? Similarly, there is a great deal of work that needs to be developed and studied in the area of technological interaction between software and student. Simulations, for example, require more development in design to clarify purpose and simplify instructions in order to gain greater credibility with students. Continued development of university teacher education programs that support technology approaches should be encouraged. As well, projects like TESSI should be fostered and expanded into other curricular areas.

F. Conclusions

The findings of this study indicate that an innovating teacher (i.e., the teacher who attempts to change existing practice to incorporate new pedagogy or instructional strategies) requires a great deal of support and time to plan, implement, and reflect. Specifically, a teacher attempting computer-based activities in their classroom deals with the duality of implementing a new pedagogical strategy as well as a mechanical device - a computer. Each aspect of this duality requires time for mastery. Computer software has a place in the pedagogy of a teacher, but many issues impact its use. Teachers need time and support to make appropriate judgments in the placement of computer-based activities. Support needs to be provided by administrative structures within the school and the district. Software and hardware manufacturers need to improve the graphical interactivity and student usability of their wares. The learning curve required for the teacher using computer-based activities is steep. A teacher requires substantial time to learn how to use the technology and to establish its role in their practice. The findings of this study suggest that teachers need to be able to rely on several support networks. Teachers need to ally themselves with other computer-using educators for both moral support and for implementation ideas. The teacher also needs to be able to quickly gain technical assistance for troubleshooting. In addition, the demands placed on the teacher with regard to their “techie” role within the school needs to be minimized. A technical resource person on large staffs could alleviate such concerns or problems. Or in smaller school settings, the computer-using educator could be given administrative time to assist others. It is difficult for teachers to refuse assisting others but they do need time to more fully plan, implement, and reflect upon their own use of computers within their subject field.

In conclusion, this study has attempted to add to the existing knowledge and research base regarding the issues that a teacher faces while implementing computer-based activities under the guiding principles of the technology enhanced instruction model. The case described in this study has shown that there are many issues that impact the innovating teacher’s professional and personal lives.

As computers become more readily available, the use of computers in all academic subject areas will make major changes in the way that teachers deliver their services. The students will be asked to use the computer as a tool for analysis and manipulation of data as well as word processing. Ultimately, it will be up to teachers to fashion learning environments and develop meaningful activities in order to effectively implement computer-based activities. This study has shown that, even with slight adjustments from a traditional classroom setting to a setting where the use of computers occurs more frequently, teachers need to play a major role in the implementation of activities. It is a natural consequence that teachers who attempt change in their practice will face a variety of issues as discussed in this study. Society has come to expect greater and greater results from their educational dollars, and given the fact that computers are an expensive addition to any classroom, it seems that more resources are needed to assist teachers in dealing with the personal and professional issues that they will eventually have to face. This study has illuminated some of these issues. While more research into teachers' changing pedagogical practices is needed, the key to the success of developing technological skills in our young people will reside with the teachers we ask to implement the use of computers in their classroom instruction.

G. Closing Remarks

Teachers possess an insider's perspective, a window into the world of teaching that cannot be thoroughly interpreted by an "outside" observer. As teacher-researchers, teachers can describe their role in the educative process from their perspective. Through systematic self study it is possible for a professional teacher to examine, reflect upon and report about their practice. George Bernard Shaw's affront to teachers: "He who can, does. He who cannot, teaches." has dogged the profession for decades. In response, Shulman (1986) writes: "Those who can, do. Those who understand, teach." I wish to add that those who understand their practice can explain the story of a teacher's experience. This study has attempted to drain the swamp (or at least parts thereof) described by Schön and expose issues important for teachers who implement technology into their practice.

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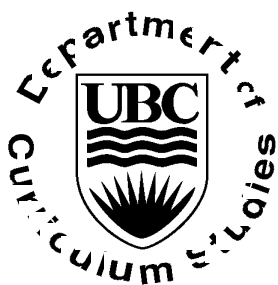
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APPENDIX A
Letter Of Consent To Participate In The Study
September 1997

THE UNIVERSITY OF BRITISH COLUMBIA



Department of Curriculum Studies
Faculty of Education
University of British Columbia
2125 Main Mall, Vancouver, BC V6T 1Z4
Tel: (604) 822-5422 Fax: (604) 822-4714

INFORMED CONSENT TO PARTICIPATE IN THE STUDY:

Innovation in teacher practice: Issues that arise as a teacher introduces technology enhanced instruction

Principal Investigator:

Jolie Mayer-Smith

Co-Investigator:

Brad Hutchinson

Faculty/Department:

Education/ Dept. of Curriculum Studies

Contact Telephone:

(604) 822-5293/ (604) 853-7191

Purpose of the Study

I am involved in a research project called TESSI, Technology Enhanced Secondary Science Instruction, which examines the application of computer-based technologies to the teaching of high school science. The TESSI project has furnished my classroom with computers, sets of chemical probes, and several software packages. This equipment is for student use and will be part of some classroom activities to learn concepts in Chemistry.

As part of my involvement in the TESSI project, I will be conducting an action research study to examine the process of incorporating computer activities into my Chemistry lessons. The study is called "*Innovation in teacher practice: Issues that arise as a teacher introduces technology enhanced instruction*" and is the basis of a graduate thesis that I will be writing to fulfill a requirement for a Masters of Arts degree. The difference between action research and other forms of research is that action research is conducted by the teacher themselves in their own classroom. All data is collected by the teacher and used strictly for gaining an understanding of the particular topic under study (in this case an understanding of the teacher's approach to teaching with technology).

Study and Confidentiality Procedures

The data collection procedure of this study involves keeping a detailed journal of events with descriptions of how various activities proceed in the course of applying the TESSI model to my Chemistry classes. In addition, I will audio tape some of my classroom lessons over a two month portion of the course. Audio tapes will be transcribed and analyzed. If student voices are recorded and used in the study, pseudonyms will be used to ensure strict student confidentiality. The audio tapes will be stored in a locked cupboard and will only be accessible to the researcher (myself) and my research committee. After the study has been completed the audio tapes will be erased. A copy of the completed thesis will be available at the U.B.C. Library and at the office of School District #34 (Abbotsford).

INFORMED CONSENT TO PARTICIPATE IN THE STUDY:

Innovation in teacher practice: Issues that arise as a teacher introduces technology enhanced instruction

(con't)

Please indicate your consent or refusal to have your child participate in this study by completing the attached form (see page 3). If your consent is granted please have your son or daughter sign the form as well. Participation is considered voluntary and students may withdraw their participation at any time. Participation in this study will not involve any risk of any kind. The researchers are aware that parents may feel pressure to agree to their child's participation because the researcher is also the child's teacher, but please be assured that you have the right to refuse or withdraw your child's participation in this study without any consequence to your child's standing in the class. If you have any concerns about your child's rights or treatment they have experienced in connection with this study, you may contact Dr. Richard Spratley, Director of the U.B.C. Office of Research Services at 822-8598.

If you indicate that you would prefer that your child does not participate in the study, then any comments made by your son/daughter during taped lessons will not be included as part of the data analysis of the study.

Contact Information

If you have any questions or desire further information with respect to this study, please contact Mr. Brad Hutchinson at (604) 853-7191 or his research supervisor Dr. J. Mayer-Smith at (604) 822-5293.

Note:

The University and those conducting this project subscribe to the ethical conduct of research and to the protection at all times of the interests, comfort, and safety of subjects. This form and the information it contains are given to you for your own protection and full understanding of the procedures, risks, and benefits involved. Your signature on this form will signify that you have received the document described regarding this study, that you have received adequate opportunity to consider the information in the document, and that you voluntarily agree to participate in the study.

Consent Permission Form

Parent/Guardian Copy

I, *(please print)* _____ have read the information on this consent form and have had the opportunity to discuss in full the nature of this study. I give my consent for my son/daughter _____ to participate in this study. I understand that participation in this study is entirely voluntary and that my son/daughter may withdraw from this study at any time without jeopardy. I acknowledge receipt of a copy of this document.

I consent to my child's participation in the study.

I do not consent to my child's participation in the study.

Parent Signature: _____ Date: _____ .

Student Signature: _____ .

--- Please Detach Here and Return the Bottom Portion To Mr. B. Hutchinson ---

Consent Permission Form

Project Copy

I, *(please print)* _____ have read the information on this consent form and have had the opportunity to discuss in full the nature of this study. I give my consent for my son/daughter _____ to participate in this study. I understand that participation in this study is entirely voluntary and that my son/daughter may withdraw from this study at any time without jeopardy. I acknowledge receipt of a copy of this document.

I consent to my child's participation in the study.

I do not consent to my child's participation in the study.

Parent Signature: _____ Date: _____ .

Student Signature: _____ .

APPENDIX B
Examples Of Journal Entries

November 8/96

A regular typical pre-Remembrance Day school day. Students went to an assembly as per usual. The Chemistry 11 students from one block were able to complete the simulation activity (3A). I was not impressed with the way it all went. This approach is new to all of us at Mouat, but the students did not seem to enjoy themselves nor find the activity a good learning experience. The following are a few thoughts regarding the completion of the activity and a synthesis of a few informal unstructured comments from students.

- **Student Issues**

Many students were confused with the operation of the simulation itself and this required a lot of small group problem solving. They had a lot of trouble knowing when to move to the next screen ... since there was no obvious clues to let them know when to do this within the simulation or the print materials. Students seemed unaware of the help function and the amount of background material that it was able to offer. I did not tell them about it ... hoping that they would discover it on their own. There were several parts to the simulations that the students had no idea what was happening ... particularly the Rutherford hydrogen spectrum and what it was attempting to show. With groups of 4 to 5 students, many were feeling that this was not an effective way to learn the concepts. I asked two students what they thought and basically they told me that were not interacting with the module/simulation at all, but were simply copying down the information that the students who were on the model had discovered. They felt that they had learned nothing and, in fact, stated that they didn't like computers and didn't learn well from them. I suggested that we all can learn from the simulations that we have but it requires using a different learning strategy ... one which is different than the lecture-recital method we are used to. Also, there are a lot of other skills to be developed using the computer other than the learning of content. They were satisfied with the response and promised to interact with the simulation more next time.

- **Pedagogical Issues**

The length of time involved in the simulation was at least twice that which I would typically allocate. The content covered was in a lot more depth than I would usually attempt. In particular, there was discussion of how scientist used Rutherford's Model to suggest that if it was "truly" representative of the atom, they would expect the atom to collapse, i.e. the electron would spiral inward as it is electrically attracted to the positive nucleus. The connection to the Bohr model was good (provided you already know the development of the history) but students were having a lot of difficulty seeing the connections and then trying to understand the Bohr approach. I wondered if I left them with too little to begin the simulation. Does more theory need to be presented to the large group prior to their running the simulation? Were my directions clear enough to give them the ability to learn from the simulation? Pedagogically speaking, I felt that there was many problems both in the print and simulation materials and also in my preparation of the students for the simulation. They were not adequately motivated, prepared, interested, nor intellectually ready (background is insufficient) for the challenge. More careful thought is needed here.

- **Technological Issues**

Computers worked fine, except I was very worried that the computer I borrowed from Rob would be tampered with since I do not have At Ease on it. It survived. The simulation, as already mentioned, has some flaws in design, particularly in the transitions from one screen setting to the next. Students do not know when to do this.

- **Teacher Issues**

I was finding that I was doing a lot of small group explanations about both content and the operation of the simulation. Much more than I anticipated. I was troubleshooting their difficulties as much as possible. I felt that there were a lot of complaints directed towards the use of the simulation - clarity of instructions and lack of background to the concepts discussed. I wonder if I set up another simulation activity like this soon if I will have a revolt?!? It became necessary to instruct all groups to use the help function on more than just the basic parts of the simulation, since it provides a lot of background to the concepts encountered in the simulation. I used small group lecture in each group to provide an overview of what was being dealt with in the simulation so that they had a better idea of the big picture. It seemed that many students were lost in the models and were not able to follow the theme of the unit (couldn't see the forest for the trees!).

I think that I need to run through the simulations better myself. That didn't stop a lot of bugs from creeping into my lesson and their activity (perhaps it's because this required a different level of planning - I did not realize where their difficulties would be - a tough learning experience).

I wonder what sort of instructions I need to give prior to the simulation to make this work better? I am confident that they will like and learn a lot from the simulation if they are better prepared. The question is how do I do that? The activity that the class went through was no picnic for them or me. I'm not sure on the level of success that we/I met ... I'm sure it's not high. I think that students will be more aware of what to expect and how to perform a simulation next time.

- **Other**

There were too many students per computer. This created a situation where some students just sat back and watched the simulation and did not really participate in manipulating the information. I asked one student what her impressions of the simulation was after they were handed in and her biggest complaint was the fact that there was not enough computers for everyone to work on. She actually said that three to a computer would be probably the right amount.

September 2/97

Well, it was back to the grindstone today. It was a good thing that I got up early yesterday so that I could go to bed early last night and actually get to sleep. Nearly every time I begin a new school year I'm up till three in the morning the night before. I don't know if it was the excitement of starting a new year or if it is just plain old nerves ... wondering if I will be up for the new challenges that accompany every year. Got there early for the staff meeting.

The meeting discussed the usual stuff (the plan for the week, locker assignments, upcoming pro-d days, our new schedule, etc.). Afterwards we went to our classes and before I could look around... students from my HAT class were there and we were completing the required activities. After that, we went through a mock block rotation from blocks A to D. I just gave a simple talk ... general background about myself and the course after I did the attendance.

- **Technological Issues**

I managed to build my new trolley (for the VCR and TV) during the day as kids came and went through the block rotation. A student and I put the TV on the top and the VCR on the second shelf and, well, I think it looks pretty good. My media center has finally come together!!! Now I just need to get the computer connected and we're in business!

Also, I picked up my new hub, but didn't get a chance to look at it yet. This is going to be a cool year, if I can only get it up and wired!!!!!!!

- **Other**

I was cornered in my classroom by a new teacher, Frederick Lee, after the science department meeting. He is taking over for Michael Davis for the year as Michael is on leave. He appeared to be kind of bewildered and told me that Michael could ask me questions about the computer lab. Frederick took me across the hall to his new computer lab and showed me his plight. First of all, he is a Novel expert and unfamiliar with Macs. Secondly, he hasn't taught high school for 10 years. Anyway, he inherited a lab in which 25 of the 32 computers do not have ethernet cards and he only has one Stylewriter printer in his classroom. He was choked. Never mind the fact that he has Mac Pluses piling up in his room and the LC475s had to be taken down from the computer tables and stored under the tables until they are distributed to the rest of the staff. I had to help him set up the printer and show him how At Ease works (and how to install it). He now has to do it to the other 24 stand alone machines. Michael left his room in a mess and this guy was left in a lurch.

One my way out of his classroom, Geoff Powell grabbed me in the hallway, showed me a package and said "is this the modem card I need for my LCIII?". I told him that it looked like it and we went back to his room to install it. After we get the thing installed, which is fairly easy (especially after I learned how when last year's ITM class did it for me) he wanted me to set up his e-mail account. Another 10 minutes goes by and I'm thinking about the hell I'm going to catch at home cause it was already after 4:00 and my daughter had to be a piano lessons at 5:00. Anyway, I got it working for him and he was excited. I showed him how to set up an address book and how to send e-mail locally and through the Internet.

It occurred to me on the way home that I have spent a heckuva lot of time in the past helping people out of their computer problems. Last year I probably spent 30 to 40 hours on the Science Department computers throughout the year ... updating, running Norton Utilities to fix little problems, fixing printer problems ... you name it. I don't consider myself to be a computer expert by any means. I've learned enough to satisfy my needs. I guess I've played around a lot on computers, customizing my desktop and features so that it tweaked just right for me. But I don't think that I know that much about them ... perhaps it is just relative to other novice users? Anyway, I do get some satisfaction from helping others. After all isn't that why I went into teaching in the first place? I wonder how much my role has changed over the last year. It seems that I am more involved with other staff members, teachers I rarely saw outside of the hallways and staffroom. They invite me in for help and we chat ... it kind of seems that I'm a more prominent staff member now.... not as invisible as I once was. I'm not sure if this is a good thing or not. All I know is that I'm a lot busier.

November 4/97

Chemistry 11 students were involved into their second simulation today. It was working quite well in my opinion with a few minor glitches. The Science 10 classes worked through the concept of Mitosis while the Chem. 12s were into prepping for their Solubility Test. It was a very busy day.

- **Teacher Issues**

I sure was hopping from group to group to get things rolling in the two Chem. 11 classes.

The students were very engaged with the simulation and found few problem areas. I think that I need to survey these students on the use of the simulations after they do their next one and compare that to the Chem. 12s. The awkwardness of the simulations (use of radio buttons and the mechanical mouse manipulations needed) seemed to be less of a problem once students got the hang of it. My trouble shooting was required, little until we arrived at the limiting reactant portion of the simulation.

- **Student Issues**

Many students are still a little uncomfortable with the simulations - sometimes unsure of what they need to do. This is getting better with experience and as confidence grows. Most of my troubleshooting involved little things that students knew but didn't remember e.g. clicking on the radio buttons. That is some of the interface improvements that will need to be made.

- **Pedagogical Issues**

None.

- **Technological Issues**

The practice test worked very well for the 12s but the Simulation 4B has a few glitches that seemed to impede student progress. The simulations need some better help features on board the program to define terms and simplify the manual entry of data. Students have to click onto a box to change data they are to add into the simulation, click onto the yellow box (where other text is located), and then to click onto a check mark icon. A pretty involved procedure to access the answers they are looking for. The whole interactive interface aspect of the simulations needs to be revamped to be more user friendly. Once student got the hang of how the simulation worked they were fine until they reached the Limiting Reactant area of the simulation - then questions came pouring out of every group. We'll have to deal with them tomorrow as time ran out in class.

- **Other**

I gave a short 20 minute presentation on how to use CSL Marks to the staff after school. Five people showed up and I ran through the basics of the teacher and office modules of the program. I don't know if I helped them out much but going through the mechanics of the program I thought that I at least appeared to be knowledgeable about the program and, I guess, it was a good learning experience for me. The best part of it was that I was able to use the screen sharing functions from ANAT and this allowed everyone to see what was on my screen. It worked beautifully without problems and drew peoples attention directly to the aspects of the program that I was trying to illustrate - what a great instructional tool! I stayed after to help people with individual problems till 3:30 PM. Whole thing took about an hour.

APPENDIX C
Examples Of Collected Artifacts

E.g. 1. An e-mail entry added into journal:

Tuesday, November 5, 1996 5:00:03 PM

Message

From: Brad Hutchinson
Subject: Computer
To: Don McLean

Hi Don,

Just a note to let you know that there was a mix up in the purchase order that was to be sent to MacStation re: a AV card for the Power Mac 5260 that Bob Brown currently has in his room. Apparently, after discussion with Gerald from MacStation, there is no appropriate AV card for the 5260 model (there are no PCI slots to expand into). The PO has now been canceled since the equipment is not appropriate. (the SBO was going to send another presentation box instead).

Gerald also indicated that the price of the Power Mac 7600 has come down such that the whole package is \$4000 retail (not educational price). Considering the technology moneys we hope to acquire from the Tech funds, I included my teaching computer station request as part of the proposal. Please see Dan to proof the proposal and ensure that it is in-line with your thinking.

Brad

E.g. 2. A Power Point presentation made to the Parent Advisory Committee of the school:

Technology Enhanced Secondary Science Instruction

*“to extend learning experiences for students
beyond traditional methods”*

Main Purposes

- to incorporate computer technology into the science classroom
- to simulate or model concepts that are difficult to present by traditional means
- to extend and enhance thinking processes by allowing more exploration of concepts
- to develop more “authentic” science activities, e.g. MBL experiments

Rationale

- Important skills to be learned
 - traditional science process skills
 - use of technical equipment
 - computer literacy skills
 - collaboration
 - personal planning and goal setting
- Alternate environment
 - fun and interesting to many students
 - greater variety of activities

Components Of TESSI

- use of traditional resources
 - textbook, notes, demos, etc.
- use of available computer resources
 - Simulations, MBL activities, laser disk
 - Internet, CD-ROM
- Interactive Testing (LXR)
 - use of other technological devices
 - video capture, microscope-TV presentation

Changing Teacher’s Role - Facilitator versus Lecturer

- use traditional methods where appropriate in balance with high tech activities
- provide small, as well as, large group lectures
- create and use appropriate computer resources to enhance thinking opportunities
- coordinate/guide students through activities
- greater focus on individuals
- troubleshooting problems

Changing Student’s Role - Active Learner versus “Empty Vessel”

- student centered classroom
- greater control and ownership of learning
- choices in activities
- independence and goal setting
- self-pacing and self-assessment

What TESSI Means To Our Students?

achieve good academic results.
gain a wide variety of process skills.
technology related and traditional
continued high participation rates
experience authentic science investigations
greater interest in science

The Next Steps

Complete the creation of the TESSI lab:

9 computers with MBL equipment (8 now)
software acquisition, particularly CD-ROM
presentation center - TV/VCR/Power Macintosh 6500
room alterations - major cost item
network with ethernet and connect to server

Climb a steep learning curve to effectively implement the model and its resources

The End

APPENDIX D
Example Transcript of Audio Taped Class
October 8, 1997

Audio Tape Session #4

Date: October 8, 1997

Class: Chemistry 11 Block B

Topic: Simulation 4A

Brad: Okay. Guys just so that I record this for and mark this on my tape recorder ... this is Chemistry 11. Block B. What date is it today?

Student: October 8th.

Brad: October 8th. Okay. This is our very first attempt at a simulation guys. And what we're going to be trying to do is change the way that you are doing some of your learning in the Chemistry class. What I'm going to be asking you to do is to use the computers as an alternative way of learning some of the material that we're trying to cover in the class. Now if you .. umm .. if you go through the simulation sheet that is being passed out to you right now you'll actually see that this one is about a concept that we've covered quite a bit about. But what I want to use this for is a way to broaden your understanding of the calculations that we've been working through. Give you a little different look at what we've been doing and, hopefully, enhance some of your thinking in that I want you to be thinking through the steps that you have to through in the calculations in just a bit different way. When you're doing the simulation today, you'll need to have your calculator with you. You'll need to have a periodic table, and you want to have your pen and pencil. I suggest, actually, that you work in pencil just in case you decide to erase anything. And what I given you is a simulation worksheet or guide to help you go through the simulation. Okay? Now, what you going to be needing to know is how to get into the simulation and that is what my little TV presentation at the beginning of this is all about. When you turn on the computers in this classroom, you'll always come up to a screen that is ... well, we refer to it as an At Ease screen. This is our security system on the computers and you'll see here that there is a variety of set-ups: Administration, Chemistry 11, Chemistry 12, Science 10. Okay? Administration is for me ... it allows me to have full access to the desktop. But, of course, you need to have the right password to get into it. For Chemistry 11, Chemistry 12, and Science 10, it's what is called a restricted view. What you're going to get is just simply some pictures of the different programs we're going to use. Okay? Now, I'm going to turn off the lights here so that we can see this a little bit better. Now the way we'd see this as soon as you turn the computer on, you'll see this view. What you want is, obviously, your course ... Chemistry 11. And then you'll see a name select come up. In this case, I've got my name there as well as student. You guys will use the student set up. And just go start. Okay, what comes up is like a folder of the different programs that you have access to. This one has the At Ease items, these are the actual programs or files that you have access to. And the one that is in behind ... you'll notice that there is a blue one back here ... that is a folder that students can actually share or put on their items onto the desktop or into computer and have access to them later. We're not going to be using that function at all for this course. We need to have a better network in this room in order to be able to use this more effectively. And, in fact, you'll find that all of your computers right now are referred to as stand alones. In other words, there are not networked up. What they are is simply stand alone computers, by themselves. You can't print from them, you can't get onto the Internet from them because there's not a proper network in place. Okay. Now, if you look at your At Ease Items, you'll notice several different programs. First of all, you'll notice in the left upper corner here something called ChemSmart. Those of you who have what you feel is a difficulty with some of the concepts that we're covering, you may want to use this as a tutorial program. Here is how it works. You

just simply press once on that icon, you hear a click and that program will load up. And it may take a little bit of time 'cause it's a fairly big program. All right. We don't need to know this information. This is referred to as a splash screen. There's another splash screen. And eventually it should take us to a menu of items that we can use to help us out going through this course. Now, you'll find that, because of all the computers out there are all equivalent to IBM 386s except for a couple of Power Macs at the back, that means that they are relatively slow compared to some of the newer computers that are out there [*filler waiting for program to load*]. Now for an example here's in this thing we've got chemistry, chemistry problems stoichiometry, bonding, solution chemistry, electrochemistry. And if you're interested in one of these topics, like say stoichiometry, you click on it once and you can go through the various parts of the menu. For example, if you want to know what molecular weight is. This is the term that the Americans use, and Americans developed this program ... umm ... molecular weight is the same as molar mass. Okay, now this goes through the basics of how to calculate the molar mass of a chemical. And you can see down here, you have a number of screens. Can you see these down at the bottom?

Student: Uh huh.

Brad: You can move right. You can through empirical versus molecular formulas and you can use this as a tutorial of information to help you out. Okay. We're not interested in this particular program today but you will be. Am I sure I want to Quit? Yes. So I quit that program. The next one over here that you'll see is Clarisworks. That's a basic word processing program. So if you are required in any course, including this one, to type something up, you can come into this lab and use Clarisworks as a word processing program. Okay? One requirement is that you guys will have to have your own disk. Or you could use one of the disk that I have available up here to store that information because, unfortunately, you won't be allowed to store information on the hard drives of your computers. You'll see on the far right something called LXR Student Interactive. This is where, as time goes on, I'm going to try to build some tests for you guys that you can do on the computer. Okay, so they are on-line tests where you guys can run through questions, answer them and get immediate feedback to the different questions that are being asked in ... of the content of the course. You'll also see something down here called Science Workshop. This is a program I'm hoping to use a little bit later on in our course where we will actually take probes and input information directly into the computer so that we can analyze the data that's obtained from an experiment.. Now, it's not as appropriate for this class as it might be for the grade 12s, but I'm hoping to try one or two of these with you guys. Okay? The program we want to be using today is called Explorer and what it is, is a simulation program. So we'll click once on Explorer and then we'll explain more about it.[*pause as program loads*] You'll see this splash screen come up ... Explorer from Logal ... and then once you hit the splash screen, click on it once, you get a menu of items. And you'll notice on the left side there's an arrow, right here [*demonstrates*] next to where it says Prentice-Hall CHEMedia ... look down ... and you guys are going to be looking at Unit 4 Stoichiometry. You can either double click on it or open that arrow and your simulation is Simulation 4A The Mole. Okay, and we'll just go down and open that up. Again we get the splash screen and then this stuff comes up. Okay, now, you'll see a lot of information on this one particular screen. What you have is various components. This thing up here which I will move ... can I move it around I can't move it around ... I can actually close it though ... there we go. That part up there is referred to as a Model window. A model window. And it actually says the word model above it. And then the rest of this is information and questions and things to do regarding this concept. For example, it says here, type the symbol of an element in the formula box in the model window and hit the return key. So, let's say for example I want to use iron. Go ... Fe. And what do I do? Type the symbol of an element in the formula box in the model window and hit the return key.

Student: Return.

Brad: Return. [*Presses return*]

Student: I know that.

Brad: Okay, so you'll see the Fe. But you'll notice that this one's got a little bit of a weird glitch to it. The next little instruction says "click the radio button" ... they call that thing a radio button ... above your symbol like this [*demonstrates*] so you can see there's the radio button clicked on this example. I'll click that on, okay. Then click an arrow in the diagram below to choose a conversion factor. Hmm ... let's see, should we go to mass? Oh, pardon me, it's right over here, sorry. Go to mass. Let's say that I have 50 grams of this chemical, okay, now the 50 grams is in blue, what I'd like to be able to do is to figure out the number of moles. And immediately this information comes up, that it is point 895 moles. Okay? Sort of what we are doing, but it is a quick way of doing some mole conversions. All right, now let's take a look at your sheet that you've got in front of you. What you'll notice is, this sheet has little hand arrows, pointers. They indicate the directions, where the directions start for a particular screen. You'll also notice in the left column there a computer icon. The computer icon tells you which screen you should be on. We're on the first computer icon, so we should be on the first screen. And actually be able to find out that later on you'll be able to move from this screen to other screens. You'll see, this is not going to show up very well here, but you'll see a little man in the bottom right hand corner. And the word underneath of it says next. When you've passed through the simulation, you've done everything in screen 1, filled in this part of the simulation sheet, you move down to the next computer icon and that's when you go forward to the next screen. And some new instructions will appear. Okay? And new little tasks to follow through on. Okay? So that's now the second screen. And, again, there's lots of questions to answer. You'll go down to ... now you go to the second page. The third little computer icon says "how can you use Avagadro's number to convert from moles to particles?". So that's now the third one, so I need to be on the third screen,. Now you'll notice the title on this says "how can you use Avagadro's number to convert from moles to particles?".

Student: It's the same.

Brad: It should virtually match what's said on the screen ... err ... on your sheet. Okay, now there's the idea guys ... is that your job is to basically use the computer to go through these sets of instructions, these calculations, and use this as a learning tool. Now, one of the reasons why I'm starting with this one is that I know that all of you guys have gone through the content of the moles. The last little while, we've talked about how to change from moles to mass, mass to moles, moles to particles, particles back to moles, and yesterday we spent a little bit of time talking about going from moles to litres of a gas and litres of a gas back to moles. So that I know that you've got a bit more background in this area and I want us to use this first simulation as a way to learn a little more of how these simulations operate. So, getting used to the model window and the various instructions, and I also want us to reinforce the concepts of what we've talked about the last little while. You'll find that as you go through it, yes, there are some calculations. Notice the unit analysis that's shown right here. It says that if you want to go from particles to moles, you'd have to set up your unit analysis like this. And you may be required to do that in your sheet. Okay? I want you to follow these as written, go carefully through it, and the way we'll work through a simulation (and we will do more of these this course) is that I want us to work in groups of three. I don't care which partnerships come together for a group of three, you have to form a partnership. We find that putting three people on a computer helps you guys to talk through the issues that are coming up on the screen, help each other through this worksheet, okay ... and that's the idea of having a little bit of collaboration ... one of things we'd like to see you guys develop is collaborative work experience and making sure that you can work effectively as a team. And we'd like you guys to be able to do

that in that group of three. Now, right now, I've got ... umm ... two ... I've got nine computers spread out through the room. Okay. So that means that we can basically have 27 people on computers. At some point in the future what I would like to be able to is to be able to have a multiple activity classroom, where people could be doing a simulation, other people could be doing a hands on lab, somebody might be doing an on-line test using the Interactive, somebody else doing an MBL activity with putting information directly into the computers ... in a different way ... by using the experimental probes. So we'd like to be able to do that, but we're not that far advanced so what we're going to do is to keep everybody together. We're all doing the same simulation today. And, in the future, we'll all be doing the same simulations ... umm ... in this course at least, together in a lock step fashion. When you guys take Chem. 12, if you do, you'll find that there may be some times where find some people will be working on a simulation, other people doing something else in the same classroom. That's ultimately what our goal is in this, in my project is, is to have a multi-activity computerized classroom. So that computers become a tool that we use to analyze data, to learn our content of our science and, also, to learn some computer skills. All right, so that's my basic spiel, okay, and what I would like you guys to do is to get into your groups of three, get onto a computer, and start working through this simulation. Typically, guys, this simulation should take 60 minutes max.

APPENDIX E
Sample of Student Surveys - Chemistry 11 and 12
December 1997

Chemistry 11

Classroom Survey

Over this course, we have used a variety of activities. I would like you to comment on the use of some providing me with your opinion of their effectiveness. Please be as specific as possible:

1. Practice Tests on Computers:

a) What do you like about doing practice tests on computers?

b) What do you not like about doing practice tests on computers?

2. Simulations:

a) What do you like about simulations?

b) What do you not like about simulations?

Other Comments (please feel free to use the other side of this sheet)

Chemistry 12

Classroom Survey

Over this course, we have used a variety of activities. I would like you to comment on the use of some providing me with your opinion of their effectiveness. Please be as specific as possible:

1. MBL Labs (using computers and probes e.g. pH probe):

a) What do you like about MBL Labs?

b) What do you not like about MBL Labs?

2. Practice Tests on Computers:

a) What do you like about doing practice tests on computers?

b) What do you not like about doing practice tests on computers?

3. Simulations:

a) What do you like about simulations?

b) What do you not like about simulations?

Other Comments (please feel free to use the other side of this sheet)

APPENDIX F
Example Of Raw Uncoded Data Of Student Surveys
December 1997

Over this course, we have used a variety of activities. I would like you to comment on the use of some providing me with your opinion of their effectiveness. Please be as specific as possible:

1. Practice Tests on Computers:

a) What do you like about doing practice tests on computers?

1. It gives us an ideal of what we will see on the test. Helps us by giving us the answer if we don't understand.
2. It gives us an idea on how the test will be like.
3. The computer practice tests help me get an idea of how I will do on the test and tells me what to practice studying if I don't understand.
4. Unlike the other computer activities, I like the practice tests because it's a good review, and it shows you how to come up with the right answer.
5. You know if the answers to the questions are right, right away and if it's wrong it shows you how to do it.
6. Get to figure out what I'm doing wrong. Get to do more questions, if having problems.
7. They were fun and interesting.
8. It definitely makes the test's easier if you do the practice quiz on the computer before you write the test. You know what's on the test as well as your weak points immediately.
9. Them were fun!
10. I think they help me prepare for the test really well.
11. -
12. It is the same to me.
13. Don't have to right anything down. Step by step explanation.
14. You get to work in groups and share ideas and you get to understand more info from other people.
15. They give us an overview of what's on the test and always tells you the right answers and how to get them after each question.
16. Working with groups with friends. Its better than review sheets. It gets us some multiple choice practice for the tests which are multiple choice.
17. It gives me a chance to prepare for a tests from a different point of view. It also shows me how I made my mistakes and what I can do to correct them.
18. That way you have something to study off that is just like the test.
19. What I like about doing practice tests on computers is that we get a chance to further our knowledge in computer work and we get a taste of what's to come.
20. It allows you to move a lot faster and correct yourself as you go.
21. I like doing them because it shows you what kind of questions the real test is on.
22. It gives us a good idea on what to expect on the upcoming tests.
23. It generally shows what is going to be on the real tests and it gives challenging questions.
24. It gives me a chance to know what the real test will look like and how hard it will be. It also gives me pointers on what to study for on the test.
25. Faster than writing and if you get it wrong it shows you how to do the question.
26. It helps me understand what to expect on an upcoming test and it helps me study better for it.
27. The fact that they help me to solidify my knowledge and correct the little wrong things on the spot.
28. If you work out a problem and you still get it wrong, the computer shows you how you are supposed to work out the problem.

29. They are very similar to the actual tests, They give corrections to questions I answered incorrectly. They show my score at the end of the test. They're more challenging than certain worksheet questions.
30. I like than on the practice tests, the questions are very similar to the ones on the tests. They are worded differently than the questions on our worksheets, so it helps us to not be so confused on the real biggie test.
31. After each question you find out the real answer, so you know what you did wrong, and how to do it right in the next question.
32. They are very informative and helpful for knowing what is on the test.
33. It helps me prepare for what kind of questions are going to be on the test and how they will be worded.
34. They help me.

b) What do you not like about doing practice tests on computers?

1. They take lots of time, and you can't really learn because someone always finishes and you can't get the chance to do the work.
2. Takes forever to figure out the questions. Too many questions to answer.
3. They are very long, but worth it.
4. The wording of some of the questions are hard but that's about it.
5. You can't work the question out as well you have to redraw it and not the same.
6. Nothing.
7. You don't learn much. You are too busy watching the funny pictures and get distracted.
8. Sometimes, if you get a question wrong, you don't get an example of how to do the question.
9. Ya gotta know how'da type.
10. They can sometimes be boring and repeat the question over and over again. It can sometimes confuse you too.
11. Can't take the questions home to use as study tools. More difficult to work out problems on computer than on paper. Difficult to work with certain people.
12. On paper I could take the practice test home to study with, but I can't take the computer.
13. Sometimes the answers get too confusing.
14. They were a bit confusing they're were too many ideas compacted on the screen you got a bit confused a what to do.
15. Nothing.
16. I don't really like multiple choice tests for chem.
17. Unfortunately, the tests do take up a lot of time that I don't feel is needed. Computers may be the "newest wave" but they don't play, or need to, that big a role in students lives.
18. Sometimes there not like the real test we have.
19. I don't like waiting for the computer as it goes from one screen to another and I also dislike the errors the computers can make.
20. Sometimes you don't get enough instruction and just end up guessing on questions.
21. Well they don't really explain the answers, if you got it wrong.
22. It seems that sometimes the wording used is different than we have been taught.
23. Sometimes the questions are too easy and often the tests are boring to do.
24. It takes a really long time to finish the practice test.
25. You don't always do the work and can start guessing.
26. It gets kind of boring, but all tests do that.
27. The errors in the program.
28. You can't go back and fix a problem if you get it wrong.

29. They're very long. It's difficult to write down all questions I don't understand and complete the test in time.
30. It gets a bit tiring staring at the screen, as they are quite long. It's hard to do the work in your head and some questions are hard to figure out as they are worded differently to our worksheets. Overall, I like doing them.
31. There are several people at each computer, so the person with the mouse might do the test at their own speed, and not allow the other people time to figure out the answer.
32. -
33. I like them. They make me think. The only problem is that sometimes the computers have the wrong answers.
34. There too long.

2. Simulations:

a) What do you like about simulations?

1. It shows you what is happening to e.g. the atom etc.
2. That we get to work on the computers.
3. It allows us to actually do experiments without all the clean up and without having incorrect data. They present info in a different way.
4. The simulations would be helpful if ... WE KNEW WHAT WAS GOING ON!
5. We don't have to do the work. We can see stuff that wouldn't be able to be shown in class.
6. Like experiments.
7. They were interesting at times. Most of the time its fun.
8. You get hands-on experience in the stuff you are studying at the time and they're the most fun part of chem.
9. They oughta rename it stimulation.
10. They are interesting.
11. -
12. I am a visual learner, so seeing diagrams and things on the computer helps me much more than always taking notes.
13. Animation.
14. They showed you what happened in actuality which you can't get from a drawing.
15. No equipment is needed to do these labs. No clean up either.
16. If you don't understand a concept from the notes you can get a better understanding of it when you see it in action.
17. They are a gam, only your actually learning something. New concepts bring experiments to life so the students can actually witness what the inventor was doing.
18. -
19. I like the fact that we don't need to set up or clean up with the simulations.
20. No mess.
21. That it wasn't a hard topic.
22. Try different things, that we can't do with experiments like make thing bigger or smaller and are the effects to what happens.
23. I like actually doing something to learn about a topic rather than taking notes.
24. It takes you step by step and it'll be easier to find out if you did something wrong or not.
25. No clean up or dangers.
26. It's fast and easy if you understand what to do.
27. Learning without knowing it.
28. You get to work with your friends and they are really easy to do because you just click the button and the computer does your work.
29. They show visual representations. They are usually correct. Computers are fun to use.
30. The programs are neat to watch and its colorful.

31. Computer simulations aide in teaching abstract ideas, like Quantum Mechanics, or in showing an alpha particle being deflected off of the nucleus of an atom. These are things that are difficult to show with real atoms, as they are microscopic.
32. They're interesting and able to "visually" learn things.
33. It gets us more used to computers. Something that students definitely need to start doing to prepare for the future.
34. I like them.

b) What do you not like about simulations?

1. You don't get to the work , after I'm done one I'm usually more confused then when I started. They take a very long time and some instructions are hard to understand.
2. Questions sometimes hard to understand. Too much work.
3. Nothing.
4. I found that I didn't understand most of the time while I was on the computer and it would have helped if we would have learned it in class first and then saw the simulations to go with the class lesson!
5. No hands on. Drawings not always clear/precise.
6. Take all class.
7. Sometimes a little confusing.
8. Not enough of them.
9. The name.
10. They are too confusing.
11. They take forever. They don't teach anything. Computers can't explain things or answer your questions. Very difficult to understand what your steps mean when shown on the computer. Usually the info is not on tests.
12. The computers run too slow.
13. Takes to long and slow.
14. They were pretty good! No faults.
15. They're boring compared to an actual lab. Also it takes too long to do (computers are too slow).
16. Sometimes the sheets that go with them are complicated and we don't understand the questions.
17. There really isn't anything wrong with them but, depending on the topic, they can be quite boring. A lot of students would say it is not important because we already know about the topic in full detail.
18. There hard, seem complex. Go more into detail of what to do.
19. I dislike the slow procedures we have to go through to get one simple answer.
20. They take too long. They're too difficult to understand. They're not as fun as real labs. (No hands on experience)
21. The test because it was to hard.
22. They can be very difficult if you don't understand what you are trying to observe.
23. They take too long to do and after a while they get boring.
24. We're not able to watch the real stuff; what happens for real when you mix 2 chemicals whether they blow up or not.
25. Not fun or realistic compared to real thing don't get a good feel for it.
26. Sometimes I get confused if I'm not sure what I'm doing.
27. The time they take and the lack of helpful information in them when I don't understand them.
28. I don't always understand all the questions so sometimes I get frustrated.
29. Labs are more fun to do yourself (if the simulation is possible to do). They are long.
30. I don't really understand them all the time, and I don't really learn much from them. They drag on so long that I can't focus in the end.

31. Sometimes the computer seems slow, and it is tedious waiting for the computer to switch to the next simulation.
32. They're very lengthy and often you need to rush through it.
33. Sometimes I don't completely grasp what is happening. I might understand it better if I actually see it in front of me.
34. Too confusing.

Other Comments (please feel free to use the other side of this sheet)

1. I think sometimes we go through a subject too fast and nobody understand. Then when we finally start to understand you start something new so we get all confused again.
2. -
3. I liked working on the computers because it allowed me to use different programs and familiarize myself with the info on the computer at the same time.
4. I found the tests good and the simulations a waste of time and I would have rather done notes for the whole test!
5. I enjoy the computers but sometimes become frustrated because the computers don't explain as well as the teacher sometimes does.
6. Not a Habs fan.
7. -
8. None.
9. Pick a real hockey team.
10. -
11. -
12. -
13. -
14. -
15. -
16. I think using the computers to learn is a good idea because it prepares us for later in life i.e. university, workplace, where the use of computers is more common.
17. I have to admit this is a clever, active way for students to enjoy learning in a new way, as well as give them a chance to adapt to new technology.
18. -
19. I think computers in the lab is an excellent idea! If you can cut out the few flaws, it will be even better! Keep working at it!
20. -
21. -
22. -
23. -
24. -
25. Heavy homework load in this course. Kind of unstructured but a fun course.
26. I want to blow things up, and do more experiments.
27. -
28. -
29. Practice tests are appreciated very much on the computer, because I feel they prepare me the most for a test. The best simulation was 2A Atomic Structure!!
30. I like your class!
31. -
32. -
33. I think Mr. Hutchinson's course is challenging but not too challenging. I just wish I had a better mark. I like to be challenged.
34. Tests are too hard.

Over this course, we have used a variety of activities. I would like you to comment on the use of some providing me with your opinion of their effectiveness. Please be as specific as possible:

1. MBL Labs (using computers and probes e.g. pH probe):

a) What do you like about MBL Labs?

1. I like the fact that when you use the computer for labs, it copies the data for you and organizes it (graphs).
2. They're not that hard to do and we learn about the pH.
3. The computers make for easier data collection and clearer graphs.
4. It is good for the experience to learn about the current technology.
5. I like using the computers and the lab equipment for some hands-on experience for university.
6. The experience. You get to have more experience in how computer labs works. it is probably the basic experiences needed before heading off to University/College.
7. The graphs are made for you on the computer instead of writing them by hand.
8. It helps to understand the material a bit more.
9. It's a break from notes and working hard. it helps me understand.
10. Its easy to do and set up. you can learn by seeing different ways of presenting data.
11. They allow the labs to progress quickly, and you can see what is happening on-screen.
12. They give us an idea and a better understanding of what the unit is about.
13. I enjoy the computer labs because we learn to use technology to help us analyze reactions and see further into what happens in the reactions.
14. I think these are good because we learn how to use probes and so forth. It might help in our further chem classes in university.
15. I could see the graphs of what we do I the lab.
16. It was good and learning new thing that how graphs works.
17. It is convenient doing a kind of complex lab.
18. I like to calibrate the pH probe.
19. Not much ... I don't know how to use them. They are confusing.
20. Nothing, I don't learn anything. If anything, it's better than just taking notes all day.
21. It's fun to calibrate the pH probe.

b) What do you not like about MBL Labs?

1. It sometimes gets confusing. Instructions. And it's picky.
2. They take a lot of time for such small results.
3. I find them rushed which creates a lot of error and frustration and also leaves little time to absorb and understand the info.
4. I don't think we have enough time to absorb all the knowledge, we are rushed for time and doing them with the computer we don't learn anything, we just push keys and measure amounts.
5. I don't learn as much because we are rushed through the lab and can't grasp material before we hand it in and move on.
6. It is not easy to understand. not everyone have a good understanding of computer backgrounds.
7. Confusing. Instructions too long.
8. Take a long time to set up. Some are too long.
9. Slightly confusing. More help is needed so we wouldn't get stuck on one thing for half an hour!
10. Not given enough time to complete the labs.
11. Complicated, unintuitive program, difficult calibration procedure.
12. The calibration of the sensor.

13. I do not like the fact that some of these are very lengthy labs. And the set up takes much longer than the lab itself.
14. I like to be given more direction in these labs.
15. If we mess up once, we have to do the whole thing over again. I hate that part.
16. I think the lab is mostly like challenging and I did not like when you have to measure the solution and didn't know how much to use it.
17. Sometimes I don't understand how to use the computer, (can't find a right button on screen). I am not used to use the computer for lab.
18. Everything else.
19. Everything! I don't like them.
20. I don't learn anything. I constantly get frustrated and its hard to get teacher's help when everyone else always needs help.
21. They are hard.

2. Practice Tests on Computers:

a) What do you like about doing practice tests on computers?

1. I think the practice test are really useful. I like how you have the exact same question from practice test on the real test.
2. They give me an idea of how hard the real test will be. It lets me know how much studying I need to do.
3. It is a nice review before the test so you know what you understand and what you need to work on.
4. They use to be quite helpful and prepared us for the test on each unit. You can test your ability and see what you need to work on.
5. I think they're a great idea. the questions are worded differently than the worksheets so we got used to the language they use. It gives us a good idea of what to expect on the test and the results show it.
6. It gives you a greater view in how tests are like. this also can test your ability/knowledge/understanding after you learnt the topic. If you seem to have wrong answers on that certain types of questions, you would know you need to go over notes/seek help.
7. Get you ready for the real exam. Easy to use. Answers immediate.
8. Some of the questions are on the test. It gives you an idea of what M/C will be like on the test.
9. Very helpful. Helps me understand calculations. Prepares lots for the test.
10. Very good way of learning and discovering types of questions that are going to be on the test.
11. The questions are good, and they reflect the type of questions seen on tests. feedback is immediate.
12. It gives us a look at some of the questions that are reworded differently. Some of the questions require a bit of different thinking. We also get enough time to do them.
13. I enjoy these tests because it helps you predict what the actual test will be like, and prepares you for the types of questions that will be asked.
14. I feel that these help in our tests.
15. I love doing practice tests on computers because we get the idea that how's the real test going to be look like.
16. It gives me an idea what will be like on test and how much I know already without looking at the notes, my knowledge.
17. I can expect that how do a real exam look like, so I can prepare for the test little better than nothing.
18. It gives you an idea about what will be on the real test.
19. It's good. They are kind of helpful but not really when there are lots of errors.
20. They're good, and I like them; they help.
21. They help me prepare for the exams a lot!

b) What do you not like about doing practice tests on computers?

1. Sometimes the answers are wrong and I get confused on how to do it.
2. Sometimes the real test is harder than the practice test.
3. The time I waste on questions with no correct answers.
4. They use to reflect the test we were about to have, the last practice quiz wasn't useful at all. it really did not prepare us for the exam. Also, all the mistakes confuse me about how actually to do the questions cause I won't know how to do them on the Exam if the answers are wrong.
5. The only problem is that there are a lot of mistakes so we stalled trying to figure out what we were done wrong when we're completely right, and its frustrating.
6. Can't think of any.
7. -
8. There are those questions that don't work, therefore it becomes a hassle (don't know how many more don't work).
9. Long ones take a lot of time and sometimes we don't have time to finish them. lots of mistakes.
10. Too many mistakes.
11. There are so many mistakes in the test that completing is painful and difficult.
12. Annoying errors.
13. I do not like the fact that it doesn't show you the calculations, if you get it wrong and therefore you cannot learn your mistake.
14. They are basic questions. We should get provincially examinable questions on them, so it can help us on tests and our provincials e.g. Acid-Base Test.
15. There's nothing I don't like about doing practice tests on computers.
16. The things that is not going to be on the test and you study for wrong subject.
17. From the Acid and Base test, I think the practice tests was useless, because it was totally different from real exam.
18. When questions are wrong.
19. They are no where near what the tests look like.
20. They're nothing like the real tests. I find the practice ones always way easier than the real tests. There's no point preparing us using computer if it's not going to be on tests.
21. Nothing.

3. Simulations:

a) What do you like about simulations?

1. It's easy. you don't have to do the experiments yourself.
2. We don't have to think all class. We usually get 9 or 9 1/2 out of 10.
3. Not a whole heck of a lot.
4. N/A
5. You get to use the computers and you can see what's going on with the little "reacting clips".
6. Makes you think.
7. Graphs made up easily.
8. Helps you to understand new concepts. Nice way to spend whole class if varied. Some are a bit long.
9. Very stimulating!! Good waste of time. (just joking) Seriously, help me understand (really)!
10. Take up a lot of class time.
11. Very little.
12. Nothing actually I like the fact that we don't really have to think. Its just point and click then take down the answer.

13. I think the simulations do a great job teaching you a new concept.
14. I like that they start you off to a new concept and you have to discover it yourself through the procedures.
15. We don't have to do any calculations.
16. It gives me information about how it's going to work and the calculations.
17. ?
18. No lab clean-up and not having homework for the next day.
19. Nothing! They aren't hands on at all.
20. Nothing.
21. They take up time and we don't have homework the next day.

b) What do you not like about simulations?

1. Time. I find that we rush through them to finish it, but don't process it.
2. We don't learn anything.
3. They too are rushed and nothing is learned. I just do what it says and get it done.
4. There is no time, I understand that we are on semesters, that everything is rushed, but computer simulations take too long to do them properly and I feel as though nothing is learned when they are completed.
5. I don't learn with them because, again, we are rushed through them and can't grasp the material before we move on.
6. Makes you think, but not getting the right idea. Simulations does not display the correct answers so you don't know if what you are answering is right or not.
7. Everything else.
8. They become repetitious. monotonous.
9. If something is unclear, the computer can't help us.
10. The computer does all the work and you copy down numbers making it very hard to understand.
11. The simulations are not interactive, they are poorly constructed, they fail to teach the material, they are slow, they are ugly.
12. Everything. Specifically it doesn't help me better understand the concepts in the unit.
13. I do not like the paperwork, and compiling information. It would be better to just go through it and pick up key concepts.
14. -
15. They are always very long simulations.
16. It takes a lot of time and they are very long.
17. I don't like to use a computer.
18. Everything else.
19. We don't learn anything.
20. I don't learn a thing. All I do is use a mouse and it's SO boring. I hate them and they're a complete waste of time. They teach nothing!
21. I don't get what they're teaching sometimes.

Other Comments (please feel free to use the other side of this sheet)

1. I really don't care either way whether we use them or not. I don't mind them, but I don't love them.
2. -
3. -
4. N/A
5. -
6. -
7. -
8. -

9. Rushing through CHEM 12 very quickly! Hard to follow, but understand you have curriculum to follow.
10. -
11. The MBL labs and practice tests are wonderful, albeit with small flaws. The simulations are horrible, and should be put out of their misery.
12. -
13. -
14. -
15. -
16. -
17. Chemistry is getting harder and harder for me. These days, I can not fully understand the explanations. I hope that you can slow down the lessons a little bit.
18. -
19. -
20. -
21. -

