Technology Implementation and Integration from the Experience of TESSI Science Teachers

Towards a Conceptual and Practical Framework for Understanding and Implementing Technology Integration

by

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ABSTRACT

There is a quiet technological revolution occurring in education today. Technology has helped catalyze new forms of teaching and learning. As technology is infused into the existing educational culture, there is a realization that the nature of technology integration into education consists of complex change processes. This qualitative multi-case study examines what teachers perceive as the issues in technology integration and the negotiation by teachers through these issues. This study reveals the experiences and perspectives of Physics, Chemistry, and Biology teachers at different stages of technology integration in the Technology Enhanced Secondary Science Instruction (TESSI) project, a longitudinal, collaborative, field-based research and development program of technology integration into government-mandated secondary school science courses. The progression of conceptual and practical issues in technology integration, and the interplay among these issues in relation to teachers, students, curriculum and the supporting infrastructure are analyzed. Conceptions of pedagogy and praxis, multiple change processes, student learning strategies and outcomes emerging from this study are synthesized to generate a general framework for innovative technology integration and to inform the research and development of the Technology Enhanced Instruction (TEI) model of technology integration.

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CHAPTER 1 -- INTRODUCTION

Since the publication of two experiments using microcomputer-based labs (MBLs) which demonstrated enhanced understanding of motion graphs by secondary students a decade ago (Brasell, 1987; Mokros & Tinker, 1987), many science teachers have been inspired to introduce advanced technology into their classrooms. Technology has become a keyword in educational reform, especially in science and mathematics education (e.g. Linn, diSessa, Pea, & Songer, 1994; Jonassen, 1995; Knapp & Glenn, 1996). But what does it really mean to implement and integrate technology into the classroom?

1. Background

1.1 A Teachers' Perspective Towards Implementation and Integration of Technology

What exactly is technology implementation and integration? What does it look like? Does technology integration mean building entirely new, technologically laden schools such as Townview in Dallas, Texas (Watson, 1996)? Does it mean, as Niederhauser (1996) describes, "students [using] the Internet to access information, a graphics package to prepare diagrams and charts, a spreadsheet to organize data collected through erosion experiments ... a word processor to organize and present textual information, and a multimedia tool to prepare the final report"? Does it mean providing technological resources and access to high tech tools for students? On one level, teachers have to deal with the day-to-day technology-related problems of time, space, supervision, and access (Hadley & Sheingold, 1993). These technology management issues are what some teachers see as the common issues of "integration". On another level, technology implementation and integration involves effectively using the best available resources to achieve curriculum outcomes, and may involve personal changes in beliefs and pedagogy (Woodrow, Mayer-Smith, & Pedretti, 1996; Dwyer, Ringstaff & Sandholtz, 1991). For teachers involved only in limited technology integration, a central, recurring and often studied issue is the impact of conditional factors: hardware and software acquisition, knowledge prerequisites, and time requirements (e.g. Brummelhuis & Plomp, 1993). False starts in technological implementations resulting from a lack of concern with professional development and teacher roles -- the human factors (Kimmel & Deek, 1996) -- can be costly endeavours in money and time.

This study defines technology integration as the development of the conceptual and practical processes in appropriating technological tools into pedagogy and classrooms. What are the critical teacher beliefs and conceptions that develop in technology-rich science classroom environments? How do these beliefs and conceptions change as teachers work in non-typical, technologically-rich classrooms with the goal to fully integrate the technology where it can enhance science teaching and learning? Beliefs and conceptions are the human factors that may represent the true challenge to technological integration.

1.2 The Technology Enhanced Secondary Instruction (TESSI) Project

The Technology Enhanced Secondary Science Instruction Project (TESSI) was conceived as an attempt to formulate a working model of how technology might be integrated into secondary science classrooms to meet the needs of established curriculum using state-of-the-art technology. The bulk of the technology integration has been focused in senior level Physics, Biology and Chemistry. TESSI had its beginnings as the Technology Enhanced Physics Instruction (TEPI) Project in 1992. Introduction of the TESSI project into secondary Biology classrooms followed almost four years later, and introduction to Chemistry classrooms began in 1997. According to Woodrow, Mayer-Smith, & Pedretti (1997),

> *The design of the TESSI model is guided by three important principles:*
> - *hardware/software must function within a model which produces measurable enrichment of learning;*
> - *communication among the participating classroom teachers and researchers must be frequent, and implementation must be sustained; and*
> - *students must perceive their teacher's and their own use of technology as integral parts of the normal classroom, rather than as an "add-on" feature.*

As an active, longitudinal technology integration research and development project in secondary science education, TESSI appears to be unique in North America in many ways because of its emphasis on the combination of:

1) a senior-level secondary science focus;

2) a multiple science subject focus: Physics, Biology, and Chemistry;
3) *open development* primarily from the perspective of practising science teachers (working in collaboration with researchers);
4) integration into the *existing, mandated* curriculum;
5) consideration of the "enhancement principle": technology is utilized if it demonstrates its value to *enhance and not replace* effective teaching and learning methods;
6) considerations to practical concerns for teachers and students – e.g., a small number of computers (8-12) that are immediately accessible and the use of commercially available software;
7) incorporation of a comprehensive range of the latest and / or `best' technological components, including:
    - microcomputer-based labs (MBLs),
    - simulations,
    - interactive testing,
    - laser discs, videos, CD-ROMs and other multimedia resources,
    - presentation systems,
    - local-area networks (LANs),
    - World Wide Web (WWW), and
    - teacher applications: remote access administration systems (RAS), network management (including video distribution, central monitoring).

TESSI teachers teach the mandated curriculum using the methods of Technology Enhanced Instruction (TEI). TEI involves teaching the curriculum with the most efficacious technology available whether it be the latest in computer applications or the traditional blackboard. However, TEI is not merely a different pedagogical delivery method to achieve what existing teachers feel they have been competently achieving for some time. Regardless of the apparent levels of achievement through traditional methods and evaluation, technology can be and should be used to do more than what traditional learning has offered. The database of all disciplines is becoming so vast that only students with a broad number of higher order skills will be capable of successfully navigating the opportunities for learning in the 21st century. For example, the use of sophisticated computer simulations was indispensable to getting the Pathfinder to Mars and assembling and flying the Boeing 777. Students' learning must incorporate similar, sophisticated simulation software. Computer technology is here to stay. Teachers have no option but to learn how to integrate chalkboard and keyboard. Teachers must take the leading edge in equipping society in the technological age.

2. Problem

The focus of this study is what teachers perceive as the issues in technology implementation and integration, and the progression of teachers through these issues. This study examines the experiences and perspectives toward technology implementation and integration into government-mandated, secondary school science courses of Physics, Chemistry, and Biology teachers with different levels of technological expertise, at different stages of technology integration in the Technology Enhanced Secondary Science Instruction (TESSI) project.

Specifically, this study examines the conceptual themes, the accompanying practical issues, and the interplay among these issues in relation to implementation and integration concerns in terms of curriculum development, technological roles, teacher roles, and student roles from the perspective of the teachers. The research problem is thus explored from both a conceptual and a practical process approach in a qualitative, multi-case study. Hopefully, this study of teachers' conceptions, approaches and rationales can be used to inform the development of technology integration models into science education, providing a framework for technology implementation and integration for future innovations in the field of educational technology.

3. Research Questions

The following questions, answered from the perspective of the TESSI science teachers, will be used to guide the study:

1) What are TESSI teachers' conceptions about teaching and learning with technology in science? (The positives, negatives, limitations and unforeseen)
2) What are the technology implementation and integration processes, issues, problems and recurring themes in the TESSI teachers' experiences?

3) What are the interacting conceptual and practical factors which are incorporated by teachers in developing approaches to technology implementation and integration into science teaching?
4) How have the conceptions and experiences of technology integration changed and been reconstructed by TESSI teachers over the course of innovative technology integration?

4. Significance of the Study

4.1 Research Evidence on Technology Integration

Solid research in the area of technology integration in education has been limited for many reasons. One reason is the rapidly evolving nature of technologies. It is difficult to assess something which changes faster than some research articles can be published—when software or whole technologies that were hailed as the dominant form three or four years ago are now found only in those places which initially embraced them. Relegated to a historical status role and acting as signposts to say how things have progressed, studies of technologies are constantly being eclipsed by more recent or more effective ones.

The nature of technology integration studies is another reason why research in this field has been limited. The two main types of studies that have dominated this field are those that consist of:

1) small-scale case studies into the use of a particular technology, which usually entail a description of a technology, its effects on teaching or learning, or some combination thereof (e.g. Nakhleh, 1994; Wisnudel, 1994), and
2) large scale, survey-type studies (e.g.; Becker 1991, 1992; Hadley & Sheingold, 1993) which usually identify trends in applications of hardware or software resources, general attitudes, barriers and incentives.

While the first type of study may give insights into the classroom practices, learning activities, student attitudes, cognition, and other specific examples of the use of an exceptional technology, they have often been unable to provide a broader picture of technology within a teaching field such as the high school sciences. This type of research also represents situations that are often unique and cannot be easily replicated. The strength of small-scale research studies, though, is in providing a rich description of the interacting forces that may be present within a given context. The second type of study, large-scale surveys, provides limited details and usually confirms the continuing entry-level type of problems that plague technology integration in education, partly because relatively few sites have achieved a high and effective integration of technology. Thus, given the complexity of technology integration, there is a need to investigate technology integration across more cases and in more detail. As Hadley and Sheingold (1993, p-263) put it:

> *For the most part, the "quick fix" beliefs that heralded the incorporation of personal computers into schools more than a decade ago have been appropriately given up, as it has become clear that technology's impact is slow in coming, challenging to assess, and a function of, among other factors, how it is interpreted and used. What we need to understand, then, is the complex of circumstances that surround the use and incorporation of technologies over many different examples, and how these are related to a variety of outcomes that are of interest.*

For the high school science disciplines, research into technology integration is needed to help develop successful models of technology integration to prepare our teachers and students for teaching and learning in the 21st century.

More comprehensive research and development projects into technology implementation and integration such as those distinguished by the Apple Classrooms of Tomorrow (ACOT) project (Dwyer et al. 1991; Fisher, Dwyer, & Yocam, 1996) and the Technology Enhanced Physics Instruction project (Woodrow et al., 1996) have been providing a balance between the detailed complexities of small scale studies and the breadth of implementation and integration experiences of survey-type studies. Although the ACOT and TESSI projects represent the standards of intensive implementations over several years, with unusual efforts and resources that may not be easily replicated, they may provide the type of research and development that is required to inform teachers, developers, administrators and researchers alike about the forms of technology integration in future classrooms.

4.2 The TESSI Context

Within TESSI, implementation of a Physics model (TEPI) has been described in terms of changes in pedagogical beliefs and practices (Woodrow et al., 1996) and the collaborative practice between the two physics teachers and university researcher (Mayer-Smith, Pedretti, & Woodrow, 1998b). However, there has been no study undertaken to examine the cross-section of teachers currently involved in the project, or their experiences and conceptions of the implementation and integration process.

Among the entire group of TESSI teachers, there appears to be no clearly stated perspective or model of how integration will actually occur throughout the project, despite the success of the Physics integration (TEPI). The Biology group of TESSI teachers is still early in implementation (three years), and the Chemistry group of TESSI teacher is two years into implementation for most members. Among the subject areas of secondary Physics, Chemistry, and Biology, there may be differences in implementation and integration approaches or procedures due to the nature of the curriculum and the teachers involved. If these differences exist, what exactly are these differences? Just as there may be differences in approach, there may be some common threads among the subject areas and teachers such as in the development and resolution of technical and curriculum concerns.

The representation from the three science disciplines (Biology, Chemistry and Physics), the potentially different stages of technology implementation and integration, the unique set of features of TESSI, and the number of sites, provides a rich cross-section of perspectives in which to situate this study. This study also acknowledges and draws upon the personal involvement of the researcher, as one of the project teachers in the TESSI project, to provide "insider" knowledge on the progress of the study.

CHAPTER 2: LITERATURE REVIEW

This chapter provides a summary of the research literature pertinent to this study of technology implementation in the science classroom. Sections one and two introduce the studies that have been done on various aspects of technology use in education, especially science education. Section three discusses some of the potential complexities associated with the technology integration process. Section four describes research from two exemplary, intensive technology integration projects: the Apple Classrooms of Tomorrow (ACOT) and the Technology Enhanced Secondary Science Instruction (TESSI) projects. Finally, section five discusses teachers' conceptions of innovation, change and teaching.

1. Technologies for Science Classrooms

In science education, the bulk of research into the uses of educational technology has dealt with applications of technology in specialized situations or in discrete tasks (Nakhleh, 1994). In this section, some studies of the main varieties of technologies used in science education will be reviewed.

1.1 Microcomputer Based Laboratories

Although currently the use of technologies in science education is diverse and eclectic, technology-rich science classrooms were traditionally equated with the use of microcomputer-based laboratories (MBLs). In MBLs, students collect data about a physical system using computer interfaces and a sensor (such as a pH or temperature probe), convert these data into graphical format in approximately real-time, then analyze and present this information in reports processed on computers (Nakhleh, 1983; Mokros & Tinker, 1987). The potential learning benefits and problems of MBLs have been thoroughly discussed over the last decade (Nakhleh, 1994).

In a very definitive MBL study, Brasell (1987) demonstrated how a brief treatment with a typical MBL kinematics unit affects students' ability to translate between a physical event and the graphic representation of it. In effect, Brassel demonstrated how real-time graphing by a computer interface -- as opposed to delayed graphing by the computer -- affected students' understanding of distance and velocity graphs.

Using a pre-test / post-test experimental design, Brasell showed that the standard MBL exercises had a strong positive effect on achievement for distance graphing, and a non-significant effect on achievement for velocity graphing. One of the most interesting findings of this study was that the control group, where a 20-second delay from the moment of data acquisition to the moment of graphing was set-up, showed a clear reduction of the positive effect of the MBL exercise. Brasell (1987) hypothesised real-time MBL had two effects on students: increased motivation for remembering the data-generating event when using MBL, and less demand on students' memory for processing and maintaining information about the data-generating event because the technology handled the data recording. Despite this study's limited treatment time span and the fact that the experiment was conducted with students who were among the higher-achieving students in the school, Brasell's analysis was useful in providing empirical evidence of the power of MBL to enhance student achievement.

Studies on graphing have had some mixed results in different situations and for different topics (Nakhleh, 1994). For example, in a secondary school investigation of heat and temperature, Adams and Shrum (1990) reported no significant differences between MBL and control students on cognitive level graph interpretation or graph construction, while Linn, Layman and Nachmias (1987) noted that middle school students, (using a heat-flow model of temperature as opposed to classical thermodynamic definitions) improved in interpreting graphs and acquiring temperature concepts. Why are there so many discrepancies? Obviously, there are more variables involved in these studies than simply the effect of MBL on students.

The overall effectiveness of MBL may depend on teachers who attempt to implement MBL -- their understanding of MBL techniques, their knowledge of the processes involved, and how they help students to link their experiences with the concepts. The students themselves may exhibit learning processes that are unexpected. For example, in a chemistry version of MBL and graphing, Nakhleh and Krajcik (1993) studied secondary students' thoughts during acid-base titrations using three different methods of data collection: MBL, pH meter, and chemical indicators. They found that students using MBL focused their observations exclusively on the emerging graph, while students using a pH meter or chemical indicator focused less effectively on a variety of phenomena, such as colour, bubbles, rate of change of the meter needle, etc. Nakhleh and Krajcik (1993) reported that students using MBL used more analytical thought processes as noted by the number of verbalizations, and through evaluations of concept maps.

Much of the current research literature on MBL reports work done in elementary and middle schools or in specialized college settings with few investigations at the senior secondary level. Many of the studies reviewed here concentrate on the graphs produced by MBL and/or how well students could construct or interpret those graphs. The bulk of the remaining research studies with MBL have focused on individual aspects of software which may help students accomplish tasks in a new way (e.g. Dori, 1995), the use of individual computer interface probes, the use of computer assisted protocols (e.g. Nakhleh & Krajcik, 1993), and student understanding of isolated concepts (e.g. Dori & Yochim, 1994; Thornton & Sokoloff, 1990; Lazarowitz & Huppert, 1993). Some student attitudes and performance on specified tasks were noted in many of these studies and there is evidence that student understanding (not just in interpretation of graphs) and attitudes towards science classes can be enhanced through the use of MBL (Stratford & Finkel, 1996).

1.2 Simulations for Science Education

A second major type of technology used in science classrooms is simulation, originally called "microworlds," as associated with Papert (1980). This type of technology models a real-world system, though it may be abstract, and allows the user to control and experiment with the variables of that system and see the results of this manipulation (Lewis & Linn, 1993; Richards, Barowy, & Levin, 1992; Snir, Smith & Grosslight, 1993). Simulations can also, in effect, replace real-world systems, such as the anatomy of a frog for dissections (Kinzie, Strauss, & Foss, 1993; Akpan & Andre, 1999). What is considered a "simulation" is diverse in the research literature, as simulations may also include a combination of graphs, spreadsheets, diagrammatic views, scripting, video motion, and other interactive tools.

The potential of simulations to enhance learning is usually associated with the conceptual and real-world bridging that is possible through manipulative exploration of a microworld (Richards et al., 1992). Studies in this area usually emphasize descriptive outcomes. The results have been mixed. For example, in a pre/post-test study of simulations for use in the Computer as a Lab Partner project, Lewis and Linn (1994) describe how middle school students increased their ability to distinguish between heat energy and temperature, to better generalize the concepts of insulation and conduction, and to explain naturally occurring phenomena. Lewis and Linn (1994) did not just utilize simulations, however. Students also used an `electronic notebook' to keep track of their data and learning -- and perhaps this notebook enhanced learning on its own by reducing the cognitive load on students, allowing them focus more on the results of their learning.

A study by Roth, Woszczyna and Smith (1996) found that simulations could help coordinate and maintain students' conversations about the subject matter, in this case, Physics. However, they also found that a significant number of students had a lot of trouble because they needed to spend extensive time learning the software thus resulting in less time learning Physics. This study suggests that students need time to become familiar with the sometimes-complex simulation interfaces (or poorly designed interfaces) before they garner the benefits of the learning environment, and that successful learning may be a function of interface design.

1.3 Other Advanced Technologies for Science Education

A growing area of computer use is the use of computers for assessment in a variety of ways that goes beyond the conventional record keeping, analysis and managing of test banks. For example, it is possible to have: a) multimedia interactive testing (Woodrow, Mayer-Smith, & Pedretti, 1998), b) figural responses where students draw the solution such as an organic compound (Martinez, 1993), or c) open-ended constructed-response testing which allows students to present their solutions within a set standard deviation for full or part marks (Singley & Taft, 1995). In their analysis of trends in computer applications in science assessment, Kumar and Helgeson (1995) suggest a trend towards testing process or performance instead of product. For example, they suggest that "solution-pathway analysis" testing, where a student can take multiple pathways, may become important and more prevalent in the future.

Another growing area of educational technology research and use is hypermedia, where studies like that of Barba and Armstrong (1992) have suggested that the use of hypermedia and interactive video may be an appropriate instructional medium for students who have traditionally experienced learning difficulties due to their inability to process highly verbal material. The true power of hypermedia may rest in the non-linear construction of learning and/or expression of concepts that this technology makes possible (Wisnudel, 1994; Beichner, 1994; Briano & Midoro, 1998). The popular World Wide Web has combined hypermedia and multimedia to take computer research and telecommunications to another level as seen in the Scardamalia and Bereiter's (1996) development of CSILE (Computer-Supported Intentional Learning Environments) and WebCSILE. The CoVis (Collaborative Visualization) project (Edelson, Pea & Gomez, 1996; Gordin, Polman, & Pea, 1994) and the GLOBE environmental study (Finarelli, 1998) are examples of using hypermedia technologies to link remote scientists and classrooms to create virtual scientific communities.

The links between traditional applications of technology such as word processors, presentation tools, graphical tools, databases, multimedia, and spreadsheets, (e.g. Hestenes, 1992; Trumper, 1994) and student learning in the science classroom have also been explored, but such technologies generally have had a low profile in science classrooms. When considering the development of technology integrated classrooms, studies of the roles that the various technologies play in relation to each other as well as in relation to the overall pedagogical and instructional environment may be warranted, but these have not been forthcoming.

Many studies of the use of technology in science classrooms are primarily exploratory and descriptive in nature simply because the technology is moving faster than researchers can possibly keep up. The full impact of these technologies is rarely assessed. Much of the software is also unique or prototypical. Using a variety of technologies in a science classroom can be challenging since the roles that the different technologies play pedagogically may need to be clarified. This sample of studies of technologies used in science education illustrates the potentials and the problems that might be encountered in the immersive integration of technology into science classrooms.

2. Educational Technology

General educational technology or technology-based education (TBE[1]) has traditionally been distinguished by two main formats: computer-assisted instruction (CAI), generally referring to drill-and-practice software or tutorials; and computer-

[1] I apologize for the extensive use of acronyms, however it is representative and plagues this field of research. I believe this problem has its roots in two things: the multiple evolving perspectives of technology in education, and the propagation of new terms by reviewers.

managed instruction (CMI), generally referring to computer evaluation of student performance, guiding students to appropriate record keeping, and computer-simulated experimentation. A third form of educational technology use that has emerged in the last seven years is commonly called computer-enhanced instruction (CEI) or technology-enhanced instruction (TEI). As a focus of this study, TEI will be discussed in detail later in this chapter.

2.1 Historical Meta-analysis on the Effect of Technology Based Science Education

In a comprehensive review of the effects of technology based education (TBE) on learning from 1980-1987, Roblyer, Castine & King (1988) noted three general trends that emerged from their meta-analysis which are still reported and important today:

1) Attitudes toward school and self were significantly and positively affected by TBE in three quantitative studies (and were qualitatively noted in most other studies).
2) TBE was found to be effective in increasing achievement levels of treatment groups over those of control groups in subject areas of mathematics, reading/language and science.
3) Results from the analysis of the type of TBE application that was most effective at increasing achievement were statistically incomparable and thus inconclusive, although simulations studies generally demonstrated larger effect sizes than other applications.

It must be noted that the findings in the area of science are from research done on the use of simulations only, and that the researchers could only find four studies from the sciences between 1980-1987 which met their minimal criteria for studies: control & treatment groups, reporting of means and standard deviations, and lack of major methodological flaws.

In conducting a science domain specific meta-analysis, Wise (1988) located 26 studies from 1982 to 1988. Although this is still a relatively small number of quantitative studies, it was 22 more studies than Roblyer et al. (1988) used in their meta-analysis. Wise's criteria for considering what constituted TBE was not very stringent, requiring only that "teachers used microcomputers in some way to deliver science instruction" (p-107). The less stringent criteria may have accounted for the greater number of science

TBE studies used. Wise reported an average effect size[2] of 0.34 (n=51) on achievement. When he looked at the effect size of different types of TBE, he found that MBLs produced the highest average effect size of 0.76 (n=6), followed by tutorials with an average effect size of 0.40 (n=7). Similarly, all other types of TBE had effect sizes significantly (ES > 0.20) different from zero.

Both Roblyer's and Wise's meta-analyses may well summarize the research done in the nineteen-eighties and they may provide an overall average measure of how technology may affect learning in science. However, meta-analyses cannot provide detailed information indicating how individual programs affected the learning process and what specific contextual factors may be at work in which the TBE program was implemented.

2.2 Integrated Learning Systems (ILS)

Often, CAI and CMI are "packaged" together in the form of integrated learning systems (ILS) – considered by some as a convenient approach to technology integration. ILS provide information from a central source using LANs for communication within and sometimes between schools. ILS are designed upon the premise that most teachers do not have the time or ability to implement a large scale curricula integration of technology. Hence, ILS usually provide in-service training on the program's system, easy-to-use and time-saving management tools, such as those used to track student progress. More importantly, ILS are supposed to require low technical maintenance.

Traditional achievement test scores have often been reported improved through the use of ILS (Becker & Hativa, 1994; Van Dusen & Worthen, 1994; Walker, 1996), though Becker's (1992b) review of nearly 100 earlier ILS studies reported that many of these investigations have methodological flaws. In Becker's (1992a) critical review of ILS in the elementary and middle grades, he criticizes the research for omitting the environmental details in which the effects of teacher training and experience, and the classroom and school culture may have confounded the results.

[2] Meta-analysis using effect sizes (ES) are calculated by subtracting the mean score achieved by the control group by the mean score of the treatment group. The result is divided by a measure of the spread of the scores achieved, usually a pooled standard deviation (Cohen, 1977). An ES ≤ 0.2 = small effect; ES = 0.5-0.6 = medium; ES ≥ 0.8 = large.

Van Dusen and Worthen (1994) contend that while ILS have the potential to increase student achievement, the systems are often not used as intended because of such problems as limited student time on ILS. Many schools believe that, because they have a high performance ILS, they provide engaged learning and access to rich resources. The fallacy in this thinking, however, lies in the fact that ILS generally supports traditional tasks and assessments, traditional student and teacher roles, and traditional instructional approaches targeted to basic skills. The centralized resource configuration of ILS also limits their usefulness, as they are used only when the class is pulled out to visit the ILS lab. Although technically easier to implement than piecing together a number of separate technologies, ILS represents a limited form of technology integration at this point and unlikely to promote significant educational change.

3. Technology Implementation and Integration

For the purposes of this study, the terms "implementation" and "integration" will often be used somewhat interchangeably. An attempt will be made to use "technology implementation" when there is an emphasis on a first-time or start-up *event*. The term "technology integration" will generally be used to describe the *progression* towards a state of implementation where no major technological, curricular, or teaching innovation, etc. is being introduced -- but where further refinements are dependent on new, usable technological advancement or new implementations. In this working definition of technology integration, the integration process is considered to be composed of discrete implementation events. Technology integration can be viewed from different perspectives, some of which will be reviewed in this section.

3.1 Patterns of Computer Use in Schools

One of the more comprehensive survey-type studies of computer use in schools was Hadley and Sheingold's (1993) targeted survey of 608 identified "accomplished" computer-using, K-12 teachers in the United States. This survey developed a profile of the computer-using teachers by documenting their current teacher practices of using technology, rating barriers and incentives to integration, and asking what perceived changes in teaching have resulted from technology integration. In terms of classroom practice, the study found that student computer use was concentrated on creating reports, publications, or presentations in project-based learning activities, followed closely by drill-and-practice and tutorial-type instructional software. The more technologically advanced applications were not the most common due to the limited computer access and restricted computing power of the computers found in most schools surveyed.

In terms of incentives and barriers to technology integration, Hadley and Sheingold (1993) found three key factors common among teachers who were considered most accomplished in using technology:

1) the teachers demonstrated a high level of motivation and commitment to their students' learning and to their own development as teachers,
2) the teachers experienced of a high level of support from colleagues, and
3) the teachers had access to sufficient technology.

The teachers who said that computer-use has significantly changed their classrooms cite that the reasons for the changes are due to:

- higher expectations related to student work
- more and better attention to meeting the needs of individual students, and
- some shift from a teacher-centered to a student-centered classroom (as indicated by changes in a lecturing teaching style to more individual and group student work situations).

Although the most accomplished teachers surveyed may represent less than five percent of teachers in general, given the right conditions and five to six years of sustained effort, Hadley and Sheingold believe that significant changes can occur with technology-using teachers and their practices.

3.2 Technology Integration: Practical & Structural Concerns

The use of computer technologies in the average science classroom computer is still relatively limited (e.g. Hadley & Sheingold, 1993; Lehman, 1995; Germann & Barrow, 1996). In order to integrate technology, there are huge hurdles for the current educational systems to overcome. For the teacher, these hurdles may cause teachers to forego any serious adoption of technology for the classroom. The problems surrounding integration include: costs, inadequate teacher preparation, the lack of good software, lack of time and planning for learning, the piece-meal nature of computer use as opposed to full courses, and “the idea of the moment” which Bork (1995) refers to as the "plague … of one new concept after another, either new hardware, software, or new ideas." Any emphasis on technology enhancing learning can be conveniently left behind.

Administrators, especially effective principals, need to recognize that teachers need extensive training, time and support to achieve the implementation of a technology enhanced curriculum (Niederhauser, 1996). Administrative support can reduce or remove many of the barriers to implementation by providing incentives, identifying leaders, giving support to developing a technology use plan, and facilitating the availability and maintenance of technological resources (Hoffman, 1996).

3.3 Technology Integration: Rationales & Cognitive Approaches

The problems of integration are not just practical, but also theoretical in nature. One of the growth areas in any relatively new field of research is to work out a theoretical framework, derived from valuable rationales. This process has been sketchy, at best, in terms of technology integration for the sciences.

3.3.1 Rationales for Technology Integration

There are many different rationales for technology integration. There is the belief that since technology is everywhere, we should embrace it since our students will need technological skills for the future. Another rationale is the belief that technology has been shown to be effective in educational settings. However, neither the conditions for the ubiquitous use of technology in schools, nor research results have made a convincing case for a positive impact on teaching and learning by educational technology (Cuban & Kirkpatrick, 1998; Clark, 1994; Roblyer et al., 1988). On the other hand, there have been promising descriptions of the enhancement of students' learning through:

1) motivation via:

- student engagement (Sandholtz, Ringstaff & Dwyer, 1994)
- engaging the learners through creating their own technology-based products (Beichner, 1994; Briano & Midoro, 1998)

2) the unique instructional capabilities of computer technology such as:

- linking learners from distant places through email, bulletin boards or web sites
- helping learners to visualize problems & solutions (Greenberg, 1998)
- tracking learner progress on integrated learning and/or testing systems
- linking learners to information sources through hypertext (e.g. the World Wide Web) (Bartolo & Palffy-Muhoray, 1998)

3) the support for newer instructional approaches (Woodrow et al., 1996) such as:
   - cooperative learning (Brush, 1997)
   - shared or "distributed intelligence" (Polin, 1992)
   - problem-solving and higher-level skills (Wilensky & Resnik, 1999)
   - situated cognition (Choi & Hannafin, 1995)

3.3.2 Four Approaches in the Integration of Educational Technology into Science

There are four broad approaches that have been used to integrated technology that have influenced science education.

First, technology has historically been viewed as another form of media, in what Saettler (1990) calls the audiovisual movement[3]. This movement led to the development of educational theory and practice concerning the best way to use media and its messages.

Second, technology can be seen as occupational or vocational training tools. The newer form of this approach to technology in education can be called the high-tech approach. Imbedded in this perspective is the belief that the patterns of the global economy require the most industrialized nations to become high-tech, technology-literate cultures and that education should ensure that our students will have the necessary competitive, technological, and economic edge in the workplace (Hurd, 1998; Raizen, 1997). For science, the argument is that the products and processes of science -- i.e. technology -- should be learned and "applied" at the same time. Criticism of the "Applied Sciences" approach is that rather than developing a generalized understanding

[3] Although this movement began in the 1930's, Saettler reports that even as late as 1986, the National Task Force on Educational Technology used a definition that equated all educational technology, including computers, with media. This movement was made possible with the advent of film and radio media technology but it is now far too limited in dealing with the extent of technology's permeation and functions.

of the role of the new technology in industry and society, students may simply learn a new set of useful but limited skills. The cognitive aspects important in a science curriculum, for example, may become undervalued.

Third, the Science, Technology, and Society (STS) approach emphasizes the study of the impact and issues of science and technology in the context of society (Kumar & Berlin, 1998). STS courses became popular in the 1970s, and by 1990, STS courses were found in two thousand universities and colleges as well as in many high schools (Yager & Roy, 1993). Although the word "technology" may be an integral part of STS course titles, these courses are more concerned about the studying technology from a distanced, evaluative perspective rather than actually using it in any way. As an approach to technology in education, the STS approach is limited to shedding light on a few educational implications of technology. Like the high-tech approach, this approach emphasizes technology as *an object* of instruction rather than *a tool of instruction*.

Lastly, technology has been viewed as part of educational instructional design and systems. Between the 1960's through the 1980's, educational psychologists adapted behavioural learning theories and systems approaches from military and industrial training into elementary and secondary schooling (Raizen, 1997). In this approach, both people and media technology were considered parts of a greater process or system, capable of being designed and programmed to achieve a specified goal. In the 1990s, this approach has responded to criticism that is has been too rigid and limits learning, especially higher order learning. Proponents have provided two responses to this approach to the use of educational technology: the *directed-instruction* approach and the *constructivist* approach (Duffy & Jonassen, 1991).

In the directed-instruction approach, Murfin (1994), suggests that computer-mediated communication can bring about interaction between students and teacher in a "multiple electronic zone of proximal development," leading to students performing at a higher cognitive level. Based on a constructivist approach, Linn's work in the Computer as Learning Partner (CLP) project at Berkeley has spawned one of the more comprehensive working conceptual frameworks of educational technology to date. Linn applies constructivist concepts in a practical instructional context called the "Scaffolded Knowledge Integration Framework" (Linn, 1995), in which a refinement cycle of technology integration into curricula is considered from a cognitive perspective.

4. Technology Integration: TEI Models and Research

Studies on CAI, CMI, and ILS usually try to show some type of efficacy in achieving certain student outcomes, although each study may define its outcomes differently and study it in different ways. CAI, CMI and ILS, however, all de-emphasize the role of the teacher in helping students learn. CEI/TEI represents a different route of technology integration where the teacher is considered essential to the learning process. Although Cuban and Kirkpatrick (1998) question both the research and effectiveness of using technology to achieve student goals, they recognize that CEI/TEI:

1) is effective based upon single models with specific organizational structures and pedagogical methods, and
2) requires teachers to play a significant role in interactions between students and machines.

While studies of CAI and CMI have provided evidence that they are more effective at raising traditional achievement test scores than CEI, advocates for the use of computers for more than just improving achievement scores espouse the application of CEI/TEI-type models.

Many School Districts and schools have yet to understand what TEI is and make it possible for teachers to create or adapt the curricula to sustain such models. TEI involves teaching the curriculum with the most efficacious technology available, by recognizing the best and most powerful aspects of educational technology and applying it. In TEI, technology plays supportive, complex and multiple roles in enhancing student learning. In doing so, studies of TEI has demonstrated that teaching and classrooms can undergo significant transformations as seen in the Apple Classrooms of Tomorrow (ACOT) and Technology Enhanced Secondary Science Instruction (TESSI) projects.

4.1 A Starting Point: Apple Classroom of Tomorrow Project (ACOT)

One of the few, and perhaps the only, comprehensive field analyses of the processes and effects of a large infusion of technology and its implementation can be traced to the pioneering Apple Classrooms of Tomorrow (ACOT) project documented between 1985 and 1998 and funded by Apple Computer Inc. Initially, there was one ACOT classroom in each of the five ACOT school sites located across the United States. The ACOT project grew to accommodate approximately 32 participating elementary and secondary teachers at the height of the project (Sandholtz, Ringstaff & Dwyer, 1992; Fisher et al., 1996). At each site, there was a large infusion of technology as well as continual technical support provided, usually, in the form of a technical consultant. The ACOT project series of reports and articles produced between 1990 and 1996 provided a landmark to educational technology's potential to change teaching and fuel the more recent education reform movements in the United States.

While initially, the ACOT program set out to see what teachers would do with technology if it became instantly accessible for their classrooms, there was an adjustment in the program towards a more student-centered, constructivist philosophy. Dwyer, Ringstaff, & Sandholtz (1990, p-2), described this shift in focus:

> *In its inception, the project's philosophy was to provide technology and actively support teachers in the directions they chose to go. However, after three years of observation, ACOT developed a decided bias towards a constructivist view of learning and began actively educating and encouraging teachers to implement knowledge construction in their classrooms. Although the direction of change in ACOT classrooms is promising, the pace of change is slow, for even when innovative teachers alter their practices and beliefs, the cultural norms continue to support lecture-based instruction, subject-centered curriculum, and measurement-driven accountability.*

This new ACOT classroom goal may have been influenced by ACOT's policy to demonstrate technology's power of change; the goal was not necessarily one that naturally evolved out of the best use as determined by all teachers. Interestingly, the pace of change was *slow* (Dwyer et al., 1990) even when a more definitive perspective on teaching and learning had been established. Why was this so?

In their studies of teacher practices and changes, Dwyer et al (1991, 1990a, 1990b) suggest that the key to technology changing teaching and learning is for teachers to confront their beliefs about teaching and learning and the efficacy of the learning activities they create for their students in the midst of change. Only in this confrontation can a transformation occur in the classroom from a *instruction-learning* environment to one of *knowledge-construction* as summarized in Table 2.1 (from Dwyer, 1996, p-20). This confrontation of deep-seated beliefs may not occur readily, especially in the earlier stages of technology implementation (Dwyer, 1996).

1. Entry:
- focus on connecting computers, preparing classroom environments, and first year teacher problems of discipline, resource management, and personal frustration.
- there is limited use or access to computers.

2. Adoption:
- pedagogical focus on using computers to support traditional text-based drill and practice instruction.
- a high level of computer access begins.

3. Adaptation:
- full integration of new technologies into 30-40 percent of class time but lecture, recitation, and seatwork remained the dominant forms of student tasks despite the increase in productivity of students

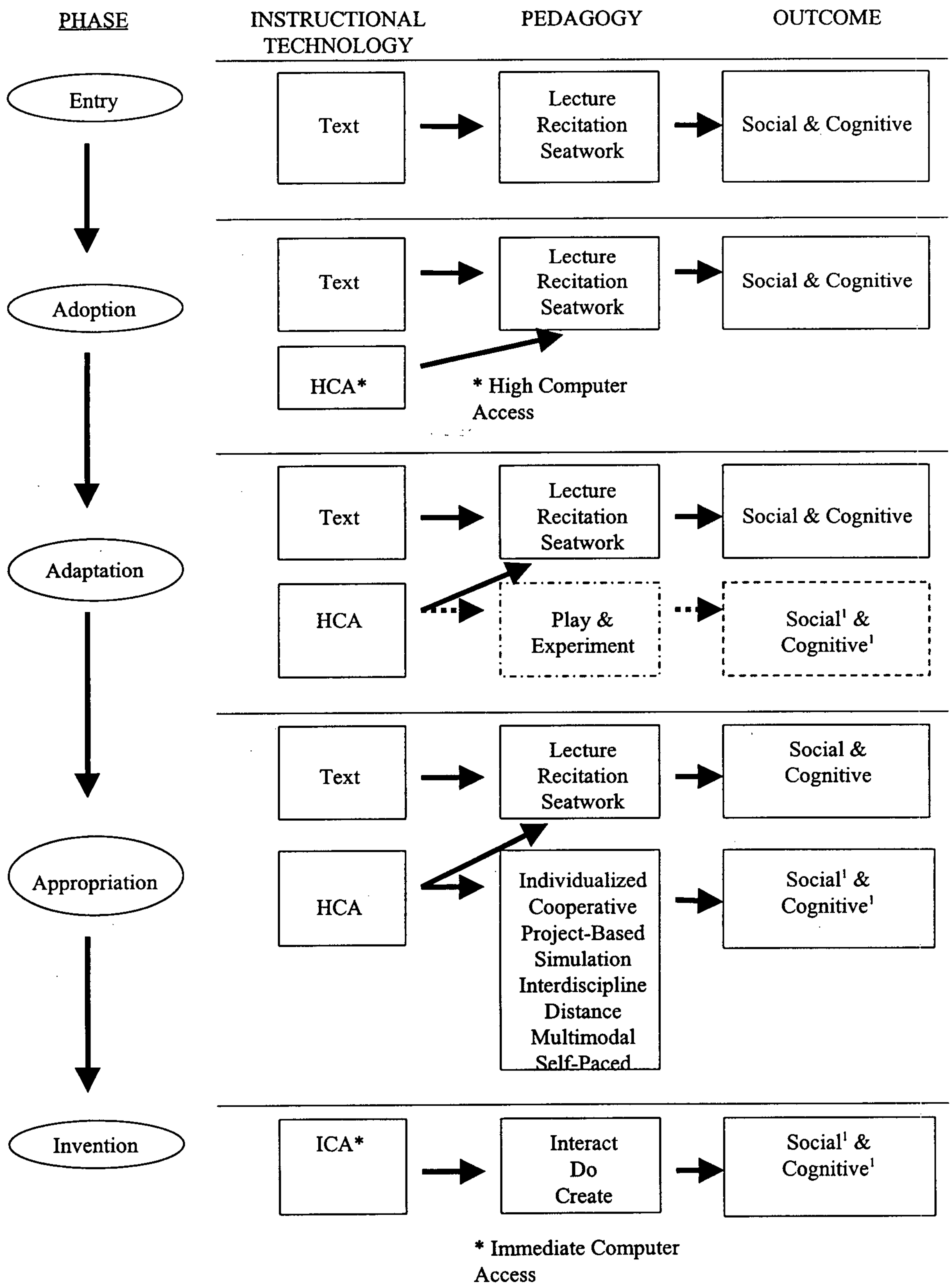
4. Appropriation:
- personal appropriation of the technology by individual students and teachers to use it "effortlessly as a tool to accomplish real work" -- this was dependent on teacher's personal mastery of the technology (especially technical issues) at about the second year of the project.
- experimentation with team teaching, interdisciplinary project-based instruction, and individually paced instruction

5. Invention:
- a placeholder for further developments, this stage suggests that traditional forms of teaching (lecture, recitation and seatwork) will be limited or non-existent in an immediate computer access environment

These stages summarized much of the evolution in instruction that accompanied the use of computers (Dwyer et al., 1991). Figure 2.1 highlights essential characteristics of each stage.

In the ACOT study (Dwyer et al., 1991) there was a high emphasis on productivity on the part of teachers and students as a measure of the stages of instructional evolution. For example, "the shift from the Adoption to the Adaptation stage is signalled by the emergence of productivity as the main theme" (Dwyer et al., 1991, p-48), but otherwise, the types of technology used and much of the classroom practice remained the same: most teachers used technology as a supplement to their established lecture-recitation-seatwork mode of curriculum delivery. Many teachers progressed to include more dynamic learning activities and experiences, but usually only after a minimum of three years to five years of total technology infusion.

Fig. 2.1 Instructional Evolution in Technology-Intensive Classrooms



[1] = These outcomes are of a different order than the other outcomes.

[dashed box] = These behaviours are emerging and less dominant than those contained in solid boxes.

While the ACOT project was exemplary in many aspects, it also had its limitations. In the first generation studies[4] of ACOT teachers, the majority of the classroom examples were at the elementary and middle school level. Although there was a large accumulation of data, there is limited detailed description of the phases of integration and the reasons as to why integration decisions were made. The ACOT series of reports includes minimal direct description of implementation in science teaching. The software available at the time of the study was limited. The majority of applications described were word processing or desktop publishing applications that ran on Apple IIe, IIGs and early Macintosh computers – now long obsolete. Later in the ACOT project, some teachers shared computer labs and did not have immediate computer access and thus did not necessarily use an immersive integration model such as that inherent in the TESSI project. However, the descriptions of teacher experiences and the five stages of instructional change identified in the ACOT project suggest a potential starting point and analytic scheme to map the integration processes that teachers might encounter.

4.2 Technology Enhanced Instruction in Secondary Science: TESSI Perspectives

Since 1992, the Technology Enhanced Secondary Science Instruction Project (TESSI) has developed into an exemplar of technology integration in secondary science classrooms[5]. The project led to a working pedagogical model – a model of how to effectively use existing technology to enhance student learning (Woodrow, 1998a; Woodrow, Mayer-Smith, & Pedretti, 1996, 1997). According to Woodrow (1998b, p-3), TESSI demonstrates how:

- *multiple technologies can be integrated successfully into daily classroom practice within the context of an existing curriculum,*
- *the use of commercially available technology can support flexible teaching practices,*
- *learning can move from a knowledge-transfer process to a knowledge-building process, and*
- *the acquisition of essential skills including time management, communication, problem solving, self-monitoring and assessment, self-confidence,*

[4] I argue "first-generation" because this is the one of the first studies of an early attempt at large-scale integration into elementary and secondary schools. It is also "first generation" from a technology standpoint – although computer hardware generations evolve approximately every two years, software can usually run on two and a half generations of hardware and is much slower to develop. Finally, it is also first generation from a human integration perspective since most implementations require five years.

[5] See Chapter 1 for more details regarding the TESSI project.

responsibility, collaboration, goal setting, peer tutoring, and technology expertise can be supported through the proper application of technology.

Thus, foundational to TESSI, is the *in situ* integration of technology, driven by the educational value of the technology and the implementing teachers:

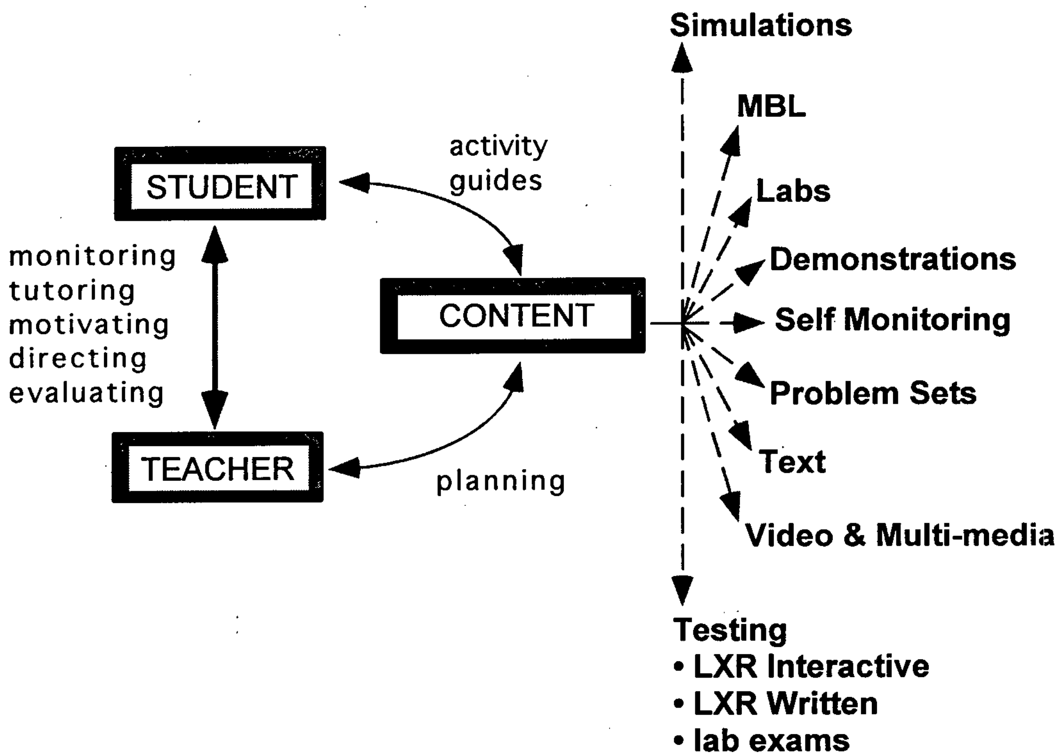
> *"A major premise of the TESSI Project is that if Technology Enhanced Instruction is to become a meaningful part of the paradigms of science classrooms, then technology applications must not be supplemental to the education process. Rather, technology applications must be fully integrated into courses, curricula, programs, and practice." (Woodrow et al., 1996, p-242)*

TESSI has been described as developing from a strong "culture of collaboration" of practicing science teachers and university researchers (Mayer-Smith et al., 1998a, 1998b). Mayer-Smith, et al. (1998b) reaffirm the central role of the teacher, and his/her experiences, perspectives and knowledge of the classroom contexts in guiding the technology integration process. In TESSI, essentials elements in the collaboration process were: 1) establishing a common vision, 2) allowing for exploration, 3) fostering inquiry into practice, and 4) recognizing and developing complementary roles that supported the conceptual changes to pedagogy. Although the bulk of TESSI research to date has focused on Physics classrooms and teachers, TESSI has extended its collaborative reach to Chemistry, Biology and a second generation of Physics classrooms (Pedretti, Mayer-Smith, & Woodrow, 1999).

Woodrow et al. (1996) describe TESSI from a framework of collaboration, shared vision and conceptual change. Changes in beliefs and practices that have resulted from the implementation of technology, in particular the change from a teacher-centered didactic-style to a student-centered one, were studied. Teachers and students alike compared the differences in the classroom environment to traditional science classrooms and a significant increase in achievement as measured by government exams and enrolment was reported (Woodrow et al., 1996).

The changes made in instructional practice were reflected in the changes in learning procedures and curriculum materials that were developed (Woodrow, 1998b). One component of the pedagogical model which developed from other explored alternatives is a student study guide[6] which acts as a flowchart to support student learning using various student activities. Figure 2.2 summarizes the relative roles of student-teacher-study guide interaction.

Fig. 2.2: TESSI Student-centered Roles (from Woodrow, 1998b)



Other teaching and learning strategies that figure predominately in TESSI classrooms include small group and individualized instruction, frequent assessment with the help of computers, providing choices in activities, pedagogical discourse with students and self-monitoring (Woodrow, 1998b; Woodrow, Mayer-Smith, & Pedretti, 1998, April).

In a study of technology's impact on the social milieu of TESSI classrooms, Pedretti, Mayer-Smith, and Woodrow (1998) surveyed student perspectives and found that most students favored the use of technology and were able to recognize and articulate the changes in their roles and the teacher's role in the TESSI classroom. Students discussed "learning to learn" aspects of student responsibility and independence, self-pacing, collaborative work, and other aspects of learning that were well beyond the science curriculum.

[6] See Woodrow, 1998b for a description and examples. Study guides are also discussed in Chapter 4, 5, and Appendix E.

Two studies have been conducted by individual TESSI teachers (Eichorn, 1997; Hutchinson, 1998). Eichorn (1997) determined some of the effects of the application of the TESSI model in Biology 12. Eichorn found that students in the TESSI course were achieving as well as those in a traditional classroom and that student attitudes and ability to access the technology was independent of both their level of computer experience and their gender. Hutchinson's (1998) 'teacher-as-action-researcher' study described his experiences with technological innovation in his Chemistry 11 and 12 courses, addressing some of the practical issues that arise as innovative technology is implemented. Hutchinson gave a detailed "insider perspective" into the early struggles in dealing with developing a technologically enhanced curriculum, finding support, managing new responsibilities, and linking curriculum with resources and student outcomes. He also found that interactive communication with students and the role of the teacher are crucial to making decisions for technology innovation.

5. Technology Integration: Teacher Conceptions of Innovation, Change, & Teaching

Early attempts to reform teaching with technology have underestimated the importance of the teacher's role in a classroom with technology (Hannafin & Savenye (1993). The breadth and depth of a teacher's belief, conceptions, and personal theories about subject matter, teaching, and learning needs to be considered (Ernest, 1995). Identifying profiles of teachers in terms of knowledge about new technology as well as acceptance or resistance to technology use can help guide a change strategy for innovative technological implementations (George & Camarata, 1996; George, Sleeth, & Pearce, 1996).

Change is inherent in the nature of innovative practices such as technology integration into classrooms. A reconceptualization of the classroom environment and the teaching and learning strategies employed may be required (Bork, 1995; Sandholtz, & Ringstaff, 1996). However, conceptual change depends on encountering and negotiating one's pre-existing beliefs, a process which strongly influences how one views, accepts, and effects change. Miller and Olson (1994) suggest that the existence of innovative practice is influenced more by pre-existing conceptions of practice than with the introduction of technology.

One way to examine existing teaching conceptions and potential changes in teaching conceptions is to give consideration to the three general curriculum orientations developed and described by Miller and Seller's (1990) as transmission, transaction, and transformation. Evolving out from Berlaks' Dilemmas (1981), Miller and Seller's three perspectives can be applied to various aspects of pedagogy and instruction, "because it is [their] contention that the development, implementation and evaluation of curricula are usually conducted within these overall frameworks" (Miller & Seller, 1990, p-15). If these three orientations are used as a guide to examine teachers' conceptions and practice, shifts in conceptions and practice should be identifiable. Certainly for those who believe that technology has a potentially large role in educational reform, technology has a limited or no place in the commonly used transmissive science instruction methods that do not promote deep student understanding (Linn, et al., 1994; Snir & Smith; Woodrow, 1997). Technology can be and should be used to transform education.

6. Concluding Comments

The multiple factors involved in technology implementation and integration are complex and potentially problematic. In order to understand, and carve a path in the complexity of the technology integration process, it is important to find approaches that are more circumspect and reflexive, yet, effective and powerful.

The studies that have been reviewed here indicate that if the practical issues (at least) are overcome, a new paradigm in teaching may follow. As indicated by many of the studies, when technology is used as part of an instructional approach involving students in complicated, authentic tasks, technology integration has the potential to support the kind of student learning advocated by current educational reform (Baxter, 1995; Kumar & Helgeson, 1995). However, the extent to which the reported successes can be replicated within the existing educational system remains to be demonstrated (Kimmel & Deek, 1996).

As with many early studies into a developing field, however, there are as many limitations in the studies already done, as there are avenues for future directions. Many of these reviewed studies allowed a very short time for treatment or they incorporated specially designed modules that were outside of a typical school curriculum. A large number of studies focus on only one type of technology, for example one sensory probe (e.g. Brassel, 1987; Nakhleh, 1994) or one simulation (e.g. Roth et al, 1996), with limited consideration to how this technology functions in the larger scheme of the whole curriculum. Many of the student assessments focused narrowly on achievement rather than embracing explorations of student understanding. Measures of higher order thinking or performance skills are not evident. There have only been a few quasi-experimental studies in the field of educational technology, and even fewer experimental studies of any type. Detailed qualitative studies are even more rare.

On the theoretical side, student knowledge constructions and interactions with technology are still youthful conjectures. The effectiveness of technology-integrated curriculum and instructional practice has not been satisfactorily evaluated. Finally, many of these reviewed studies have been rendered invalid by time itself. Technology is such a rapidly evolving field that studies done five years ago could arguably be considered not normative by today's standards of technology for the classroom.

Despite the differences and problems, the reviewed studies have consistently mentioned one factor that has made the technology-integration endeavour worthwhile: technology is motivating and satisfying for students at a variety of educational levels. Technology, somehow, has opened up new levels of interaction, not just between the technology and the user, but also among all the participants in the learning environment, and within the minds of the participants.

CHAPTER 3 – RESEARCH METHOD

In this chapter, details of the research design are presented. Specifically, this chapter describes the participants, data sources, data collection procedures, data transformations and analysis, and general considerations of quality and value in the research methodology.

The study employs an inductive, multi-case, qualitative research procedure, based primarily on the content analysis of semi-structured interviews with teachers from the Technology Enhanced Secondary Science Instruction (TESSI) project. Additional interviews with the TESSI Project Director, notes taken at the time of the interviews, e-mail conversations, field notes made during classroom visits, video tapes of group meetings and classroom visits, and journals of those teachers associated with the project were used to supplement the primary source of data. A constant comparison analysis for emerging patterns, progressions or themes was applied to the primary data (Yin, 1994; Stake, 1994; Merriam, 1991) while the supplementary data was used primarily to triangulate and guide the research process.

1. The Participants

The six teachers participating in the study were drawn from the TESSI Project and include representatives from the teaching disciplines of Physics (two), Biology (two), and Chemistry (two) at five different schools spread across the Vancouver Lower Mainland of British Columbia, Canada. The teachers were at different stages of technology implementation and integration into their science curricular areas as part of the TESSI project. All teachers were originally invited to participate in the TESSI Project by the TESSI Director, Dr. Janice Woodrow, and maintain volunteer status in TESSI.

What follows is a brief description of the participating teachers. While the teachers are "classified" here in their subject area specializations and main area of technology integration, most of the teachers have had very broad experiences teaching other science and non-science subjects at some point in their careers. All teachers have undergraduate degrees in Science, almost all have obtained specialized training or degrees in Teacher Education, and four of these teachers (Steve, Edward, Frank, and Harry) have completed their Masters degree in an area of Science Education and

Curriculum. None of the teachers have had any significant training in computer studies beyond one or two courses.

1.1 The Physics Teachers: Steve and Frank[7]

Steve and Frank were the pioneers of TESSI. Their pairing began with Frank's student teaching practicum done under the tutelage of Steve. Steve is Frank's senior in teaching by ten years. Frank had four years of teaching experience at the start of the TESSI project. At the time of this study, the two teachers had spent just over five years integrating technology into their classroom teaching as part of the TESSI project.

1.2 The Biology Teachers: Edward and Kris

The Biology TESSI teachers are Kris and Edward. Edward was in his 10th year of teaching at the time of this study and he was three and a half years into the TESSI Project. Kris had been a teacher for over 20 years teaching Biology and Junior General Sciences when he took the job in his present District, filling a newly created "TESSI teacher" position. At the start of this study, Kris was in the middle of his third year in TESSI.

1.3 The Chemistry Teachers: Harry, Lawrence and John

Harry was in his twelfth year and Lawrence was in his twenty-fourth year of teaching when they joined TESSI. At the time of the interviews, Harry was early in his second year implementing technology in TESSI, while Lawrence was in his third year.

The third Chemistry teacher who joined TESSI at the same time as Harry was John, me. I was in my third year of teaching at the time of the data collection. Because I am the author and researcher of this work, I do not regard myself a participant of the study. However, I am both the researcher and a teacher, or "participant-as-observer" (Merriam, 1991, p.92) in the TESSI Project, and this role has provided me with a unique position from which to gain access to the participants and a challenge to represent them. While difficult to do at first, I found that it was possible to adopt a stance of "emphatic neutrality" (Patton, 1990, p.55) – i.e. empathy "is a stance toward the people one encounters, while neutrality is a stance toward the findings" (p.58).

[7] Pseudonyms have been used for all participants.

2. Data Sources

The primary source of data was audiotaped, intensive, semi-structured interviews. Each subject was interviewed in-depth two times within a period of approximately six months. A sample interview transcript is presented in Appendix C. Secondary data sources included interviews with the TESSI Project Director, notes taken at the time of the interviews, follow-up e-mail conversations, field notes made during classroom visits, reflective journals of those teachers associated with the project, and the researcher's own journals. The researcher was also provided access to Semi-Annual Progress Reports of the TESSI Project, video tapes of TESSI group meetings and classroom visits, and teaching and / or student materials (e.g. lesson plans, student study guides) produced by the teachers involved in TESSI.

3. Data Collection Procedures

A purposeful sampling method was used to uncover the possible "multiple realities" and "mutual shapings" (Lincoln & Guba, 1985, p.40) which emerged during the study. Since the interviews were the primary source of data presented in this study, further detail of their collection process is presented here.

Prior to the interviews, informed consent and information forms were sent to each of the participants and contact with the subjects was made via phone and email. Abridged sample interview questions were also sent via email to the participants just prior to the scheduled interview. The data collection was conducted at the convenience of the participants. Almost all interview meetings were longer than initially anticipated, lasting between one to three hours each, since all subjects were extremely accommodating and initiated continuation of the interviews. Subjects were all enthusiastic to discuss the questions and issues posed from this study and undoubtedly the researcher's familiarity with the subjects facilitated the interviewing and email follow-up processes in data collection and analysis. Interview notes were recorded during these interviews and were added to the collection of field notes of this study. All primary interview data was collected between November 1997 and July 1998.

Three stages of interviewing were initially identified. Interview questions were developed around these three stages to serve as a structure to guide the interviews and data collection process. The first stage was intended to elicit general issues and contexts, while the second stage probed the issues identified in the first stage. The third stage was intended to be an evaluative one where subjects were encouraged to evaluate their reflections and comment on issues (especially those identified by the researcher from the previous interview). This third stage was sometimes facilitated by emailing portions of the original interview transcripts to the subject before the second interview or email follow-up. The interview guide structure is presented in Appendix B.

A reflexive journal was kept for the duration of the study. Immediately after the interviews, entries were made in the researcher's interview log section of the reflexive journal. The reflexive journal recorded the field notes and the researcher's own reflections, and major decisions made during the course of the data analysis and writing of this work. Preparations for transcription and basic data transformation and analysis (Level One and Two - see below) were initiated immediately after each data collection incident.

4. Data Transformations: Management, Interpretations and Analysis

The primary interview data was transformed on three levels: production of the verbatim transcripts, identification and coding of conceptual categories within these transcripts, and pattern analysis based on common categories as described in detail below.

4.1 Level One:

After the interviews, the audio-tapes were transcribed and given an initial administrative coding scheme to identify the subject, interview number, time and date, line number and page numbers (Merriam, 1988). All data were checked against the original audiotaped recordings and reread.

Field notes collected during the interviews, during classroom visits or other meetings were also reviewed for completeness. Other observations recorded into the Interview Log section of the reflexive journal were also reviewed.

4.2 Level Two:

Transcript data was processed on a combination database-word processing computer program (author-programmed Microsoft Access® and Microsoft Word®) which was able to section and assign additional codes to the different sections of data according to user defined categories. In this case, tentative categorical codes were assigned (Lincoln & Guba, 1985) to identify the individual components of data.

Figure 3.1 provides an example of the coding scheme applied to a section of the transcript data. Note that the last three coding fields can have multiple codes.

Figure 3.1. Sample section of coded data transcript

Source	*Section / Line*	**Data**	*Comment*	*Stage / Time Index*	*Code 1*	*Code 2*
SGT	3.12	**S:** For sure. There was a little hesitation, because you know we're gonna be trying out a few different things. Okay, how much work is that going to take, you know, that end of it didn't really bother me. I don't mind working. But it's trying something out and not being successful. **J: That worried you.**	• Commit ment • Uncertai nty -> Need for validation	E	2	2,15

In order to manage the data during level two transformations, a data coding scheme was developed. This data coding scheme and a brief explanation of each category is displayed in Figure 3.2:

Figure 3.2. Data Coding Scheme

Source: entry field for source of data

Section / Line: item line based on the master copy

Data: entry field for actual data slice

Comment: field for researcher's personal notes

Stage / Time Index: places a time reference to the data

1. General (G) - not time dependent
2. Reflective (R) - at present
3. Early (E)
4. Mid (M)
5. Developed (D)
6. Future (F) or prospective

Code 1 - relating to conceptions about teaching and learning with technology in science.

Example: Concept / Issue

1. *Technical (Tech)*
2. *Personal (Per)*
3. *Pedagogical (Ped)*
4. *Conceptions of Learning (C)*
5. *Support (S)*

Code 2 - relating to the issues or processes of implementation and integration (there were over 20 codes used here)

The "Code 1" data field was intended to address the first research question,

> *What are TESSI teachers' conceptions about teaching and learning with technology in science? (The positives, negatives, limitations and unforeseen)*

The "Code 2" data field was intended to address the second research question,

> *What are the processes, issues, problems and recurring themes in the TESSI teachers' experiences of the implementation and integration of technology?*

Both "Code 1" and "Code 2" fields were used to address the third research question,

> *What are the interacting conceptual and practical factors which are incorporated by teachers in developing approaches to technology implementation and integration into science teaching?*

Particular attention was given during the interviews to the reference point of the participant's reflection – i.e. when it was situated in their implementation and integration in order to develop the Stage / Time Index. The Stage / Time Index code was used primarily to address the fourth research question,

> *How have the conceptions and experiences of technology integration changed and been reconstructed by TESSI teachers over the course of innovative technology integration?*

Because the danger exists that the analysis of data sections become too fragmented, each data section was analyzed with reference to the data sections before and after it. Care was thus applied to maintain the contextual integrity of each data section.

Level two processing of the data also allowed for quick retrieval of desired data. Interpretative analysis of these data sections required repeated sorting into conceptual categories based on the constant comparative method. Cross-checking with secondary data sources was continually utilized throughout this process.

4.3 Level Three:

In the third level of data transformation, data with similar coding schemes were brought together and re-examined to identify emergent themes and dominant patterns. The coding scheme was also re-evaluated at this level to see if it limited analysis in any way. The focus of level three transformations drew upon various theoretical frameworks, stage-time analysis, and analysis of the relationships between themes. A profile of the subjects was also compiled and matrix display strategies (such as those in Appendix F, Table 4.1 and Table 5.1) were developed to augment and organize the claims of this study.

Feedback and consensus (Eisner, 1991, p.56) was requested to ensure that the final analysis of this study was a reasonable and accurate representation of each participant's view of reported events. Although not within the scope of this study, there were additional insights provided by each participant's feedback. As an aid to judge the quality of the data and results in the process of this study, the data presentation (Chapter 4), and discussion and conclusions (Chapter 5) were emailed to the participants of the study on separate occasions, and many times to the TESSI Director, as a form of member checking (Lincoln & Guba, 1985, pp. 313-316).

In order to demonstrate as much as possible how the research interpretations evolved, the audit trail (Lincoln & Guba, 1985) or case study database (Yin, 1994) maintained in this study consists of the transcripts, the coding scheme, and the reflexive journal that contains information regarding analysis processes and personal notes.

Referring to case-to-case study research specifically, Yin (1994) claims that "any finding or conclusion in a case study is likely to be more convincing and accurate if it is based on several different sources of information" (p.91). At all levels of analysis in this study, data triangulation was applied by reviewing and analyzing the primary and secondary sources of evidence together so that the findings are based on convergence of information from different sources to enhance the scope and clarity of the study. The number of participant-cases also constitutes another form of triangulation.

The net result of the analysis produced a single "story" of technology integration from multiple perspectives, and a framework of processes in which technology integration proceeds. These products will be presented in the chapters that follow.

5. Further Considerations of Quality and Value in the Research Methodology

Where quantitative research seeks prediction, generalization of findings, and causal determination, qualitative research seeks illumination, understanding, and extrapolation to similar situations. For this qualitative study, it is hoped that the research methodology results in a type of knowledge that provides insight into teachers' experiences, conceptions, and understandings of the events in a pedagogical innovation. In this process, certain expectations of research quality arise which are intrinsically linked to a value system. In this case, this value system is left to the researcher and reader who ultimately will judge the usefulness and credibility of this research, because in qualitative research "there is no statistical test of significance to determine if results `count'" (Eisner, 1991, p.39).

Stake (1978) writes, "we expect an inquiry to be carried out so that certain audiences will benefit – not just to swell the archives, but to help persons toward further understandings" (p.5). Thus, for this study to be more than the description of facts and events, the researcher and the reader must be able to share the interpretations, meanings, and reconstructions of experiences presented here. There has to be a degree of resonance of understanding between reader and researcher. This form of "pragmatic validation [of qualitative research] means that the presented perspective is judged by its relevance to and use by those to whom it is presented: their perspective and actions joined to the [researcher's] perspective and actions" (Patton, 1990, p.485). A goal of this research is to provide the reader with sufficient evidence to decide whether the evolving findings can be 'extrapolated' to some new situations, in hopes that it be "sufficiently applicable to a multitude of diverse situations within the substantive area" (Glaser & Strauss, 1967). However, it is more important that this study provide a form of `interpolation' to the reader's current context, or what Eisner calls, a form of "retrospective generalization" that can allow us to understand our past (and future) experiences in a new way (1991, p.205).

CHAPTER 4: PRESENTATION OF DATA AND RESULTS

This study examines the experiences and perspectives of senior secondary Physics, Chemistry, and Biology teachers toward technology implementation and integration into government-mandated secondary school science courses. The teachers had different levels of technological expertise and were at different stages of technology integration in the Technology Enhanced Secondary Science Instruction (TESSI) project. The purpose of this study is to describe what teachers perceive as the issues in educational technology implementation and integration, and to document the experience of teachers as they work through these issues. This study is guided by the following four research questions:

1) What are TESSI teachers' conceptions about teaching and learning with technology in science? (The positives, negatives, limitations and unforeseen)
2) What are the technology implementation and integration processes, issues, problems and recurring themes in the TESSI teachers' experiences?
3) What are the interacting conceptual and practical factors that are incorporated by teachers in developing approaches to technology implementation and integration into science teaching?
4) How have the conceptions and experiences of technology integration changed and been reconstructed by TESSI teachers over the course of innovative technology integration?

The qualitative data (i.e., the interviews, journals, emails and other artifacts) collected in this study were analyzed for patterns and themes relevant to the four research questions and are presented here in five main sections:

1) Personal Aspects
2) Infrastructure
3) Student Learning & Pedagogical Practice
4) Student Learning and Curriculum
5) General Conceptions of Technology Integration

Within each of the five sections, the emergent issues and themes arising from the data analysis are presented. Anecdotes from all the participating teachers are used to form part of the resulting "story" of integration. There are some overlaps between sections because the stories occur in parallel and because each represents a slightly different angle or perspective of the issues in technology integration. Together, the stories help to develop the conception of technology integration put forth in this work. Where feasible, the presentation within the sections is as linear as possible in time (developmentally or in terms of occurrence) in order to help denote the progressions within each of the domains.

Although the experiences of six teachers in different contexts form the basis of this study, the similarities in the themes and issues of their stories are striking. These themes and issues have been blended so that there can be considered one overall story of technology integration. At times, multiple quotes have been included to support a theme or issue, to reinforce its recurrence, and to give slightly different views on the point being presented. An alternative format would have been to give each teacher's story a separate chapter, but a higher redundancy would have resulted. Where significant differences do exist among teachers, for example in the relative rates of progression through integration, these are discussed in the relevant sections.

1. Personal Aspects

This section presents the dramatic changes and effects in the teachers' personal and conceptual concerns regarding technology use, pedagogy, personal life, and professional responsibilities as they negotiated the integration of technology into their own teaching practice.

1.1 Prior Personal Conceptions of Teaching with Technology

Prior to their involvement in the TESSI project, the focus of the teachers' acquisition of technology was for teacher-only functions. For example, most of the teachers felt that technology could be used for simplifying teaching tasks such as record keeping, test-creation and word-processing. As Frank states,

> *It wasn't at all thought as a change in pedagogy or in the way I worked. It was simply a tool I could use to do marks or tests. <Frank>*

The teachers expressed the idea that, in education, computer technology was conceived as an expensive novelty that some teachers hoped would simplify life but only some of the most technology-enthusiastic teachers would find ways to acquire them. Edward was such a teacher. He states:

> *I was pretty big on technology. I wanted to get it in to the student's hands and I wanted to get more computers in the school. Finally, they changed the textbook funding rules so we could use 20% of our recommended textbook budget on technology. So I used that to buy a little Macintosh computer for each classroom. It's kind of interesting in the kind of effect that happened. We got them in each classroom but no one used them for student use. <Edward>*

For most of the teachers, the potential of technology to enhance learning did not fuel the step towards technology integration. It took a personal interest in technology and a general desire to provide for better learning and teaching experiences beyond that typically found in Science classrooms to furnish the initiative to seek out ways to acquire and integrate technology. But because the use of education technology was so new, even these enthusiastic teachers initially experienced difficulties about how to effectively implement computers and related resources. They had little, if any, vision of what technology could or could not do for the students.

> *If anybody would like to do something with computers and Science and Chemistry, it would be me. But I had, from the early days, no idea where this was going to go. I hadn't heard of this TESSI stuff. What I knew was that people had been using probes. I guess I had an innate, raw interest. <Harry>*

> *I had a conception that I didn't agree with the way most Science education was being done. There were far too many notes that weren't interesting to students. My original idea was to have a station approach so that in every unit there would be less notes, and more work stations for the students to rotate around in. It would work better for some than others but just the sheer volume of the equipment involved and the moving around and having everything set up for a grade eight class and then the following block, having grade 10s, it just wasn't practical. That was the big problem with it. So when I walked into Frank's room and saw what some of the more recent computer technology was capable of, I thought that perhaps this was how I could achieve a variation of my ideas in a more practical term. <Edward>*

Occasional observations of technological applications inspired some ideas related to the potential of technology for teaching, but as Harry recounts, *"But the problem is you only have one machine. That means, what do you do?" <Harry>*

1.2 Joining the TESSI Team

Through different circumstances, the teachers of the TESSI Project were assembled over a five-year period. The earliest members were the two Physics teachers who were invited to join the project by the director in 1992:

> *It was a very vague invitation of, "Would you guys (she was saying this to both Steve and me simultaneously) would you like to explore using computers and teaching Physics?" We naively said, "sure, what could it hurt?" And since then it's never been the same! <Frank>*

The Biology group was assembled in 1995 and the Chemistry group was added in 1996.

When the teachers joined TESSI, they were initially very excited but there was also some apprehension regarding the prospects of being able to become a successful innovator in technology integration, especially in light of the teachers' many previous commitments:

> *I was on Cloud Nine! We were very pumped up about the whole thing – I could hardly contain myself. The first meeting we had with her [Janice], I was like, "Yeah! I'm really into this!" I get to play with all this interesting, cool stuff. I was really, really, happy with the overall situation, of course, but a little apprehensive because the project had already started and I knew we would be part of the Chemistry portion. I wanted to make sure I had enough time to continue the Masters, I was teaching Chem. 12 for the first time, and I wanted to be a useful contributor to TESSI as well. < Harry>*

> *There was a little hesitation, because you know we're going to be trying out a few different things. Okay, how much work is that going to take, you know, that end of it didn't really bother me, I don't mind working. But it's trying something out and not being successful. I'm going, well, what if I fail? But I've learned to overcome that now. <Steve>*

Yet there was an overriding elation over the potential to do something new and potentially very beneficial for themselves as well as the education community.

1.3 Personal Experiences – The Early Years

In their early tenure in the project, most of the teachers found the "newness" factor and the number of new things that needed to be learned and mastered to be initially overwhelming to some degree. Having to learn new computers, operating systems, security systems, and programs (and then newer versions still of the above) compounded the stress and time requirements in the early days of implementation – and all this occurred alongside the process of resource development. As a result, some of the initial excitement faded and the teachers began questioning their personally perceived lack of progress.

> *Time. It took a personal toll. <Frank>*
>
> *At first it was like, my head hurt every night when I came home. It was like, a new program every week and still a bit like that. I'm getting a little further along in the thing but I'm nowhere near where I want to be with this thing... At first it was almost like a freak out state ... "what have I got myself into it?" Just long, long hours... Now I'm at a stage, one removed from where I started, that I have some stuff that's working but I'm still constantly producing new things.<Kris>*
>
> *There's some learning that's going on at the same time. And as you're trying to bring more and more of the computer-used technology, etc. and different methods all into play, you're really taxing everything, so there's more opportunities for things to go wrong. <Steve>*

The teachers were all self-taught in using technology and computers. None had taken any significant training in educational technology, using computers, or in programming beyond an introductory course. Nevertheless, each teacher was quite confident in their ability and persistence in tackling technological problems. This confidence was frequently put to the test when the appropriate sources such trainers, technical support, or even manuals were, more often than not, not available to help the teachers through the technical problems. The application of skills such as learning on your own, finding sources to help you learn, gathering the resources, and finding colleagues who could help became essential for their continued work in the project:

> *I've been using a computer for a number of years and software was fairly intuitive. I was able to learn most of it. Interesting enough, a lot of the software I got hold of through the project didn't come with manuals with instructions. So, it was sort of 'learn by the seat of your pants,' sort of thing. And if you have a problem, phone Frank, phone Steve, or phone Janice, right? There weren't too many of those where I just couldn't do something but I think I spent many hours learning how to use the individual software programs. <Edward>*

Although there were few explicit expectations in innovation with respect to the ultimate form of the "product" of the technology-integrated classroom, teachers experienced anxiety as they fed off their own excitement. They produced pressure on themselves to learn the new technologies and the new programs, to ensure that their computers were running, and, generally, to be a perceived as a "successful teacher."

Most teachers also felt that they needed to maintain this 'aura of knowledge' for their students and their own professionalism as teachers as they strove for the goals of implementation.

> *... When Janice initiated the project, she said we should do this in just Physics 11. Steve and I both said, "No, no, we should do it in both Physics 11 and 12" and we doubled our workload from Day One. <Frank>*
>
> *The expectations I felt were from the TESSI group, I guess that would be Janice and Frank primarily, ... that I would take this on at least and do my best with it as far as possible. I never got the feeling from either one of them that I wasn't doing enough. As long as I was putting in the hours and try to do the best that I can, that was good enough.*
>
> *The stress was just that, I could not learn the stuff fast enough. I just wanted to do it. I could see from the stuff that Frank was showing the potential of the things I could try to do and as a teacher, you always want to make sure that you can do something yourself first before you force it on the kids because it inevitably, it blows up. (That is another story!) I've got away from that feeling. So it was pressure I put myself to learn all the stuff as much as I could. You want things to work and they are not working. You go to their machine and you try to fix the problem and then you're totally immersed in the machine, and you totally lose control of the class, and you don't know what's going on around you. So I very quickly figured out that that was not the way to go. <Kris>*

Since the teachers were experimenting with resources and troubleshooting their technologies, their perception of their own progress was slow. There was also a feeling of the lack of cohesion and reaching immediate goals as the individual teachers often pursued their own interests in implementation. The necessity to find and set personal and professional limits was soon realized.

Despite reassurances and an openness to allow for mistakes from the Project Director, teachers experienced a great deal of personal uncertainty regarding whether the implementations was on-track and whether students would be able to learn the mandated curriculum and "whether it was all going to work." As Steve puts it, "You need that validation," from students and administrators alike:

> *A lot of things that go on as a teacher, well, you can't, you'd need another set of eyes to look at. So, having that validation was very satisfying: Wow! Great!*

No matter how much teachers thought they were ready for change, the reality and extent of the changes involved in technology implementation did not occur to teachers at first --- and was greater than expected. Teachers report that the first or second year of implementation was generally the most difficult as they struggled to achieve technology integration beyond just replacing some non-technological activities with technological ones, as Harry was experiencing at the time:

> *I think that if I was completely honest right now, with myself and you and Janice, I would say that for myself and my classroom, technology has been an add-on and replacement of certain things. But it has not really changed my real modus operandi of teaching. I function in much the same ways, but my activities have broadened, my scope of activities has broadened so I can choose from a wider variety of things. Certain things I've done in the past, I've replaced with technology. Many other ways, especially with simulations, most of the simulations I've used as an add-on, which is then taking away from my lecture-aspects of the class. I saw myself as being a fairly lecture-oriented teacher in the past and I think this has allowed me to be a little more activity-orientated. But I still feel I'm too lecture-bound. I still have the same modus operandi for me. In other words, I still have too much of a teacher-centered classroom, instead of a student-centered classroom. <Harry>*

To make the changes Harry would like, he realizes the continued risk-taking and work ahead that would be required of him to truly integrate technology:

> *Well, the desire is there, but the bridge to go from teacher- to student-centered hasn't been fully constructed at this point. I just don't feel that...maybe because there is some risk-taking involved, and I just don't feel I've made those steps. Maybe I'm partway there from where I was but it hasn't been the sort of progress I would have like to have seen. I think that if I look at what Steve and Frank have done, you're looking at four years of development where we're in the year and a quarter of what we're able to do. Plus, we're piecing together things still and we've got the other problems, like the network and stuff, so we're not making the progress as quickly as I would have liked to see. Maybe it's too much of an expectation on my part to make that whole change. I'm willing to take the risk to edge my way in that direction... It's an evolution that is going to occur. <Harry>*

1.4 Pedagogical Questions and Shifts – After the Second Year

After two years of working with technology in their classrooms, many of the purely technical problems diminished and the focus of the teachers shifted to concerns of pedagogy. Prior to implementing technology into their classrooms, most of the teachers had an established, lecture-based, content-orientated, routine-based teaching style, similar to that described in this example:

> *Well I started off as a lecturer, particularly in Biology 12, which was so content-based. So I would perhaps do a little teaching every class and then have the students work through some activities from a book or some other way, and then the following period, we would discuss some of the answers and then move on to the next unit. <Edward>*

Although the teachers were very comfortable with lecturing and traditional teaching strategies, there was a general feeling among them that more students could be reached if their repertoire of teaching strategies was broadened. For example, Steve explains:

> *I think the best way in which kids learn, I don't think that it's listening to me in all situations. Some students... they need to be told specifically, or other students, they could get the book, the actual IRP, and see you later, and they'll do well whether we're there or not, I believe that. Students are like that. There are others that need the motivation, you've got to pull them along, and others are floundering, keeping their head above water. So you've got all those things. Well, if I lecture, I'm only going to the middle group, really, because I've bored the top end, because they understood me the first time, I've lost the bottom end, because they don't know what's going on, and I wasn't comfortable with that. I was effective, but not comfortable with that. <Steve>*

Technology was viewed as a viable means of broadening teaching practices and introducing pedagogical change. These changes were introduced to the classroom slowly, particularly at the very beginning of the implementation when there was limited technology available.

> *I would for the very first year, teach the way I had taught, or was used to teaching and try to use the media center, and the overhead, to implement some use of technology as a lesson aide, in the sense of maybe using a computer simulation through the LCD panel on the overhead as a teaching aid. I would add computers later ... At the end of the first year I think I had four computers for the kids. <Kris>*

As resources became more available and teachers became more familiar with the capabilities of the software, the pace of experimenting with different learning technologies and instructional strategies increased.

The increased implementation of technology quickly led to questions about perceptions of classroom control. The teachers were forced to examine their own teaching styles, "what it really means to teach," and to manage a classroom:

> *Giving up that control of 'I know your eyes are all forward,' it's not an easy thing to give up. So where I think that comes from is the old view of the administrator coming around doing a walk-by, saying "Oh that's a quiet classroom, you must be a good teacher." <Steve>,*

For some teachers, the feeling of the loss of control was not just limited to classroom management. The teachers also experienced a loss of control of what the students were actually learning as learning with technology opened up possibilities for extending learning beyond the mandated curriculum. The perception of controlling what content students "received" through lecturing, for example, became contentious.

> *The whole control thing goes away in the sense that you were not the center anymore. You are not to dishing it out at the front teaching, lecturing, whatever. It was freaky a little at first. Normally you lecture on a certain topic and you know you "covered" this section of the course. When you are doing it TESSI-style, you do not have that feeling. [Lecturing] is just a false sense of security that you have covered the course. 'If you have said that, you have covered it.' What makes it that you have covered it any better than the system? <Kris>*

> *It was more management in terms of the outcome that I was trying to get the activity to address. When I was doing a lecture, I could do the lecture demo and made sure every student understood Lenz's law. But with the simulations, students would explore and get different things out of it, and not necessarily the outcome that would be measured by this damn exam. It's still useful Physics and it's still useful problem solving and all the rest of that good stuff, but it wouldn't be a multiple-choice question on that exam. That was a stress in management. <Frank>*

Another consequence of the increased use of educational technology was an increase in the diversity of classroom activities. Instead of lecturing, teachers found themselves adjusting to different and sometimes unpredictable types of learning situations as their students became more engaged and self-directed with the technology and activities:

> *I think certainly that teaching Biology from straight lecture point of view -- which 99% is how it's apparently done in the province -- it's boring for the kids. They get an assignment and it's always like that. There isn't much variety. I don't think I'd ever go back to that method because that was boring for me. I had three to four blocks of biology and I'd give the same notes to every class. Three to four times and you'd go out of your mind! Now the students are much more involved, much more active. They're moving around doing different things... Some I think are learning better but at least everyone is learning as well. <Edward>*

> *My role is wandering around, dealing with any technical problem that arise, like a computer freeze or whatever, listening to students and their conversations. You always have kids that go, "I need help with this. I need help with that." There are sometimes that I'm not needed. I'll go do some marking, work on the next test or work on the study guides. You're multitasking more. I could tell you what I'm doing in a lecture environment. In this kind of environment, I never really know what to expect. I sort of deal with it as it arises. <Steve>*

The teachers viewed these changes in their classrooms as indicators of a significant change in general pedagogical approach from lecturer to organizer of information / manager-coach, from a `transmitter' of knowledge or giver of content, to a one who `transacts' learning or negotiated learning:

> *I certainly lecture a lot less, a lot less now to my grade 12 students, hardly at all, in fact. And I very rarely teach anything in that manner. I'll still review it with the whole class, but the difference now is instead of me providing them with the information when I do one of these whole class reviews, the students are giving me the information and I'm just organizing it, rearranging the content if necessary or reinforcing certain things that I think are really important. I'm no longer the provider of instruction. I'm more the organizer, perhaps. <Edward>*

> *You're their facilitator, you're their coach, providing that human contact. You do whatever you do to help the kids. It's easier to do that now because you've got the time to do it as opposed to your time being taken to hand out the notes. <Steve>*

Steve and Frank have summarized the pedagogical challenges and choices they have made in integrating technology in light of Berlak's (1981) dilemmas:

> *Getting people to identify which orientation they're in with what you're doing now, what orientation are you currently in, how does that match? Sort of going back to your philosophy. Are you practising what you preach? It [TESSI] brought that up a little more. People change from doing more transactive than transmissive. Transmissive is the lecture mode. ... The thing you have to realize, and this is what we always try to get across, one [orientation] is not better than the other. I may have a bias towards one, but it doesn't mean that it's better than the others. I know some outstanding transmissive teachers, and I don't think they should change, because they are so good at the way they do it. For me, I think I'm good, but I'm not that good. In this mode, I'm great. ... I've found my niche. That's what everybody has to do. <Steve>*

Choices have to be made in terms of teaching mode, each with its own strengths and weaknesses. For example, to encourage a more transactive teaching mode, helping students to learn from each other and dialogue, requires the teacher to give up time from the transmissive, lecturing mode.

Despite realizing the many benefits and enjoying the pedagogy that has evolved out of a technology integrated classroom, some teachers lament the loss of the "performing" aspect of teaching and plan to reintegrate it or keep it within their teaching style. They enjoy the performing aspect because there is a certain "comfort-zone" about it, and because they feel that they can use this aspect to keep students motivated:

[I used to do] a lot of demonstrations, a lot of engagement in demonstrations ... I enjoy performing. That was something that was impacted by TEPI[8] -- I don't do it anymore. I'm hoping to integrate more of it now in this coming year. But in the last three or four years, not very much at all. It's pretty much been all student-directed. It's something that I miss. And I still think I could effectively integrate it and yet still leave the class self-directed. <Frank>

I'm still not comfortable with that [more student-directed teaching style] because my big strong point is that I can lecture. That's why kids love to be in my course is because I can make analogies, I can tell stories, I can bring in anecdotes, I can make them laugh. All the kids I have ever had back "x" number of years have come back and said I was one of the best lecturers they ever had. For me to give that up, which is one of my strong points, is really, really, tough. That's something I haven't completely figured out yet. ... To set up TESSI, and say that this part will be set up on the media center, but this piece will be mine. I'm going to lecture this piece, even if I have laser discs and other stuff kids can use as a backup, this is a piece I'm not going to let go of because I know this is something I can turn them on with, and that's a big part of our job, to turn them onto Science. <Kris>

The younger teachers found that working in the TESSI project helped them solidify their conceptions of teaching, while the older teachers found that their views shifted as their repertoire of strategies and experiences broadened. In all cases, teachers found that their view on teaching had been challenged.

My views on education were more or less, in evolution. I wouldn't say that I had these hard and fast beliefs that somebody turned them upside down. I think Kris's interview would be more appropriate for that because I was still quite a young teacher when I started doing this. I'm still evolving my ideas and the Master's program that we went into simultaneously introduced a lot of concepts that we could explore. In my own personal case, I wouldn't say it changed something. It helped me evolve to something that I think is more sound than it would be otherwise. <Frank>

1.5 Professional Development, Change and Risk

Being an innovator in technology innovation also broadened the teachers' professional roles. Staff colleagues view the TESSI teachers as technical gurus or "techies," i.e. "technophiles who can fix your technology problem for free." The lack of suitable Technology Enhanced instructional resources necessitated that extensive development work be done on student resources. The teachers find themselves called

[8] Technology Enhanced Physics Instruction – early name of TESSI

upon to make presentations at workshops and conferences and to act as advocates and models for technology integration. Some of these roles are played out in necessity in order to achieve their goals of technology integration. For example, TESSI teachers found themselves explaining technology integration to peers, parents, students, and administrators in order to gain support. Some roles were assumed as a result of professional commitment to the teaching community. TESSI teachers also found themselves working with software developers and promoting what they perceived to be quality software design in order to obtain better software for their classrooms.

> *I'm going to go to this conference in April which they're going to have an educator's consortium that is mainly a software designer's conference, the Computer-human Interface Conference. They want educators to come down and say what they think is wrong with the type of software that we're using. Here's my soapbox and here's my horn. I think practically, there's room for improvement, plus it would be a good opportunity for me to promote TESSI. <Edward>*

The combination of the need to be a developer of resources while simultaneously adjusting to the demands of new pedagogical approaches was demanding for each of the teachers. Frank expresses these concerns as:

> *It was a real stress with the resources because we knew even then some of the things we could do to make it better and so we were pretty much multitasking between mentoring and tutoring with the students to sitting at my computer and trying to get some resources together. Some of the early interview data, you may see comments from students like, "Mr. A was never available ... Because he's not standing and directly teaching us, he's not available for tutoring because he's sitting there making the next damn study guide that we need. That was a real stress initially. We just had to say, "tough", this is what it takes. Then the administrative support would come back to that. A student would complain or a parent would complain and the principal would say, "tough!" <Frank>*

While being a technology innovator can be exciting, the teachers did not lose sight of the fact that their "real job" was that of being a teacher. They were concerned about the risks of assuming different roles while at the same time experimenting with different technology and pedagogical approaches in the classroom. For example, Steve describes his response to a specific experimental approach that he initiated as:

> *But I tried for four months, okay, I thought I was going to lose my job! Because here we are, in January, we have 48 percent of the year gone by and I only had 25 percent of the course done. I thought, this is it, game over! <Steve>*

Similarly, Frank commented that:

Because of the variety of jobs that Steve and I have been saddled with, something has to go, and several things had to give. You're not doing as good a job in your classroom as you think you could have done because of the leadership roles in TESSI we had assumed. <Frank>.

The roles assumed by the TESSI teachers have included: teacher, resource developer, technician, network administrator, professional developer, technology consultant/ advocate, researcher, student, and curriculum designer and implementer. Yet these teachers assumed these multiple roles well, in light of their challenging situations. Whether acting as professional developers for other teachers or when teaching their students, TESSI teachers reflected an attitude of life-long learning:

Just tell the kids, Hey I am new with this let us learn about it together. If you find something new, tell me. I want to learn with you. And they find that neat that they can do something that the teacher does not know. It is a trip for them, sort of a power trip. He doesn't know all the answers. One of the worst things teachers can do is know all the answers. But with this technology is it is definitely like that. <Kris>

2. Infrastructure

Infrastructure is the supportive framework of human resources, funding, technical, physical, and organization structures, upon which technology integration can proceed. This section identifies issues related to infrastructure encountered by the TESSI teachers and describes the negotiation of the teachers in resolving these issues.

2.1 Financial Infrastructure

Since the TESSI Project classrooms were innovative technology pilot sites, they were fortunate to have funding provided through various combinations of the school, the school boards, commercial and foundation sponsors, and research grants co-ordinated through the Project Director, Dr. Janice Woodrow. The earlier project sites required and received much more funding than the later ones. These funds were used to cover the costs of the initial stages of development.

We spent a lot of that money making mistakes which a pilot project has to do. We were also bought out with some release time. Those things were essential at the development level. Janice was very generous and very supportive, and a lot of her commitment was to proposal writing. <Frank>

Typically, teacher-related sources were purchased first, followed by student-related resources, as funds became available.

But anyways, there was only enough funding initially to get a teacher computer. And that teacher computer was a Mac IICI. Also at the same *time, we purchased the colour LCD panel and the Interactive Physics software. <Steve>*

To supplement the funding provided by the project, the teachers also sought funding on an individual basis from within their schools, and wrote innovative technology proposals to their School Districts and to the business community. Because the goal of creating a technologically integrated classroom was not considered to be the norm, extensive lobbying had to be done to acquire funds:

Lobbying in terms of getting the extra release block, getting some preferential treatment in terms of getting some wiring in and that kind of stuff, yes, there was a little of that. We made presentations to the school board, always, and that certainly helped. The more high profile you are, in some ways, the easier it is. `Oh, you're with the TEPI group.' So you get what you want. I'll tell you one thing, the money is there. There is no doubt about it. <Steve>

In some cases, lobbying for funding unfortunately led to the perception of preferential treatment or jealousy from other staff.

2.2 Setting Up the Physical Infrastructures: Technology in the Classroom

A goal of the TESSI project was to make effective and timely use of technology so that technology would become `transparent,' or `just another tool'. Thus, an essential feature of TESSI was the installation of the technology in the classroom so that students could have on-demand access. Only in this way would technology be considered seamlessly integrated and capable of impacting student learning.

I would [prefer to] have all the computers in the classroom because I think it facilitates the attitude that it's just another tool. Well, if you want to have something that is a tool, it had better be readily available. How would you like to have a mechanic working on your car go, `oh, sorry, I can't do that, I have to bring it somewhere else to change the gas cap' or whatever. It's not right. If you want it to be seamless, it has to be readily available. The only way it can be readily available is if it's in the classroom. <Steve>

Prior to TESSI implementation, some of the teachers considered the possibilities of pulling-out their classes into the limited computer labs that were being made available at some schools. However this option was not appealing because of the organizational hassle to access the computers.

And eventually they set up computer labs in the school, but it was always a bit of a pain. It was offered to us that we could take a class and book them into the computer lab and do something, but I never took that opportunity because it was just too much of a hassle. That was the bottom line: it was too much hassle to move the kids down there, and then, what are we going to do for one period session? <Kris>

Computer labs are designed to house computers. Science labs are not. In setting up the computers in their science classrooms, many considerations surfaced for the teachers. For example, classrooms must have adequate space to be able to accommodate the computers while allowing up to three students to sit near the monitor and still be able to perform experiments to the side of it. Other common issues that arose in the conversion of the classrooms to technology enhanced science labs were access to electrical power and networking cables, and the use of a local area network (LAN) to speed up installation of programs and manage security and computer desktops Variations in science classroom design ensured that many other factors contributed to the lack of properly set up classrooms, each presenting its own difficulties and requiring a unique solution:

> *The start up for last year, trying to do full-blown TESSI in grade 12 was quite difficult. I had the computers, but I didn't have the network. I didn't necessarily have all the software. I didn't have all the resources. I didn't have proper chairs for the kids to sit in. There's just a whole bunch of things. It made the transition a little bit difficult, I think. <Edward>*

> *First of all, placing equipment in a useful manner. I have "x" number of computers at the back, and I want to get computers on this other side of my room, but kids require that space in order to form some sort of little group... With the MBL equipment, I left the serial boxes plugged in now. So it's a matter of plugging the probe in. I didn't do that last year because I was quite worried about the damage they might suffer. ... Trying to find a right place for the hub and laser printer, and television, and those sorts of things -- it's not really a large room, it's a very average sized room. I've got to worry about kids washing beakers and putting them back on the shelves and dripping drops down the back of the monitor. That's a big problem for me. <Harry>*

Other physical infrastructure problems faced by the teachers were unforeseen concerns of damage and theft, adequate room ventilation, controllable lighting, lack of chairs at an ergonomic height and storage.

2.3 Maintaining the Technical Infrastructure

Once the technology was installed in the classrooms, teachers encountered a new responsibility—that of maintaining the technology in optimal operating condition. The teachers found that teaching with technology requires that the teacher be persistent in learning about, managing, and solving the myriad of technological problems that arise not just initially but throughout the course of integration, whether they be simple plugs that work loose, installing RAM upgrades, or complex diagnoses of networking problems.

> *The earlier problems were more technical-based ... and not having a server, having to manage each workstation individually. It became a real challenge that we could actually manage that. <Frank>*

> *Installing more RAM was really simple. I had never done it before this project but I watched a kid put them in the LC3s and went, "Yeah, I could do that! That's not a problem." So he showed me how to open them up and I did some more myself ... I learned a lot about those sorts of issues. It was a great learning experience, more that anything. <Harry>*

> *Even when you're pretty comfortable and you think you know what you're doing [you're going to have problems]. For example, the first time I was going to give an interactive test last year, the students were all really pumped, they were raring to go. I was raring to go. I sat down and designed a test of simple six-question test and set it up and everything worked fine, but every time I tried to open the test, the computer would freeze. I tried all kinds of combinations and permutations and nothing was working ... But the questions all printed fine. So, I was really at a loss. I called Frank. You know, I'd been working on this for about four hours at this point. Seven o'clock at night, I call Frank and said, "What's the problem here?" He didn't know. So, we went over things on the phone for about half an hour and basically he recommended things -- many of which I had tried already. I thought, "Oh, boy!" So I went home and had dinner and relaxed a little bit. I went upstairs to my office and started again ... Finally, it worked. But, you know that thing probably took close to five hours in which I was just at my wit's end. <Edward>*

The installation of local area networks (LANs) and related security concerns marked an important escalation of technical expertise required of the teachers, causing many additional problems.

> *Well, the biggest problem with this lab has been the connectivity problem. The computer themselves are fine but they are all stand-alone ... and when I tried to connect all eight computers, but I was unable to. ... I literally spent about two months playing with it here and there as much as I could. I wouldn't doubt it if I put about 20 hours of just direct time on the networking problem itself. It wasn't worth the hassle anymore. <Harry>*

In Harry's case, mixing and matching different levels of computers added to the challenge of technical maintenance but installing and managing a network was a hurdle for all the teachers. On the positive side, LANs provided many worthwhile advantages allowing the teachers to quickly install software from a central location, access files anywhere on the network, screen share, control desktop profiles, and implement interactive testing procedures:

Once the network was up and running, it was a headache to get all the bugs out, but it's great. I just love that. When it works, it works great. And most of the time it does work now... If I need to put a program on that the kids are going to use, I can do that from my machine to their machine in a matter of seconds, minutes at the most. I've got whatever program I want on all eight computers. I can screen share and they are sitting at their machine watching what I'm doing, that's great. Then the server part of it with the kids can store stuff on the server and I can go and see what they have stored in their folders, they can actually hand stuff and I can look at it. That's great. <Kris>

These advantages have come to be relied upon by teachers to help maintain the network and facilitate diverse uses of the computers.

The technical support that the TESSI teachers received was no more than what a typical teacher might experience in a School District where technical support is a low priority for teachers. The teachers became adept at finding alternate sources of technical support including students and other 'techie' peers.

You can't put a computer in a teacher's room and expect either him or the students to use it ... otherwise the teacher is just going to get frustrated. I mean, I probably would have given it up by now if I hadn't had Steve, Frank, or Janice to rely on to help me out with certain problems. Something that is fairly complicated, like setting up each station so the students could access interactive tests. I mean, Frank tried to tell me how to do it, I tried to go back and do it, but it just wasn't happening, so I asked him, "Can you come over?" and he did. Somebody has to be there to get help from. Teachers simply aren't going to address this, no matter how keen they are. If you give them enough of those sorts of problems then eventually they're going to say "forget it." <Edward>

As the issues related to the selection, support and physical implementation of resources approached resolution, the focus of the teachers shifted to fine-tuning the effective integration of the acquired resources with pedagogy and to developing resources that enhanced student learning.

2.4 The Student Resource Infrastructure and Issues

While teachers were acquiring and setting up the technology, they addressed a parallel infrastructure issue—that of the availability and appropriateness of resources, especially software. At the outset, it was not clear what types of technologies could be effectively used within the curriculum as teachers had limited experience with the range of technologies available. It was hoped that the teachers would not have to do extensive software development work. Rather, TESSI teachers actively sought out the best of commercially available courseware software to test for classroom use. As well, beta-versions of software were regularly tested on the initiative of commercial developers as well as the teachers. All of the teachers cited the primary hindrance of "the resource issue" – i.e. the problem of finding good resources which they could actually use in the classroom, resources which would do more than just present content as an electronic textbook.

> *Yup! The resource issue! There aren't adequate resources and the resources that exist I don't think are adequate, so that's a problem. There's certainly room for more and better simulations, better quality animations, more creativity on the part of the design, I shouldn't say "creativity" but "awareness" [of what the student is doing, of what the student understands and does not understands]. <Edward>*

Teachers were reluctant to use software that did not match the required course curriculum or content. Even small or subtle differences in content or presentation discouraged teachers' use of the software because of the potential of such differences to create problems, such as representing a idea in a unclear way leading students to miss a more important point, or assuming students understood a particular representation when in fact they didn't.

> *It's really not the same curriculum overall, that simulation takes them through that but it does it in a totally different way that it doesn't seem to match up with what I'm teaching. For example, the Bohr model shows the size of an atom, and then a little flash of light appears. The kids don't make that connection. <Harry>*

The diversity of potential programs and the need to carefully evaluate existing products before implementing them for student use required significant amounts of time. Initial evaluations were based upon the teachers' professional judgement:

> *You look at it and say it doesn't feel right. It's a gut feeling in the sense that you know what you are trying to present to the kids, you know the concept and you say does this piece of technology, program or CD, really do that? If I was a super-duper programmer and could do all the glitzy stuff myself, is this what I would produce? The answer is "no way" or "yes, this is cool, this the way I would do it, I agree with this, or it isn't." <Kris>*

Other assessments entailed classroom trials of the resource:

> *Last year with my Chem. 12's, I found that they really enjoyed the simulations. They liked them and they found the MBLs a little difficult to get going with. I was trying to get constant feedback. They found some simulations to be pointless, some to be good, others to be areas of big confusion. <Harry>*

The teachers observed that many times the design of the software itself made its implementation very difficult or did not contribute to student understanding:

> *I must have spent a week trying to design an [genetics] activity for them that took them one class period, and I spent hours and hours ...and there were 32 steps of instruction. Do this, then do that... there were far too many instructions for them. There was not easy way around it. That's the interface. The interface has to be much more user-friendly than that. They design their material... but I think they're garbage. <Edward>*

In the following quote, Edward, one of the Biology teachers, anticipated and observed an example of students missing the point of a technically well designed, but pedagogically poorly presented, animation:

> *What I found was they would show a computer animation of a biological process, say a reaction, something to do with photosynthesis or respiration where this molecule is coming together or reacting. They show the enzyme in this is shown as a cylinder. So these balls go through the cylinder and they come out the other side split and maybe a little Mickey Mouse head-shaped molecule wanders off. The animator, or narrator, says, "And water is formed." Well, I know that a Mickey Mouse head-shaped molecule is a water molecule, but kids don't. And you know what? That whole thing is meaningless to them. They don't understand.*
>
> *... it's really quite fascinating that these animators are producing this material that kids don't understand. We can understand it because we have already seen it the other way. <Edward>*

Edward pointed out that a simple labelling of the "Mickey Mouse head" and cylinder would probably have solved the above problem.

The quality of the sampled resources varied greatly—and only ten to twenty percent of that which was examined by the TESSI teachers was judged suitable for use in the classrooms. One of the major factors used in the resource evaluation (besides the above mentioned aspects) was that of finding a small number of software interfaces or styles that could span the different teaching units with some continuity and provide the different types of learning enhancements that technology can offer. Where student resources were lacking, the TESSI teachers compensated by modifying or designing relevant resources.

2.5 Making Effective Use of a Small Pods of Computers and the Evolution of the Study Guides

How, when, and where should technology be used? Should a class set of 30 computers be purchased? One part of the answer to these questions initially stemmed from the answer to the following question: "How does one justify spending "x" dollars for computers when it may be the entire department budget of most schools for that year?"

See you can't have a Science classroom of 30 computers. Financially, you just can't justify it. So, whatever we did had to work with somewhere between 6-10 computers. <Steve>

Early in the TESSI project it was projected that eight to twelve computers might be reasonably purchased for a Science classroom over a five to ten year period. Accordingly, each TESSI classroom was equipped with a minimum of eight student computers with the expectation that high, on-demand access for students could still be accommodated. The teachers discovered that in order to make efficient use of this small number of computers, classroom and student activities had to modified. One major modification that was implemented was to have a variety of concurrent activities from which students could choose ("student multi-tasking"). A second modification was an instructional plan that enabled students to progress at different rates ("student multi-pacing" or "self-pacing").

With the implementation of these modifications, the eight computers found in most TESSI classrooms became a reasonable working limit. These modifications eliminated the need for all 24 to 30 students to have access to the computers at all at the same time or for all activities. Also, students were encouraged to work in small groups of two or three:

Steve: ... Because we were experimenting, "let's have the kids do this, let's have the kids do that," but with 8 machines, we were running into bottlenecks.

John: You can't get everyone on.

Steve: Exactly. So we ran into that problem. How do I have 24 kids do the same activity and they can't do it alone? Science teachers, you work in groups, but that's for labs. You know, generally, when kids do problems, you want them to do it on their own. That's the old school, right? So we're going, "They can't do it on their own. They've got to work in groups." But we only have one laser disk, and you can't have everybody crowded around. And we started to find that the best way to use the technology was to let the kids spread out, do different things -- spread out in terms of the content they were covering, you know, like, maybe these kids were a day ahead, and these kids were a day behind, and doing different activities. <Steve>

With a small pod of eight computers, some sort of infrastructure was required to organize and control student use of the limited resources as well as direct student learning. The development of the study guides provided this centralizing force. The study guides enabled and supported student self-direction in addition to self-pacing and class multi-tasking:

> *[The study guide][9] is the roadway through the course and then you are doing all these little stop-offs on the road. You pull into this restaurant, you pull into that gas station or whatever and you look at this, if you try that lab, and you go and pick up this simulation. It is like a roadway. To me it seems like the center ...It is the student-centered piece and it is the main organizational tool. I guess there would be other ways of doing that if a teacher could still be teacher-centered with the teacher would run the thing and say, now we're going to do this lab and it could still be technology enhanced. ... Basically the study guide is like an over blown course outline. <Kris>*

TESSI students use the study guide as a means of organizing their learning and progressing through curricular concepts and supporting activities.

2.6 Administrative Support

School principals have played vital roles in the integration process by providing support for funding, moral support, and understanding and communicating the sometimes experimental nature of the pilot projects to staff and parents.

> *[Administrative support at my school has been] incredible. Very, very positive. Steve Francis[10] was the initial principal who was the sponsor as it evolved. If some of the staff were not supportive, the administrators were. And ultimately, that's what it comes down to. They are the filters with parents and they are the filters with the community and staff. At points, they had to make the decision to spend $10,000 on this and they did that. When they were questioned by the staff committee, he was very direct and said, "I'm the boss. I'm making a decision." And that was crucial. Even if some of the staff were resentful of what seemed to be favourable treatment, where did all this technology come from? I felt supported. <Frank>*

> *I had Norm Dubecheck as a principal and that was just his style where he would walk around and yeah, he came in. Sometimes, from my viewpoint, he would walk in, look around, the kids were working, doing their own thing, I'm not sure he really appreciated it. But in talking to him afterwards, he was aware of it. So having that support was really good.*
>
> *There was one incident where I had a parent interview with two parents from the PAC committee. This was the very first year -- the same year that we started the TEPI stuff. And I had them come in. Their daughters weren't doing very well. In their eyes, they thought their students should be getting A's or high B's where they were getting B's minimal C+'s . We had an hour chat. And after an hour, they weren't*

[9] See Appendix E regarding the origins of the study guide. See Woodrow (1998b) for description and use.
[10] All principals' names are also pseudonyms.

> *going away! I said "I sense you want something from me. What is it?" One parent slams their fist down and says, "I want some good old-fashioned teaching going on here." And I said, well, you're not going to get it. He said, "We'll see," because he was going to go up and talk to Norm. I never heard anything back because Norm knew what we were trying to do. If you're going to take risks, you have to be allowed to fail. That was the kind of support that he gave. He said, I know that you're trying to do something, I'm not going to think any less. He didn't come out and say this but that was the kind of feeling that, "Hey, if it bombs, so you tried something different. This is a huge risk to take. If it doesn't work out, that's okay." That's a big load off your shoulders. <Steve>*

The support of the principals gave the TESSI teaches confidence to learn from mistakes and succeed.

2.7 Peer Support and Collaboration

The TESSI teachers also enjoyed the support of their peers. Indeed, Teacher collaboration has not only been a hallmark of the TESSI project but a necessity:

> *Fortunately, Frank was right across the hall and it was just "OK, don't worry about this." The first time I ran into a roadblock, like, how do I do this? He helped me. I don't know, you guys are all younger than a and I don't know if that means anything with more energy or whatever, but without him, I don't think I would have made it. At least not anywhere near coming up to speed the way it is now. <Kris>*

Collaboration has taken the forms of technical support, co-development work on student materials, sharing ideas, observing each other's classes, and constructive, peer criticism in various formats:

> *We all had a common goal, we all wanted to do the best job we could and use the technology in the most effective ways. If someone had a critique of what happened in my room, it wasn't a personal critique. It was a critique of something that we had tried. And that was very crucial in the group that it wasn't a personal issue. <Frank>*

2.8 Support from the Project Director

Dr. Janice Woodrow is the originator and facilitator of the TESSI Project. While operating in the official capacity as Project Director and University Researcher, she is variously described by the teachers as "the glue for the TESSI Project," "an incredible peer," and even "like a mother." TESSI teachers appreciate the positive atmosphere of learning and collegiality that Dr. Woodrow brings. The supportive role Dr. Woodrow played gave freedom for the implementers to take the necessary risks to transform their teaching:

Janice didn't want to direct which way everything evolved. It just evolved, you know? <Steve>

So what happened was Janice was in our classroom very often, about once every two weeks, most likely, for the first few years [to observe and debrief]. That was where the administrative support came crucial. We were allowed to make some mistakes -- that was essential in the development phase. I felt quite confident that if things were going to go off the rails, I could pull out at any time, or I could stop at any time. Janice made that very clear. I felt like I still had a safety net. I would still encourage students to try things, and if it didn't work, okay. <Frank>

Dr. Woodrow also gave a buffered credibility to the teachers, wrote grant proposals, selected the participants, chaired the meetings, encouraged collaboration, and provided the "gentle direction" required to allow the program to evolve. She helped to articulate the project's developing framework and pedagogy, publicizing and promoting integration projects through dissemination, journal articles, conference presentations, workshops and "chats with the principals." In so many ways, Dr. Woodrow was the key advocate.

2.9 Impact of the TESSI Classroom Infrastructures on the School infrastructure

In each school, the TESSI classrooms have become "wall-less," functional areas that not only serve the classroom teacher during scheduled classes, but other teachers and students in the school who take advantages of the technology infrastructure at all times in the day:

Kids just drift in and out all the time. That's something really weird I had to wrap my mind around. You are used to closing door and you have your own little empire, well, that's just close out the window. You cannot to close your door because constantly someone is knocking on at wanted to come in and pick up something from the printer or they want to use the computer or they want to see if they can use the computer if your kids are not using them all. It is neat.

It has a spill over effect. One of the neatest things that happened in the first year I taught kids CricketGraph, some of them were doing a population growth occurs in social studies and a kid comes up and says " Hey, Mr. A can I do this on the computer?" I said, "Sure, go right ahead." then the social studies teacher comes up and says, " Boy, that was a pretty neat graph that the kid produced. How did you do that? " They didn't even know that this was a possibility. They were working with their old graph paper. So it has some positive aspects of that way where it spills over to the whole school. <Kris>

Although technology integration may occur only in one classroom, with one teacher, the pedagogical and technological impacts may be felt throughout the school and even in the School District:

In terms of the pedagogy and the technology, things have certainly filtered through the rest of the building. The level of technology has gone up in the school. Most of the science department is using technology in active ways in their lessons. We've had quite an influence on the way we spend our money in technology, getting it more in the classroom, and very little money has actually been spent on Computer Science and Business Ed. Just about all of our money has gone into classroom technology. So we've had influences in that way. But in terms of the program itself and being warmly accepted by the staff, not at all. It's been quite isolated and that's been very difficult. It's been embraced in the District, however, within my school, the staff has not always been that supportive. <Frank>

In some schools and School Districts for example, the TESSI teachers have helped put positive pressure on the school or District to evolve technologically, changing the way that their School Districts view technology integration and the funding technology.

3. Student Learning & Pedagogical Practice

This section presents the technology integration from the perspective of the evolving conceptions of student learning as mediated through the teachers' changing pedagogical practices. The issues that are addressed include teachers' conception of how they make their classroom work with technology, the responses of their students through the years, the choices teachers made in using or not using certain technologies, the change in student-teacher dynamics, and the differences in student evaluation and feedback as technology integration progressed.

3.1 From Centralized Teacher Functions to Early Student Functions

When the teachers first started using computers, their use was mainly limited to word-processing and other teacher-functions such as keeping marks. Few had any ideas of how the early generation of computers could be used to enhance for student learning:

From the students point of view I didn't have any specific goals. <Steve>

I had no idea. I mean, when I started, you have to remember that when I started, first of all, when I graduated from high school, my parents' graduation present to me was a slide rule. Calculators in that day cost two hundred dollars and they would add, multiplied, divide, and take percentages -- what the cheapest calculators do now. And that was a two-hundred dollar calculator in those days and we could not afford that as students. So we had no clue. And then we had the Commodore 64s, and all that kind of stuff, and that was big, big news back then ...

and we started doing word-processing and stuff that made worksheet, labs, and stuff for the kids so it would look nicer. <Kris>

The few commercially available student programs at the time were considered optional teaching materials. Indeed, TESSI did not "officially" begin until a promising piece of software for enhancing learning emerged:

> *The very first version of Interactive Physics, came out and Janice had seen it and went, "Hmm." Now technology is at a stage, software and hardware, where it's more than just an electronic textbook". So that criterion had to be met or was met. Then Janice had an idea: How can this go into the classroom? <Steve>*

The early days of the technological implementation were spent gathering resources and testing their classroom suitability. Success was mixed. Some of the teachers went through a "media-center" stage, where a few pieces of technology were centralized for teacher presentation (supplementing lectures and demonstrations of concepts) and improving teacher functions such as resource testing.

> *I acquired some technology: a big screen t.v., an Apple Presentation System to allow the big-screen t.v. to mimic the computer, like an Averkey-type of thing ... and I started to use it in a demonstration way in my classroom, sort of a Level 1 use with the teacher using it for demonstration purposes. So I continued doing that for the following school year as I learned more about the sort of technologies that Steve and Frank used and whether or not they could apply to Biology and started to look and review resource and accumulate resources. That was the first year. <Edward>*

As teachers began to experiment with students using the technologies, some of the early applications were graphing, word processing, and interactive testing:

> *I found it was better if the kids were using the stuff also if they were working from some kind of sheet and they were looking for answers on the laser disk. If they had control of the system, they could stop it, make it go backwards, do this piece again ... So I used it that way almost immediately. The computers --- for the first while I only used them for LXR, making up exams, interactive test. Some of the kids used the word processing programs to type up their labs, CricketGraph I used right away as soon as I was comfortable with it, I saw the beauty of that rather than plotting stuff on graph paper. It was not much more that that. <Kris>*

At this stage also, the teachers began to recognize some of the benefits in student learning that could be achieved.

While technology allows for a greater selection of tools and resources for student learning, the question of which resources to use and their sequencing proved to be challenging.

When to do this and that? Do we use a simulation? When's the best time? Some of them seem to fit in very nicely as an introduction and that's been a real struggle to find because if you don't place them in the right spot, I don't think kids feel they are getting any benefit from it. <Harry>

3.2 Introducing Students to the Technology Enhanced Classroom Environment

As technology was increasingly introduced into their classrooms, the TESSI classrooms increasingly became a learning environment different from that experienced in other classrooms. The teachers realized that they needed to prepare students to function effectively in this changed environment. In particular, the teachers emphasized that the focus is not technology but learning.

> *The technology is merely a tool, just like the calculator. So we don't focus on that at all. I normally tell them, yeah, we're going to use computers and multimedia and all this fancy stuff, and I'm assuming you know nothing, so don't worry about it. As we hit it, we will teach you how to use it. But that's not what I'm concerned or interested in. We focus on the pedagogy and why we are running the classroom that way, why we are teaching this way, what the benefits are for them in doing it this way. I also try to explain how their role and my role will change. That the teacher is going to be seen doing different things. They may perceive him as not teaching. So I have to re-educate them about what I do and re-educate them about what they're expected to do. <Frank>*

Frank describes in detail how he inducts students into learning with technology by introducing the technology classroom environment:

> *I show them the TESSI videos, portions that show what the students are doing, and saying, "This is what, in a few weeks, it should look like. " When anybody walks into this room, they shouldn't be able to find me, because I'm going to be in the midst of you somewhere, probably kneeling down next to you or sitting next to you, or something. But they should see you doing a variety of things simultaneously, being quite self-directed in it. For the next few days, they begin working with the study guide, and I try to reinforce at all times that they should be on task. Often I'll interrupt them and say, "Look around in the room. What's happening right now?" And I'll describe what I see happening at each station and say "this is good, or this is not good."*
>
> *Once the pedagogy is down in terms of the idea that you're on task and working on things, trying to solve a problem without necessarily the teacher, then we begin introducing aspects of the technology one piece at a time... So the technology really isn't the focus, it's the pedagogy that we focus on, or that I choose to focus on. <Frank>*

An alternative introduction is to maintain a more traditional classroom environment where there is an emphasis on establishing classroom management and teacher rapport and then evolve to a more self-directed one as more technologies are introduced:

> *Steve would do it differently. Steve would focus much more on the technology first because he is directing and controlling his classroom much more. So the impact of the pedagogy of the self-direction is a little less. In a way, he does it smarter. It's a much more incremental change for students. Again, I don't think either is better. It's different. <Frank>*

3.3 Preparing Students for Technological Interfaces

As well as providing an introduction to the new environment of a TEI classroom, the TESSI teachers found that they needed to introduce and prepare students for every new interface. Students are often surprisingly weak in this area.

> *[Students] had no inkling of how, what was going on, how to do this sort of stuff, they were just following the worksheet... I say, here's what you're going to do, and I'm expecting you to open up this file. Here's its name -- I go through a whole spiel. When they're on the computer, they say "how does it turn on?" Well, you find the knobs here and here, you know, so you have to go around and troubleshoot that. In some ways, it's worthwhile to give that 10-15 minutes of here's the computer, it's our friend. Here's how you turn this one on... You almost need to do that because it seems like so few of them have any real skills. Even the ones that are really good at computers, you know, expert-type kids, who play with the Internet everyday and know how to network computers, even their level of ability on the computers is not that great. They have trouble with the more technical aspects of the program. So they need a lot more time to know, for example, how the MBL activities work. <Harry>*

Generally, students new to this type of classroom environment require approximately three to four months to feel comfortable with the learning approaches and the variety technological interfaces.

3.4 Mixed Student Responses to Learning with Technology – Early Years

Teachers noted that student response to the implementation process, particularly in the early years when the teachers were still experimenting with a variety of resources, was varied and seemed to depend on what they perceived the teacher should be doing ("what teachers are suppose to do for you") and how well students personally adapted to the changed classroom environment:

> *That's been hard because one the things I've prided myself on over the past few years ...relationships with kids and I feel in some ways that I'm forcing them into some activities in which they're not enjoying. It's taking me away from the lecture that they are coming into my classroom expecting ... I'm making them so through some stuff where they have to*

go through their own sort of groundwork. They don't feel they're learning as much. I'm having a hard time with that.

I think there are a certain percentage of kids, that do not like to use the computer for learning. I would have no idea what that percentage is, but I always get some kids who refuse, or say, I don't like this or I get nothing out of it... Other kids don't seem to mind one way or the other, and other kids enjoy it. For me, the biggest adjustment I had to deal with is the feeling that, in some ways, that teacher-student relationship is damaged by their feeling that this is not the experience they are looking for in chemistry. A lot of that is due to the little technical glitches that occur ... Errors show up. And they say, look, I did everything right. Yeah, you did everything right, but go look up the answer and the answer is not there. It's discouraging. The little things in the simulation, they go very far in the simulation and they get to the point where it's like, what the heck is it talking about? And that's discouraging. For the MBL activities, it's just a simple sort of calibration. Not calibrating correctly leads to all sorts of significant problems. <Harry>

`I don't like this, I'd rather have you telling me, teach me. Tell me what I need to know. Obviously, the kids have that perception. They just didn't feel comfortable approaching me directly. I think that is just because it's new. Once its been in place for a bit, I don't think that issue will be there because the students will never have seen [me] ... stand up and lecture all the time. It will be like, `what are you doing?' The students' perception of that is unbelievable. Unbelievable. `You don't do anything, sir!' ` Well, no, I don't do what the other teachers do.' ... It's not so bad with the kids who haven't seen you before. It's only a problem with kids who have seen you before because they go, you're not doing what you did last year. What's going on? That's the resistance. I guess tied in with that is the students' perception of what a teacher's job is. <Steve>

Student responses become more positive, usually during the second or third year of integration, as the various conditional factors come together and as the teachers become more comfortable with their new pedagogy:

Students weren't as accepting of it, for example, than they have been this year. This year has been such a tremendous difference. This year there have been no questions, they've done it, they're happy with it. There have been no complaints. Last year, there was a fair bit of heel dragging. It's like, "No, no, we don't want to do this. We want to do it the other way." I heard that quite a bit last year and this year, I haven't heard that one single time. Not ever. <Edward>

3.5 Changing Student and Teacher Relational Dynamics

The introduction of technology into the TESSI classrooms had a dramatic impact on student-teacher relational dynamics. The teachers realized that they had to become more flexible in managing the classroom if they wished the students to use the technology effectively. It was acknowledged by most teachers that inevitably, teachers would have to be more flexible in managing the classroom:

> *Steve: As much as I say that I'm practising what I believe in, however lectured for so long, I like the quiet classroom. So that there's that whole control issue. Oh, you give it up, and that's the biggest thing for somebody to deal with.*
>
> *John: Is giving up control of your classroom is inevitable?*
>
> *Steve: I don't think so. I think to really utilize the stuff, it does lead to that. It doesn't mean you have to go there, but that is where the path is definitely headed and you have to make a conscious decision to not go down that path.*

Although not easy at first for the teacher to accept, the control that teachers gave up became assumed by students. The teacher was still in charge of course, but the responsibility for learning shifted more to the students.

Because the multi-paced, multi-activity technology integrated classrooms tend to towards high student engagement and self-direction, the teacher could become much more aware of individual student understanding and progress. There could be more individual attention given to students. Students opened up more in less-threatening small group or one-on-one situations with the teacher. The pattern of student and teacher interaction typically became much more varied and different:

> *I move around a lot more, too. I think I'm much more aware now of what students know and don't know because I'm working with them in small groups. In particular, the way I structured my classroom, I have it set up to try to keep the marking down to a do-able level. I have an answer key to their study guide. I'll have a homework check on it at a period. I tell them the period before they have to have it done to a certain point by the next period ... and then at the beginning of class, I'll go around to each student and check to see if they accomplished that. Now if there is a particularly hard section in there, a section that I know traditionally kids struggle with, then I'll go to each student and talk to them a little bit about it, at least check what they're written down and ask them some understanding-type questions. That way I can find out if they're getting...and if I find out a whole bunch of them aren't, then maybe I'll do a class review of it on the spot. I don't think that in a normal classroom with lecture-style you get that opportunity to really understand students unless you give a quiz. You ask the students, if you don't understand, please speak up, but they don't. They don't want to look stupid in front of their peers. This way, individually, they're much more comfortable. They get used to it too, saying, "No, I don't really get this." Or sometimes I'll go*

around and say, hang on, and I'll pull five to six kids up to the board and go through it with them. I think that's a real plus. <Edward>

However, it took time and experience to establish these new classroom dynamics. Compare the above comment of a teacher with three years of experience with TEI with a teacher early in the integration process who found it difficult to create the conditions required to sustain such a classroom environment:

> *With the time and management aspects, I'm having a hard time still seeing us as the chemistry TESSI teachers setting up a room where kids are working at their own pace, and working on different activities and multi-activity room. I'm having trouble with that now. That's one thing that maybe will work its way out and we'll be able to do that sort of thing. But I think there are some real benefits in that though I'm having trouble seeing it at this point <Harry>*

When the students' attention was drawn away from the teacher and toward learning, an interesting transformation of classroom dynamics appeared: students who are prone to off-task behaviour and difficult to manage in a whole class group situation get isolated, becoming less detrimental to the class as a whole and allowing the teacher to respond to their behaviour more effectively.

> *[Passive kids] really stand out in a TESSI classroom because they're sitting there not really doing anything, yacking away to themselves. The kid's passing and not creating too big of a problem, then maybe it's not necessarily that big of a problem. But when you're trying to lecture to a big group of kids, that is a problem. Kids are off task and talking to one another when you're trying to teach. In a TESSI classroom, it's not such a hindrance when you're trying to teach as a teacher,...It becomes really obvious in a TESSI classroom, too, but maybe it's not quite so harmful except for that particular kid and the kid they're talking to. It's not quite as detrimental to the whole class. I don't know if it's less annoying now than it used to be able to. <Edward>*

When the teacher is constantly moving around the technology-integrated classroom, there is a characteristic high level of interaction between the teacher and individual or small groups of students. This interaction changes the traditional teacher-large class dynamics in a variety of ways. For example:

> *The other thing is, you get to know the students a little bit different. I don't get a chance to tell all my good stories anymore that I used to tell when I was lecturing. .... I don't know if the students get to know me in the same way they used to get to know me. It's a different way. Maybe I'm not the all-powerful, omnipotent teacher-being that I once was -- not*

that I think it's a bad thing – but it changes your relationship with the kids. <Edward>

Thus the relational dynamics between teacher and students changes, due in part, to the pedagogical choice of the teacher and in part, to the role the TESSI teacher plays in being a leading developer and implementer:

> *Teaching with technology has impacted my relationship with students, in the opposite way than what one might think TESSI would. I think that the perception of TESSI is that the teacher would be much more engaged with individuals and in a classroom sense, you certainly are. In an academic sense, and a traditional "teacher-role" sense, you certainly are. You are tutoring and mentoring and motivating individuals much more often one on one. However, a lot of what students seem to respond to is part of a group dynamic of performance and charisma. And they are attracted to that in some master teachers. I haven't been doing that for several years. That relationship has certainly changed. They've even said things like they don't see me as teaching anymore, although I am teaching more now than I was before to individuals. I think I have lost something in the relationship to students because of TESSI. And I would like to qualify that. I don't think it's necessarily because of just TESSI per se, the pedagogy, or the classroom level, I think it's been significantly impacted by the time pressures of the leadership roles we have had to do, and resource development in workshops and presentations and funding and grants and travelling and trips. <Frank>*

3.6 Enhanced Teaching and Learning – The Maturing Classrooms

As teachers became more comfortable with the learning technologies they began to use them effectively in the classroom, often creating technology-based, innovative learning. It was at this point that the teachers began to really notice how technology enhances student learning. This change was most apparent in the more mature (in terms of technology integration) classrooms:

> *One of the traditional things I would do with the unit on cell structure would be to have the students do a poster of the parts of the cell and draw them and label them and indicate the functions. It's still one of their assignments although there's more flexibility in doing it. I give the option of maybe doing a multi-media presentation. And a couple of students this year did it. One kid put together a really nice PowerPoint of it, another kid did a HyperCard stack of it... What they also see is a number of computer animations of the different cell structures which are quite good, 3-D computer-generated animation like things opening up, how they work, the labelling of the structures. <Edward>*

In another activity, Edward describes how he uses an imaging tool, called NIH Image, to help students learn cell structures not from the text-book diagrams but from actual electron micrographs:

So what I have them do now with this particular thing is to use a computer to look at these electron micrographs. They have to identify and measure organelles on the one which is not nearly quite as easy as it sounds because they realize that, "Oh, these things on the electron micrograph don't really look like the book" ... The second part of this activity, they look at a number of different electron micrograph images and they have to cut out organelles and design, basically, their own cell. For example, cutting and pasting ... Kids after that, I've found, and also they've told me, they really understand what these electron micrographs are in doing this activity. I think it's a tremendous way for them to learn these structures, one that they couldn't do, necessarily without computers. I suppose they could do it with photocopies on paper, but not quite as efficiently as they could do it on the computer. <Edward>

Teachers and students alike found that they could do more or different things than previously possible without technology:

From the response but I got from some of the students, they felt that some of the results we've got were quite more instantaneous. When the probes worked, the results were right on the screen. That was interesting and they liked that. They didn't have to wait around and plot points. It was actually there and they could see the cause and effect very, very quickly. I thought that was beneficial because we could spend more time experimenting and trying different things that and seeing the results right away. <Lawrence>

I am doing more things than I did before. For example, analyzing tests. When you give a kid a question, how you know if it's a good question? You have to analyze the stats. Without computers, you can't really do that. I'm able to give them feedback now on concepts that they know and don't know using LXR... I print out the mastery report for the students. They can see what to areas they haven't done well in. <Steve>

Teachers came to rely on the technology to support student learning:

If somebody took my computers away, I could go back to lecturing like I did before. [But] that would be very difficult to do. Very difficult to do. Yeah, I'm in my comfort zone right now. There's no doubt about it. <Steve >

And gradually, the technology became transparent to the students:

Other than that first wave of kids, the first two or three years, the students now, they look at you...I try to explain that you're in an unique classroom here. "What? You mean all physics classrooms aren't like this?" <Steve>

3.7 Reflections on the "Traditional" Teaching Strategies

Integrating technology means finding the best practices and perhaps this may involve balancing between traditional and technology-based learning strategies. There are advantages to the traditional teaching strategies in certain situations. For example, the lecture may be used as a motivational speech or to make up time, as a means of pushing the students along or simply for broadening the learning repertoire of the students. Homework problem sets and textbook work is still used in the TESSI classrooms as a source of information and for problem solving. Edward expresses the general attitude of all teachers towards traditional teaching strategies as:

> *I have no problem with keeping the traditional stuff in if it worked well. Something that works good, hey, leave it. But if there's something that the computer could do that does it better, let's do it that way. <Edward>*

While a starting implementer may fall back on traditional learning strategies for various reasons such as lack of choice or familiarity, teachers further along into technology integration may continue to use traditional learning strategies out of choice and consideration for breadth of student learning. Technology is used where it can truly enhance learning, otherwise it is regarded as an expensive, add-on toy, and abandoned.

The hands-on lab is one "traditional" teaching strategy which most teachers indicated that it should be retained or even mandated for the purposes of skill development and physical problem-solving. This attitude was most striking among the chemistry teachers who felt that Chemistry, as opposed to Physics or Biology, required the mastery of a greater number of physical and manipulative skills.

> *You must do at least this number of hands-on activities, as a minimum number. But once they've met that minimum number, if they want to do solely simulations from that point on, that's fine. They have to be able to learn to use a ruler and a thermometer and a piece of string and deal with something in the real world. They can't all be simulation-based. <Frank>*

> *There are some things that have to be done throughout hands on chemistry such as making up a solution. Process skills kids still have to have. I'm thinking that the computer is fine for certain measurements, but if they are going to do a titration, I would like them to be able to see phenolphthalein change from colourless to pink ... That sort of thing, you cannot do without. There is no way technology can change my mind about that. There is something about the process of actually physically mixing the materials that kids really enjoy. If they just get it off the video clip, then why not just watch Bill Nye? There's that physical, kinaesthetic learning that they do while they are mixing things. Same with the titration. There is a lot of manipulation to that. <Harry>*

Hands-on labs can also be technologically enhanced by coupling them with technology – the physical learning component is thus retained and perhaps even enhanced. For example, a physically created motion can be interpreted with the help of video analysis or a titration may be recorded with the help of a pH sensor.

3.8 Student Evaluation and Feedback

As students became accustomed to the new patterns of learning in technology integrated classrooms, they needed constant feedback as to their progress as well as careful direction to support the development of self-pacing and self-direction skills:

> *The other thing is that with the TESSI-thing being so student centered, it is like I've found the kids, to keep the kids motivated or working, they need constant feedback on what they have done and how well they have done on that. So in other words, the mark and there's no way you can do all this marking. I know that everyone is a little bit different, the way I've worked it out tasks me is that the kids work on a task and I call all their assignments tasks, and then when they have it finished, they bring it to me and I talk to them about and check it over individually. One on one -- so this is what I spend most of my time doing now. I might give a small lesson at the beginning of the class, and then they're working. So it's a similar kind of seatwork as you would have been in a regular classroom but then they bring it to me, and it may involve using computers or where they're producing a graph to go with their labs, or whatever, and I analyze this stuff with them and check it over and this may go two or three times. They may take it back to their seat, work on it some more, bring it back to me, we'll talk about it, this is still not quite right, this point you might want to fix, back and forth, until finally it's pretty good, or basically, looking over quickly, I can't see a lot of mistakes. I sign that and then I have an answer key in a binder right beside me at the front of the room ... they come to me, they come to me all the time. <Kris>*

When students interact multiple times with the teacher, they actually receive a lot of feedback, more, perhaps than in traditional classrooms. Teachers found those student perceptions of evaluation also changed:

> *At first, another interesting thing, kids thought I wasn't doing any marking. They said, "Why do we have to mark everything?" [I tell them,] think about that, haven't I marked it when I looked at it with you maybe two or three times? "Oh, Yes, you did sort of mark it, you checked it, but you did not put any marks on it--we do that ourselves." Once I get over that hurdle, they don't mind it. [I also tell them] in addition to that, if you had handed it in the first time, I would have marked it, and you would have got a whole bunch wrong, in which case, you would have a poorer mark then if we had checked it, talked about it, you fixed it, and ultimately, you get a better mark, right? I don't know if that's artificially inflating their mark, but I have a feeling that they are actually probably learning more. <Kris>*

Although it was a novel teacher tool at first, interactive testing evolved to give students another source of instant and detailed feedback. Some students initially resisted this form of evaluation:

> *They wish it were on paper --some of the kids. Some of the kids I had, particularly if I put on it a practice test, they say, "Can I print this off and*

take it home? " No, I said you can do it as many times as you want on the computer. Why would you want to take it home? Why should we waste the paper? It's here. You can come in any time you want, you can do it as many times as you want, just go for it until you feel fine about it. <Kris>

Interactive testing, particularly interactive practice tests, eventually became a student favourite in most cases.

Interactive testing allowed for flexibility in evaluation. For example, the option of providing re-tests or re-quizzes to promote mastery learning was available should the teacher choose to implement this capability. Various experiments in using re-tests by TESSI teachers yielded mixed results thus far. Using re-tests has the potential to spawn a 'second-chance pseudo-philosophy' that was good or bad depending on how students took advantage of this second chance.

What I found last year was some of the kids who would really, really benefit from the retest weren't doing it anyways. Some of the kids who were in the middle were redoing it and they were doing better but not usually significantly anyways. With the interactive quizzes, they do get a chance to retest it but only if they do a corrective assignment first. We do a corrective assignment as something that will take them half an hour, and if they don't do that and hand it into me, I don't count it. If they do hand it into me, I'll count the higher of the two. <Edward>

Another element of flexibility in evaluation, borne out of the nature of a multi-tasked classroom, was the timing of evaluation:

One thing that TESSI does is allow me a lot more flexibility in accepting their assignments. The study guide due dates are by period and they have to be due by that time. Unit tests are universal, but things like their interactive quizzes and things like their handing in assignments that are listed in the study guide, like NIH imaging activities or labs, or MBL labs, they are usually due the period before the unit test or perhaps the period of the unit test. It's not so important to me that they have it done at the same time because they're not all doing it at the same time. <Edward>

Perhaps the easiest and most rewarding indication that students were learning was the observation:

Man, they're arguing about the concepts! Wow, that's so nice ...That's all you have to do. Just talk to them. And if they say they like it, great! <Steve>

4. Student Learning and Curriculum

This section presents the teacher's conceptions of how technology has enhanced student learning directly and indirectly, the emergence of alternate goals, and some of the conceptual and practical differences in technology integration into senior Physics, Biology, Chemistry and the junior General Sciences.

4.1 Conceptions of Enhanced Learning: How Technology Directly Enhances Instruction

Each teacher was asked, "How has it [technology] enhanced your students' learning?" The resounding "bottom line" answer here was increased student motivation and self-engagement. TESSI teachers attribute much of the success of their students to the increased motivation and the corresponding engagement that result from a combination of the following learning enhancing strategies that they have implemented in their classrooms:

1) Multiple representations and enhanced visualization:

> *Ultimately I think that the more different ways you can present something to somebody the more easily it will learn or understand it. Either because they have seen two or three or four or five ways of presenting the same concept or that one of the five is something that stays with them whereas the others didn't. I think the more ways you can hit a kid with something the more likely it will be to sink in ... Biology in particular has a lot of diagrams. Kids traditionally take the diagrams you might hand out as a handout and memorize the labels clockwise fashion around the diagram for example and then wonder why on the exam you give them a different diagram, they get totally screwed up... That is where technology comes in. It allows that to do that even more. Particularly where you have processes in biology or something it's moving across a membrane -- you can see this in an animation which shows that concept much more brilliantly than you could ever do on a diagram. <Kris>*

2) Measuring components not normally or easily measurable

> *The simulations were quite realistic situations that I couldn't model in a demonstration. They could measure things that were happening in situations that in a demonstration, we couldn't hope to measure. Something as simple as a bucket on the end of a rope twirling around in a circle, what's the tension on the string? I could demonstrate that the water didn't fall out of the bucket, that was great, but to actually do some real Physics on it was impossible. So now we could take a situation that was relevant, I could demonstrate, they could see physically, and we could measure and verify the laws of physics or apply the laws of physics to it, so I think the relevancy of physics really clicked in there. ... And the motivation -- students had control over it themselves. They didn't have to sit and watch [us, teachers] as much fun as we are to watch. Given that, that they could actually play with it and control it themselves and that was much more motivating for them. <Frank>*

3) Enabling students to assume some control over their own learning micro-environment resulting in playful exploration and motivation

4) Allowing students to take risks in learning or experimenting:

> *It's not very harmful to the psyche, it's not bad to make mistakes! It's quite friendly. I think students are willing to take risks with it. <Lawrence>*

5) Facilitating cooperative learning

> *Technology sometimes teaches higher-level skills that aren't necessarily measured on the exams we give them. For example, ... last year I had a group of four students, three girls and one guy and they were amazing. They did everything together as a group and they helped one another. They'd sit there before they write their interactive quizzes. They'd quiz one another about the study guide. They did all the activities. They did them in a really high level. They'd help each other. They'd check each other for understanding. Lots of peer instruction going on. It was amazing. It was perfect. There were a couple of groups like that, but this group in particular just clicked. That's certainly something you wouldn't see in a normal lecture-based class. You wouldn't have that opportunity for interaction. So I think that's a real plus, the way kids can collaborate. <Edward>*

6) Providing quick and detailed computer feedback

7) Allowing students more time to spend on higher order skills:

> *[MBLs] leaves more time to attack more critical kinds of questions. Instead of spending the whole period gathering data, they can gather the data and play around with the parameters to explore other questions and maybe some deeper questions instead doing mundane things that the computer can do: plotting graphs, showing relationships. It's a really good vehicle for that aspect. I think students enjoy that part, where they don't have to draw the graphs but they still do the thinking part. I think it enhances it tremendously. <Lawrence>*

> *I think that one of the simulations that was really hitting the point home in Chemistry 11 is the one where they deal with the periodic table. In the past 7 years, I would have given them an activity where they had to plot the atomic radii of the atoms. They go through it in about half-an-hour or so. Well, they go through the simulation and press a button and they get the whole set of atomic radii already plotted. Now instead of having to go through the tedium of plotting, they've got the graph to work with. Now they can look for that pattern. And so, I think they were better able to analyze the patterns. Then, not only that, they were given the opportunity to analyze other patterns which I had not done anything else except lecture about. They were looking at the ionization energy, electronegativity. Those are things that I would mention and get them to draw up on their periodic table: here's the trend for electronegativity, but they got a chance to develop that for themselves. That was really good and it hit home because they got to spend more time doing the analysis of the data instead of manipulating it to produce the graph and then try to do some simpler, almost superficial analysis. <Harry>*

8) Addressing more learning styles by increasing the number of presentation

styles or experiences:

> *[One of the students] actually told me was that [learning with technology] changed his particular way of learning. His old way of learning was just one way: just from the notes the teacher gave or just from the textbook if that was the case, depending on what the teacher reinforced. Now he's learning from a number of different sources and he really found it much easier and he was doing better. Perhaps, in a way, in that particular case, we are reinforcing to look at more than one resource. <Edward>*

9) Linking conceptual models with mathematical interpretations

> *The one thing I thought that was really good about the simulations in Chemistry 12 is that when they do the equilibrium graphing and presentation and calculations -- that aspect really does help them do the K-equilibrium calculations. So, I thought that helped quite a bit with the mathematical side of things because it then puts that physical reality, they get something out of that little model where they see a reaction happening, but it shows you the graphical representation with calculation, and that's something I don't think I could do as effectively as a straight lecturer. <Harry>*

10) Using MBLs to allow for realistic instrumentation or relevant observations:

> *In Chem., recognizing that the instruments have certain levels of tolerance, certain levels of effectiveness, and then they are able to produce some things that they could not normally. For example, the pH curves. In terms of enhancement, they are able to do a greater level of analysis, it means they don't have to worry about doing so many tedious activities, but they can also broaden the types of activities they can do. So they can generate those things on their own, for example, pH curves.*

11) Broadening the types of student activities

4.2 Conceptions of Enhanced Learning: The Indirect Enhancements

Although most students think "it's cool" to work with computers, a small percentage of students initially have computer phobia. Yet another group do not have a high work ethic. The motivational aspect of using computers can help both groups:

> *They are learning in spite of themselves. You know the kind of kids I mean: hard to motivate. They won't write anything but they will click a button. <Kris>*

Even a lower-level use of computer technology, such as word processing a lab report, can produce important benefits in organization, pride and motivation as Kris explains in this example:

> *It's trivial but the kids always think it is a big deal if they get one extra mark on a that if they type it up... What is one mark out of 40? But they go for it and what it does for them is:*
> *1) It produces a nicer looking product.*

2) They can read it, I can read it --- there's no problem reading a printed page.
3) And this is probably the most important thing, I think it helps them in an organizational way, that if they can organize something on the computer then they are also helping them organize it in their mind, which is probably the most important.

... Sometimes kids produce something that they are really proud of because the looks nice. It is a pride thing ... aside from just learning it, there's a sense of self esteem. "I have produced this, it looks nice". On Parents Night, I have the file folder with all the kids stuff in it and parents are really impressed by it. My kid did this? I didn't even know he could type.<Kris>

The teachers observed that the motivational benefits of learning with technology did not seem to require that students be proficient in using technology:

> *I would say that the technology factors are the least important -- that their attitudes about technology and their previous skills in technology are essentially irrelevant. What really matters is their own personal motivation. Do they care? Also their own ability, in terms of their academic ability, doesn't seem to have much bearing either. <Frank>*

Although some teachers report enhancements in terms of self-direction and time-management, not all teachers observed this outcome—perhaps because of their particular stage and style of integration. Many of the enhancements seem to develop gradually or appear in later stages of implementation as the classroom changes. Indeed, some outcomes may not even be possible earlier in implementation:

> *To me, [changes in student attitudes] is all sort of a grey area. When you talk about Steve and Frank's teaching the kids to be better students, they're looking at the collaborative work, timing themselves, and marking themselves. All those other sort of TEPI goals, I'm not at that point where I can be looking at them yet. I just sort of say, that's great but I still need to put the pieces together before I can be at that level. <Harry>*

4.3 Conceptions of Enhanced Learning: Towards Alternative Learning Goals

Many of the enhancements in learning with technology are not directly related to learning the curriculum. For example, as students experience using computers, they are more likely to use it more and in different ways as an "expansive tool":

> *What I've seen in the last five years is that once they've learned to use a particular piece of software, the technology is much less intimidating to them and they're much more apt to try another piece of software with themselves, to explore and see how it worked. I noticed they use most of the computers and the software in other classes. They would sneak into the physics labs and use it to do their graphs or to do some research with an encyclopaedia on a CD ... that sort of thing. <Frank>*

They soon realized that this laser disc is full of a whole bunch of other stuff and it may lead to various areas that are way off the map and things that they could get interested in, you never know where it is going to go, like the Internet, who knows? Just sort of an expansive tool. <Kris>

Though the possibilities were there before the integration project began, the alternate or unintended learning goals were considered only when teachers realized that the students were learning more than the government mandated curriculum that was tested on the government final exams:

The results on the final exams were showing [us that] we were getting more kids into the course and maintaining the same stats, if you will, with more lower kids in. When we started to really analyze this, we saw that not only were they doing that, but also look at what else they are learning! All of a sudden your eyes open up and you go, Wow! I never really thought about it before. It's really amazing. <Steve>

Thus, learning with technology allows for, and almost requires, teachers to consider innovative ways to evaluate the possible new outcomes. Then the question is whether these goals should be pursued at all:

The challenge we're faced with is time. Learning by doing things, which is essentially the TESSI model. Learning through experience as opposed as learning through lecture does take more time. How can we take a packed curriculum in terms of content in the academic sciences and still hope to complete it within 95 hours? It's unrealistic. So somewhere, we've got to adjust and cut some corners until the evaluation of our courses from the structure of the Provincial exam to [a brief aside] say, here are the nine units in Chemistry 12. Select any three on this exam and they will be tested in depth and we will test skills and the ability to problem-solve (genuinely problem solve, not have you memorized an algorithm and you recognize the type of questions). To me, that's much more sensible. It's not, "have you been able to memorize the breadth of content, rather then go for depth." TESSI is much more suited for that. The exam does not measure the skills that TESSI teaches to students. <Frank>

4.4 What Teachers Do to 'Enhance the Enhancement' of Learning with Technology

Teachers have devised some strategies to take advantage of the learning technologies beyond the boundaries of their individual subject areas. One to these strategies is to teach students the "how's and why's of learning with technology" to help students understand why they are learning this way. This, in turn, enhances their learning:

Number one, I preach that fact --- the need to look at more than one way of looking at things. That is one of the things that I tell them. The more ways you can look at something the better way you can understand it. <Kris>

Another strategy is to encourage self-direction and self-pacing. A technology integrated classroom allows the option for a teacher to let students decide their learning options with respect to time and method to some degree, and this in turn allows students to control and empower their own learning.

4.5 Distinctions among the Sciences: Physics, Biology and Chemistry

Although there are many common elements that have developed in technology integration in the Biology, Chemistry and Physics TESSI classrooms, there are some aspects that are clearly distinctive due to the nature of the subject matter. In Biology, for example, there is greater use of "pre-canned" multimedia software and imaging software because they are of good quality and tend to fit the curriculum requirements well; there are few simulations or MBL labs. In Physics, there is a heavy reliance on simulations and video imaging analysis as compared to the other areas:

Really, it comes down to it; it's very different in Chemistry. In Physics, when the kids would do a lab, there isn't anything I cannot simulate. It just shows you the strength of that program. Right now, I can simulate with the Interactive Physics program or hands on. Now we're trying to bring in more MBL. These are closer to hands on things. <Steve>

Much uncertainty has surrounded the implementation of technology in the Chemistry classrooms, perhaps because it is only two years into development at the time of this research. There are more diverse types of software and technology being tested and used in Chemistry than in the other subject areas. Although there are personal pedagogical preferences at play as well, Chemistry teachers attribute much of the differences to the nature of the subject matter:

One of the questions asked has been how will the different subject areas look? I think that we, as chemists, we've got a little bit more of the whiz-bang subject compared to Physics and Biology. We get the hydrogen and oxygen together in a balloon and blow it up. There's a greater level of wanting to excite kids, a little more opportunity to do that. That's hard to give up. So we have the showmanship side of things. I think that our safety concerns, because we are dealing with different sorts of chemicals, that's an issue that Physics would never have to deal with because they are dealing with mechanical things. Most of the mechanical things that they touch are not going to do any damage to the kids' skin if they happen to get it dropped on it. So there's that issue.

The courses that we're dealing with, the Chemistry, to me, is far more technical than Math, Physics, and Biology. Technical in the sense that there is a lot of little details to deal with in the content. You've got the physical reactions that are occurring, the physical states of matter, the balancing of equations, and you have to tie into that the mathematical side of things. You have two different sorts of domains that you have to mesh together in Chemistry. Maybe it's difficult to see where we're going to head up with it again. I'm sure that our model in Chemistry will be different than the Physics just because of the different nature of the course material and the types of hands-on activities that we're doing or simulations and whatnot. <Harry>

Part of the Chemistry problem has been finding good software that enhances student learning by linking physical reality with mathematical models well at the high school level. Another problem resides with the visualization aspects of Chemistry that are either `a fuzzy macroscopic colour change or a molecular consideration well beyond the high school curriculum.' As a result, Chemistry will probably continue to use more traditional laboratories or MBLs than the other subject areas, and this in turn limits other implementation aspects such as multi-tasking:

If we are doing labs, it's really difficult to have different labs going on at the same time. Just for the safety, equipment, the organization of all the materials you need, it's just unbelievable. A few Chem.12 classes are behind a week and with all the labs, it's just a headache. And I'm finding that with some of the lab procedures, I have to show the students how to use the equipment. A lot of the stuff, it's going to be impossible for them to learn to use on their own. <Lawrence>

The Physics and Biology teachers concur with the Chemistry teachers in suggesting that the Chemistry integration model may have to evolve very differently than that seen in the Physics and Biology classrooms.

4.6 Distinctions between the Junior General Science and Senior Science Courses

Implementation opportunities in the Junior General Science courses (grades eight to ten) have been fewer and have also been a lower priority in TESSI as compared to other programs. Despite the limited integration at this point, there are signs that while the technologies used will be a combination of those used in the senior courses, the structure of the of the junior Science courses will be different:

Everything is structured in such a way that it can work within one period. For example, with the grade eight's, I use the Internet a lot. That was good. Have them find some information. It was a training process where I used portions of a study guide, if you will, not as elaborate as what we have now, but they have to use their textbook to find some answers and

> *they would have to solve some problems. Now they ran into difficulty. They didn't know how to get it. How are you going to get this answer? You can use your textbook. You can use your friends around you. You can use me. You may find your answer on the Internet. That was the way in which I brought it in.* <Steve>

The General Science curriculum is also more content-flexible and focussed on process and learning skills:

> *I think content is less important at the junior grades. If you ask any pure secondary teacher what do you want of the students coming to you, the last thing they will say is I want you to teach them chemistry or I want you to teach them physics. That's not what they'll say. They'll say I want a student with a good attitude who works hard. All the things that aren't related to the content. For the junior science, let's get excited about learning.* <Steve>

As a result, learning how to use the technologies has become important in the junior courses developing skills for the senior grades. Combining skill development (both technological and process) with a flexible curriculum has encouraged the use of technology for research and presentation. For example:

> *In grade ten Biology, I have the students do a report on a genetic disease, or should we be able to select babies, or those kinds of thing. I gave them about three weeks to do all that. Some library time. I said they must have a digitized image. I had the scanner in. They had to get magazines and scan. We had to learn all these different technologies at the same time. That's why it was three weeks. I had students use a video camera to interview somebody and we digitized them that way. Or I had them take screen snaps of people so your first page was the topic with the three people in your group or whatever and that was done through the video camera. Now there had to be images, so that was using the scanner. Then there was just entering the text and everything else. Some people actually did digitized movies, which I thought was great.* <Steve>

Overall the integration of technology into the junior courses will probably still be very experimental within TESSI for a while yet.

5. General Conceptions of Technology Integration

This section presents some broad perspectives toward technology integration that have emerged from the experience of teachers. In particular, the "three levels of technology use" perspective is introduced and how this has framed the experiences and outlook of teachers in the TESSI is described.

5.1 The Three Levels of Technology Use Perspective

From the point of view of teachers who are six years into technology integration, the questions and concerns of integration have evolved into complex issues. For example, technical problems have subsided in importance, while pedagogical issues have become more crystallized:

> *And the pedagogical issues, ... now we do have some answers. We do have some direction and some goal posts that people can shoot for and they can move the goal post for sure, but at least they can say, "Ah, this is what it is supposed to look like. " or "This is an issue and that's okay." There are some right and wrong answers and there is some encouragement or correction that can happen. But we didn't have that. I think we can hopefully, save some of the agony for the other development sites to fast-track some things. What we can't say is the resource development. That's the headache that everybody has to go through.* <Frank>

In fact, many of the dominant themes of integration discussed so far in this chapter can be summarized from the perspective of time (or phase of technology integration) versus activity (of teacher and students). To do this, Frank describes a "Three Levels of Technology Use," perspective that has caught on with a few members in TESSI. The Three Levels of Technology Use describes a process of incrementally increasing the level of technological use with a corresponding shift from a teacher-centered to student-centered pedagogical model and an increase in the number of the types of activities occurring in the classroom:

> *I see it [technology implementation] as three Levels. One level is teacher-directed, lecture-based. Using technology to enhance your lecture. The second level is teacher-directed, student-based, here students use the technology. However, they are directed to use it by the teacher. And generally, only one activity, at most two, is happening at the same time in class. The third level is student-directed, full integration of technology, several activities happening simultaneously in the room and the teacher's role drastically shifting from teacher-centered to much more of a mentor or coach.* <Frank>

For Frank and Steve, the two most experienced TESSI teachers, the three-levels model developed serendipitously based on the observed changes that have occurred in their classrooms and linked with their readings through their Master's program:

> *Luck! It was an evolutionary thing. There was no model to refer to when we first started, there was no answer, when we started. So we tried a lot of things that worked and didn't work. We tried giving students complete freedom. We bailed out of that one pretty fast. We also found that it was a function of teacher style. Teachers preferred to have more control. For*

example, Steve prefers to have more control than I do. And so the way we implement TESSI is a little bit different. My students tend to have a little more choice for control in what they do and in Steve's classes, he has more control over what the students do. Neither is better. They are just different ways of managing it. *<Frank>*

Frank describes the story of how Frank and Steve evolved into the Three Levels perspective in detail in the interview extract in Appendix D. The Three Levels of Technology Use can be summarized in the following table:

TABLE 4.1: Three Levels of Technology Use

Level	Teacher Activity	Student Activity
1	▪ Teacher-centered classroom and instructional style	▪ Student watches teacher using one computer with overhead projection
2	▪ Teacher balances control of technology use with students	▪ Students do all activities together at the same time in "lock-step"
3	▪ Few teacher-led instructional activities; teacher facilitates	▪ Students utilize technologies as required to accomplish tasks in a relatively independent, self-paced manner

5.2 Consideration of Progression in Integration

While the themes of technology integration presented thus far in this chapter have been very similar for the TESSI teachers, the rate of progress of teachers through the integration process has been very different. The Chemistry classrooms, in particular were rapidly thrust into the equivalence of Level Two (using the Three Levels approach) in comparison to the Biology and Physics implementations for example, while the Physics and Biology implementations can be considered more gradual.

Edward found the Three Levels of Technology Use a satisfactory description of his experience with technology in his Biology classroom. Although he was up and running through the Levels very quickly, he recommends spending more time on the Level 2 or a transition period between Level 2 and 3 so that the pace of change would be more manageable:

It [the progression through the Levels model] works fairly well for me. If anything, I tried to push it a bit from what I was probably ready for in order to prepare and research my thesis. I think I would have been far better off to use it at a Level 2 for a while before jumping to Level 3.
So it wasn't much of a transition period. I mean, that was the way I wanted it, but in retrospect, a transition period would have been quite

> *useful.... Using a Level 1, getting comfortable with the technology. I'd use this for a novice, an average novice teacher, or an average novice technology teacher. Getting comfortable with the technology and knowing how to use it yourself, realizing the potential it has for your curriculum, then moving to where the students can be in lock step. Demonstrate the technology. Here are some of the features. Here's our NIH image activity for the day. Go to it. That's a step that I missed, and yet I think it's an important one. Because when you're trying to get the students to do it self-paced, there's many different activities going on in the room to deal with all the issues, to deal with the issues of students not perhaps appreciating the benefits that they're getting, or complaining about the fact that you're not teaching them, and then trying to work through all the technology issues that they're encountering that you've never seen before, is pretty difficult. I think the Level 2 step is a pretty important one. <Edward>*

While Kris had heard of the "Three Levels," Kris preferred to describe his overall integration experience slightly differently, to include his personal progress of mastering the technologies and developing a technology enhanced curriculum:

> *The first year was like, here's the media center, here's how to use the computer on the media center to teach the kids how to do programs on their own computer...*
>
> *As for me, I take control of the machines in my room and say, OK kids, sit down and watch what I'm going to do on your screens, screen share, and I work through with that, and now go to it. Then I walk around and help them individually if they run into problems. So that's the second stage: I'm comfortable with the technology now and I have a certain base of stuff to work with, but I'm nowhere near where want to be.*
>
> *The third stage as I see it, and I haven't gotten there yet, would be: I have everything finished and in the sense that I can run a whole course as TESSI, with a study guide, all the stuff available, all the simulations and programs that work.*
>
> *Then the fourth stage for me would be now adding on anything new that comes through, like a new simulation module comes, a new program comes, ... upgrade this, make this better. <Kris>*

Kris also commented that the pace of change for him was very rapid and the momentum of change seemed almost inevitable because the integration forces just "pulls you along" into itself:

> *You just have to jump into it and you sink. Gradually you come up for air. That is all there is to it! <Kris>*

Steve reminds us that his "comfort zone" in technology integration only occurred after five years, and like the other teachers, there were some critical periods when he weighed the choices to integrate technology into his teaching:

> *I don't think we were convinced probably for about two years. We felt it, that it was the right thing to do, but there are all these experiences, frustrations, about technology. If I believe this is the right way to go, then when I have a problem and it is taking up all of my time, and I don't know what to do or should be doing, that creates stress. Is this technology worthwhile? <Steve>*

While his last question, "Is this technology worthwhile?" is not one directly explored in this study; it is an important question that has driven the pioneering efforts of the TESSI teachers as described in part through this chapter.

6. Summary

In this chapter, the major themes in the integration and implementation of technology were identified and contextualized within three major domains:

1) Personal Aspects
2) Infrastructure
3) Student Learning:
    a) Student Learning and Pedagogical Practice
    b) Student Learning and Curriculum

A possible framework for outlining the progression of technology integration was also presented.

The "Personal Aspects" section considered the changes and effects in the teachers' personal and conceptual concerns regarding technology use, pedagogy, personal life, and professional responsibilities as the teachers negotiated the integration technology into their practice. "Infrastructure" examined the supportive framework of human resources, funding, technical, physical, and organization structures, upon which technology integration was set-up. The "Student Learning and Pedagogical Practice" sections described the evolving conceptions of student learning as mediated through the teachers' changing pedagogical practices. As technology integration progressed, the teachers' conception of how they made their classroom work with technology, their students' responses, the choices teachers made in using or not using certain technologies, the change in student-teacher dynamics, and the differences in student evaluation and feedback were addressed. In the "Student Learning and Curriculum" section, the discussion focused on the teachers' conceptions of how technology has enhanced student learning directly and indirectly, the emergence of alternate goals, and some of the conceptual and practical differences in technology integration into senior Physics, Biology, Chemistry and the junior General Sciences.

In the next chapter, how the major themes in technology integration interact with one another, their implications, and significance will be discussed. A model for considering the conceptual and practical aspects of technology integration into teaching will be formed.

CHAPTER 5: DISCUSSION: FINDINGS, IMPLICATIONS AND CONCLUSIONS

This inductive, multi-case study documents some of the issues facing teachers who have implemented, and continue to integrate, technology into their science classrooms. This chapter summarizes the results of this study, discusses the implications of the findings, outlines some limitations, and suggests issues for further research. In the final section, the findings presented are used to develop a framework in technology integration in the field of educational technology.

A. The Student-Teacher-Infrastructure Triad: Domains and Relationships for Examining Technology Integration

The core issues pertinent to technology integration, as identified by TESSI teachers, occur within three domains, the student domain, the teacher domain, and the infrastructure domain, which are defined as follows:

1) **Student Domain:** the issues and concerns of student learning and pedagogical practice, student activities, student evaluation, and curricular and non-curricular concepts and issues.
2) **Teacher Domain:** personal, professional, and pedagogical issues and conceptions.
3) **Infrastructure Domain:** technical, physical and logistical concerns, financial and student resources, people resources, and administrative support.

These three domains encompass the dominant emergent themes in this study. Each of these domains will be discussed with respect to the findings, implications, and conclusions at the beginning of this chapter. While the issues discussed were experienced in the past by the TESSI teachers, they are likely to be experienced by teachers implementing and integrating technology today. In fact, the issues discussed here continue to form part of the "ongoing story" today for most of the teachers in the TESSI project. This discussion is concluded by a presentation of the inter-relationships of the three domains with respect to their progression in the technology integration.

1. Student Domain: Products and Processes

1.1 Evolution of Student Learning and Teachers' Pedagogical Practice[11]

The evolution of changes in student learning and pedagogical practice over the course of technology integration in the classrooms studied is delineated by simultaneous transitions in:

1) student responses,
2) role of technology and use,
3) student-teacher and other class dynamics, and
4) pedagogical approaches: conceptions, strategies, and activities.

The sequence of these transitions begins with the limited, teacher-centered use of technology prior to the teachers' full-scale integration of technology. Student software programs are generally considered to be optional teaching materials of little value in the classroom. A beginning stage for introducing the use of technology to enhance student learning is a "media-center" stage, where a few pieces of technology were centralized for teacher presentation (supplementing lectures and demonstrations of concepts) and improving teacher functions such as resource testing. Classroom dynamics at this stage remain unchanged from a teacher-orientated classroom.

As students begin to use small pods of computers in the early stages of a full-scale technology implementation, student reactions vary. These responses are attributable to a variety of factors including:

1) resources are still being gathered and tested for suitability,
2) sequencing of resources and activities is still preliminary because the teacher may not have had technical nor pedagogical experience with these types of technology, and
3) students have not personally adapted to their role in class or to what they perceive as the teacher's role.

Generally, students new to this type of classroom environment require approximately three to four months (for most of the students) to feel comfortable with the new learning approaches and the variety of technological interfaces.

[11] Pedagogy is introduced in both the Student Domain and the Teacher Domain. In the Student Domain, pedagogy is discussed more as the apparent *products and practices* of instruction such as student activities and strategies, while in the Teacher Domain, pedagogy primarily refers to the *beliefs* within the teacher.

At about the second or third year of technology integration, the various conditional factors come together to sustain a higher level of technology use and TESSI teachers notice that student responses improve and student-teacher dynamics diversify and change. At this stage, the student learning environment becomes characterized by:

1) high student engagement, student talk, and self-direction in the multi-paced, multi-activity technology integrated classroom ,
2) high levels of interaction between the student and teacher and within small groups of students (with or without the teacher), and less interaction as a whole-class,
3) more awareness by the teacher and student of individual student understanding and progress because of the increased individual attention in less-threatening small groups or one-on-one situations,
4) reduced interference from students who are passive or troublesome (in whole class situations),
5) change in student perception of the teacher's role, and
6) technology being more accepted and used by most students as routine learning instruments in diverse ways.

The teachers' conception of student control also changes. Although not easy at first for the teacher to accept, students demonstrate that they can assume the apparent control that teachers give up, i.e. the responsibility for learning shifts more to the students.

In the mature TEI classrooms, teachers and most students are very comfortable with the technologies. Consideration of how technology can be used effectively and creatively by teachers to enhance student learning and to create learning activities typically takes precedence over the early infrastructural and personal concerns. Students and teachers alike find that they can do more and different things with technology. Eventually, students and teachers come to *rely* on the technology to support learning; and the technology becomes *transparent* to the students.

1.2 Preparing Students to Learn in TEI Classrooms

Students who have not been learning in a TEI classroom need to be initiated to the process and taught how to learn in such an environment. Specifically, there are three factors to which students must adapt:

1) technological interfaces for learning,

2) new learning interactions, and
3) different learning strategies.

Students may be unfamiliar with the intensive use of technology for learning. Thus some effective strategies are required to initially enculturate students to TEI and to maximize the advantages of the learning technologies. First, students need the technical "how to's" when beginning to learn with a new interface whether it is using the basic operating desktop or manipulating the sophisticated interfaces found on some simulations. Second, learning with technology may require the student to learn a new set of interactions for learning with the technology, with the teacher, and with other students. Third, if students are to take advantage of the learning situations in a TEI classroom, then they need to know what types of learning strategies are employed and the "why's" of learning this way—the purposes, learning benefits and the learning processes. Learning processes, as well as learning management strategies for self-direction and self-pacing, can be encouraged successfully in a multi-tasked classroom.

In the enculturation process described above, most TESSI teachers find that they prefer to maintain a more traditional classroom environment early in the semester or first term where there is an emphasis by the teacher on establishing classroom management and teacher rapport. Later in the teaching year, there is an evolution to a more self-directed classroom environment as more technologies and learning styles are introduced.

1.3 Student Evaluation and Feedback

Based on the experience of TESSI teachers, changes and differences in evaluation and feedback emerge as a consequence of technology integration. The list of changes and differences in student perceptions of and teacher practices of evaluation and feedback include:

1) As a consequence of self-pacing and self-direction, students require more constant feedback to monitor their own progress and direction.
2) The increased interaction between students and teachers allows for more feedback and informal summative evaluation.
3) Student perception of evaluation shifts from just "a teacher thing" to "a student and teacher thing".

4) Interactive testing is used as a powerful tool to give students another source of instant and detailed feedback. Interactive testing also allows for flexibility in evaluation in the use of practice tests, and re-tests, towards mastery learning.
5) Teachers become more flexible in the timing and types of assessments and evaluations.

The data presented in this study suggests that most teachers relegate evaluation concerns to the background early in the technology integration because it is does not appear to be as important as other issues, such as those in infrastructure. When teachers have a more developed TEI pedagogy however, changes in evaluation procedures become more important as teacher see the need to reflect the various changes in the TEI classroom.

1.4 Role of the "Traditional" Teaching Strategies

Integrating technology involves striking a balance between traditional and technology-based learning strategies to provide an effective range of learning experiences for all students. While a starting implementer may fall back on traditional learning strategies for reasons such as lack of a range of resources or unfamiliarity with new pedagogical approaches, teachers further along into technology integration use traditional strategies out of choice. The choice is based upon each strategy's potential for effectively enhancing student learning.

TESSI teachers report that there are advantages to using traditional teaching strategies in technology-integrated classrooms in certain situations. For example, the lecture may be used as a motivational speech or to make up time to 'complete the curriculum'. Homework problem sets and textbook work is still utilized as a source of information and for problem solving. In fact, no technology has yet been found to be particularly effective in helping students solve complicated and diverse calculation problems in TESSI classrooms. Teacher modelling is still required.

For the purposes of skill development and physical problem solving, the use of hands-on labs is one "traditional" teaching strategy that is still effective in TEI classrooms. However, in TEI classrooms, coupling hands-on labs with technology becomes a natural extension of scientific investigation that retains the physical learning component while technologically augmenting learning in other ways. This finding that effective traditional learning strategies are still important in TEI classrooms suggests that:

1) the role of all learning strategies, technologically-linked or not, should be determined and used to their full advantage in the classroom, and
2) the teacher is still critical to the education process in orchestrating student activities, learning strategies, and technological use.

1.5 Student Learning and Curriculum -- Conceptions of Enhanced Learning

TESSI teachers are in agreement that increased student motivation and self-engagement among students, and between students and the curriculum in their classrooms is a critical outcome of technology enhanced learning. Teachers also note that using the technologies diversifies the types of learning activities and strategies they implement in their classrooms. TESSI teachers cite a combination of *direct* and *indirect* learning factors as influencing their conceptions regarding what it means to "technologically enhance instruction and learning".

1.5.1 How Technology *Directly* Enhances Student Learning

Technology use can directly enhance student learning because technology can provide:

1) multiple representations of concepts through the multimedia approach,
2) advanced and sophisticated visualization,
3) measurement of components not normally or easily measurable,
4) instantaneous feedback,
5) the linking of conceptual models with mathematical interpretations, and
6) realistic/authentic instrumentation and relevant observations.

Student learning is also directly enhanced because an immersive technology use environment facilitates:

7) student risk taking in learning or experimentation,
8) cooperative learning,
9) student control, questioning and exploration of their own learning micro-environment,
10) learning through multiple styles (by the increased presentation styles or experiences),
11) more student time spent on higher order skills, and

12) acquisition of "modern technology-related skills."

These *direct* learning factors explicitly contribute to learning the mandated curriculum.

1.5.2 How Technology *Indirectly* Enhances Student Learning

Student learning is also *indirectly* enhanced by technology use. These learning factors are classified as *indirect* factors mainly because they are linked to learning outcomes that are not officially evaluated or directly related to the mandated science curricula. These factors are also dependent on the classroom and pedagogical context, are generally unintended, and were typically only identified by TESSI teachers when they realized that the students were learning more than the government mandated curriculum. The use of TEI enhances the following *indirect* learning factors:

1) the growth of technological literacy—as students experience using computers, they are more likely to use them more and in different ways as an *expansive tool,*
2) the development of a sense of pride—as students produce high quality products using technology,
3) the motivation of generally unmotivated students---using computers seem to encourage learning even when the students were not using computers as well as when they are,
4) the development of self-direction and self-management skill—as facilitated through using study guides and interactive assessments,
5) the encouragement of student collaboration—technology provides both a collaboration tool and medium, and
6) the fostering of student choice, control and empowerment of their own learning—a resource-rich, technology-integrated classroom allows the option for students to decide their learning with respect to time and method to some degree.

These benefits of learning with technology do not seem to require that students be proficient at using technology, but accrue through the students' adaptation to learning in a TEI environment.

1.6 Distinctions among the Sciences: Physics, Biology and Chemistry

TESSI classrooms share common elements in terms of the pedagogical framework and the variety of technologies implemented—interactive testing, simulations, multimedia, MBL, hypermedia, graphing and analysis tools, and productivity applications (e.g. word processing, spreadsheets). However, among the Biology, Chemistry, and Physics TESSI classrooms, there are some aspects of technology integration that are clearly distinctive due to the nature of the subject and curriculum. As a result, students experience different applications of technology in the different science areas.

1) In Biology, there is greater use of multimedia and imaging software. There are few simulations or MBL labs.
2) In Physics, there is a heavier reliance on simulations and video imaging analysis as compared to the other areas. MBL labs are also frequently used.
3) In Chemistry, there is a greater diversity of software and technology being tested than the other subject areas. MBL labs are prominent.

At a practical level, these differences are attributed to software limitations. With continued development of new educational software, these differences may diminish but will not likely completely disappear. At the conceptual level, teachers' personal pedagogical preferences play a factor. Some TESSI teachers prefer certain teaching modes and activities to others. Some examples are the varying amounts of project-based work, Internet use, and self-pacing. Certainly, how each subject matter's integration will continue to evolve or how each teacher implements technology will be somewhat different.

The differences identified by this study between the Biology, Chemistry and Physics (and even the Junior General Science) curricula suggests that the mode of technology integration is in part a function of the nature of the curriculum. What the variables are in this relationship could be explored in more detail with respect to teachers' conception of the curriculum and what types of technology and pedagogy they feel is most effective and why. Further research is needed to better identify the relationship between technology and curricula and how these influence the overall learning of a student.

1.7 Student Domain --- Conclusions

Technology integration does not mean just placing a few extra pieces of technology in the classroom. Rather, it suggests a dramatic altering of the learning environment. Many of the observed changes in the TESSI classrooms are consistent with the change from a "knowledge instruction to a knowledge construction" environment found in the ACOT classrooms (Dwyer et al., 1991). The significant changes in the student domain do not occur early in technology integration but emerge only as the infrastructure-based and teacher-based changes (discussed below) become more apparent.

The TESSI classrooms demonstrate that the integration of educational technologies can encourage and support movement towards a more constructivist model of learning without sacrificing the government-mandated curriculum. The TESSI teachers' conception of how student learning is changed by technology did not occur immediately; it changed only as they gleaned more experience observing how students learn with technology. Some of the *direct* learning enhancements described have become understood by TESSI teachers through their own professional development and literature in the field of educational technology.

The simultaneous occurrence of *indirect* enhancements as described in this chapter leads to the consideration of alternate learning goals. Some of these learning goals are similar to the skills that students learn in an information technology curriculum. The difference is that these goals are implicit in the TEI environment. Other indirect enhancements, such as personal management skills (e.g. time management) are both a result of TEI and a requirement to be taught alongside the formal curriculum. To demonstrate that TEI can "do the current curriculum" is not unexpected; to do it better and in different ways has been very interesting.

The technology-integrated classroom is a new environment in which both students and teachers need to adapt. Using educational technology as a tool of instruction and learning is currently not commonplace. Students need preparation to learn effectively in a highly technological environment. The technologically enhanced learning goals and problem-solving skills need to be clearly communicated by teachers to students. Learning with technology allows for, and almost requires, teachers to consider innovative ways to evaluate the possible new outcomes. The sum of these varied adaptations requires a conscious effort and time allotment by the teacher early in implementation. In fact, further study into how students effectively learn to use technologies may be warranted in order to inform teachers of how to effectively introduce learning with technology as an 'everyday experience.'

2. Teacher Domain: The Three P's

In the teacher-based domain, three areas will be discussed: 1) personal characteristics and experiences, 2) professional roles and development, and 3) pedagogical change.

2.1 Personal Characteristics and Experiences

Personal experiences accompanying the process of technology integration begins with the excitement, apprehension, and anticipation of meeting a new challenge and continues with the immense time and energy commitment required to deal with the many changes occurring simultaneously in the infrastructure, in pedagogy, and the professional realm.

Although the TESSI teachers did not engage in this project with clear visions of how technology could be used to enhance learning, they did share a number of characteristics including:

1) a strong personal interest, ability, confidence and persistence in tackling technological problems,
2) a desire to provide for better learning and teaching experiences beyond the that in typical classrooms,
3) a strong inner motivation to create a beneficial learning environment for themselves as well as the greater educational community,
4) a desire and ability to learn on their own and to find collaborative colleagues, and
5) a recognition of the time and effort required in successful innovations.

Complex and conflicting personal feelings may arise in teachers, especially early in technology implementation, from a combination of potential stressful situations and factors including:

1) concerns about whether implementation is on-track and whether students will be able to learn the mandated curriculum,
2) demands placed by administrators, students or parents,

3) the "newness" factor: the number of new things that needed to be learned and mastered,
4) lack of appropriate sources of support -- especially technical and financial,
5) lack of appropriate resources and/or resource development,
6) experimentation with resources and troubleshooting their technologies, and
7) realignment of personal teaching beliefs with the changes in teaching practices.

These problems manifest themselves by teachers questioning their personally perceived lack of progress. As professionals, the TESSI teachers place a lot of pressure on themselves to learn the new technologies and new programs, to ensure that their computers were running, and generally to be a perceived as a "successful teacher" by their students and peers.

2.2 Professional Roles and Development

Most TESSI teachers find that their professional roles and responsibilities have had to expand and diversify to include:

1) resource developer / consultant,
2) curriculum designer and implementer – linking and applying technology to the curriculum,
3) professional developer – helping other teachers to use technology, presenting workshops at conferences,
4) technology consultant – advising on implementation and direction,
5) technical guru / "techie" / technician and network administrator,
6) technology advocate (including "tour guide") – promoting and/or defending technology integration to peers, parents, students, and administrators, showing guests and visitors to the class,
7) student – becoming a student of technology and its applications, and
8) researcher.

Being at the leading edge of educational reform, TESSI teachers have had to play these multiple roles because the conservative school system and environment necessitates them to do so.

Professional development and change are a natural part of technology integration for teachers. An attitude of professional risk-taking and an active commitment to improving education need to become trademarks of those teachers integrating technology. Teachers need to be able to deal with setbacks in implementation, experiment with applications, and find effective ways to use technology to help learning --- all of these aspects require research, time to digest, and freedom to fail. A commitment to ongoing personal learning about the functioning of technology and its educational applications is essential for success. For some, a change to working collaboratively, sharing expertise and resources, and developing a common vision is a critical factor for successful integration.

2.3 Pedagogical Change

2.3.1 Patterns of Pedagogical Questioning, Change and Growth

Prior to technology implementation, most TESSI teachers had established a traditional, lecture-based, content-orientated, routine-based teaching style. As teachers allowed for more student engagement with technology in their classrooms, teachers underwent a pattern of change marked by:

1) questioning their own perceptions of classroom control,
2) uncertainty and adjustment regarding the need for a more flexible classroom management style,
3) examination of their own teaching styles,
4) analysis of the effectiveness of more student-centered learning,
5) perceptions of losing control of what content students "received" – what students were learning, and
6) realization that some students were learning beyond the intended curriculum.

The questions and new situations required some tolerance from teachers at first, then adjustment, and then an acceptance. In terms of classroom management, it is acknowledged by most TESSI teachers that, inevitably, teachers will have to be more flexible and interactive in the TEI classroom.

While pedagogical change was gradually introduced into TESSI classrooms, the pace of change can be traced with respect to some variance with age, enthusiasm, collaboration, and degree of infrastructure concerns. Generally, the pace of pedagogical change in teachers is slower when limited technology was available, but as resources became more available and teachers became more familiar with the capabilities of the software, the pace of experimenting with different learning technologies and instructional strategies increases.

In all cases, teachers have found that their prior conception of teaching has been powerfully challenged as their repertoire of strategies and experiences was broadened. However, the younger teachers in TESSI, who had not developed an established pedagogy, more readily accepted change in pedagogy. The younger teachers developed and broadened their conceptions of teaching as they worked through technology integration while the older teachers found that their views of teaching definitively shifted.

2.3.2 Products of Pedagogical Growth and Change

By the end of the third year of technology integration, TESSI teachers felt that they had significantly changed in their general pedagogical approach from lecturer to organizer of information / manager-coach, from a `transmitter' of knowledge or giver of content, to one who `transacts' learning or negotiated learning.

Most of the teachers in this study who have made the transition to the highly student-centred, variably-paced teaching style lament the loss of their previous lecturing teaching style as a matter of past personal preference and comfort level. Lecturing and "performing" can be enjoyable to teachers and can be used to motivate students.

2.3.3 Change Forces and Choices

The relational dynamics between teacher and students in TEI classrooms changed, due in part to the pedagogical choice of the teacher and environmental forces. A technology integrated classroom environment exerts inherent forces favouring pedagogical change, but TESSI teachers were adamant that it is the teacher who ultimately decides how to deal with the change forces.

2.4 Teacher Domain: Conclusions

While the signs of change are obvious in "the classroom product" of technology integration, less obvious are the tremendous changes experienced within the technology-integrating teacher. The orchestration of the infrastructure and student learning with respect to curriculum and instruction requires the teacher to change personally, professionally and pedagogically. Prior experience and/or training may not exist or be helpful in anticipating changes resulting from technology implementation. Thus, anticipating and preparing for these forms of change and a willingness to give up traditional methods are important factors to consider if teachers choose to adopt the use of technology.

While the "lists of stresses" described in the teacher domain are in no way comprehensive, understanding the potential sources of frustration can help teachers and administrators anticipate solutions to the issues as they arise. Teachers (and administrators) must realize that changes of the magnitude that accompany the introduction of TEI take time to master. Innovation in teaching draws teachers who are already very committed to other aspects of the profession. Working from the perspective of a pioneer in technology innovation, the personal time and energy used in technology integration requires the realization of personal and professional limits.

Teachers will experience a great deal of personal uncertainty in the midst of change. Teachers will need validation from students and administrators to counteract these uncertainties. Teachers need to know that mistakes are part of the risk of the innovation process. Although the first or second year of implementation is generally the most difficult with regards to personal change, teachers also must realize that sustaining technology integration requires a willingness to absorb and embrace *continual* and rapid change.

The achievements of the teachers documented in this study testify to the fact that teachers self-taught in using technology and computers can successfully implement technology in their classrooms, provided a critical mass of support is available. Given the prevailing conservative educational system and the current lack of pre-service technology preparation in teacher education, teachers will realize that professional change and growth is mandatory to successful technology integration. Technology integration means that the teacher's professional role will become redefined with a multitude of roles. Personally, teachers can anticipate experiencing patterns of stress upon encountering various forces of change and expectations. Experienced TESSI teachers note that the cumulative effects of the change processes for teachers seem to require between four to five years before the teachers felt "comfortable" again.

The evidence gathered in this study suggests that some pedagogical shifts must occur as student learning time now entails interaction with a learning agent other than the teacher. Being inherent and inevitable in the process of TEI integration, these shifts confirm that the key to technology changing teaching and learning is for teachers to confront their beliefs about teaching and learning and the efficacy of their learning activities in the midst of change (Woodrow et al., 1996; Dwyer et al., 1991). This confrontation may appear to be an obvious prerequisite, but the flip side is that pedagogical concerns and change only *occurs when* teachers work from the premise that student learning can be enhanced by technology. This co-requisite is essential since it forms a large part of the basic motivation for a teacher to integrate technology.

In the course of pedagogical shifts, there is a critical point where teachers must face a serious reconsideration and change in teaching styles when teaching in a technology integrated classroom. This point is marked by certain choices. These 'change choices' can be viewed in terms of the framework of Miller and Seller's (1990) curriculum orientations. Technology integration in the TEI framework encourages a more *transactive* teaching mode, helping students to learn from each other and dialogue. But the shift to a more transactive mode requires the teacher to give up the *transmissive* mode characterized by lecturing and content delivery. In doing so, the teacher may have to give up telling a coveted, motivational story in exchange for increased student self-engagement in order to take advantage of the enhancements technology can offer. This is a reflection of Berlaks' dilemmas (1981), where the teacher gives up apparent control in order to allow for enhancement of student controlled learning.

3. The Infrastructure Domain

In contrast to the student learning and teacher concerns, the "background" context to technology implementation and integration is the infrastructure, a supportive framework of human resources, funding, technical, physical, and organization structures. In this study, six forms of infrastructure were identified by TESSI teachers as significant to the integration of technology:

1) Financial resources
2) Physical and hardware resources
3) Technical support
4) Student resources
5) Administrative support
6) Innovation advocates and peer support

3.1 Financial Infrastructure

3.1.1 Funding Required

Extensive funding and technological resources are required to facilitate technology integration, though the start-up costs of implementation for each TESSI site has decreased as technology has become more pervasive and more affordable.

3.1.2 Finding Funds

Because the goal of creating a technologically integrated classroom is not considered the norm at present, teachers may have to do some lobbying for funding, writing innovative technology funding proposals to their School Districts and other sources. With the status of pilot research and development sites, many of the TESSI sites were fortunate to have funding provided by the combination of the schools, the school boards, various commercial sponsors, and research grants. Lobbying for funding, however, can lead to the perception of preferential treatment or jealousy from other staff.

3.2 Physical Infrastructures

3.2.1 On-Demand Access

Technology placed in the classroom in order to have on-demand access eventually becomes `transparent,' fostering the student attitude that technology is `just another tool'. Pulling-out classes into a computer lab is not appealing to teachers because it is an organizational hassle and does not promote seamless integration of technology and learning enhancement.

3.2.2 Room Design

Because current classrooms are usually not designed to house computers, certain physical aspects of room design can initially affect the integration process. Conversion of the classroom to use with technology is often required. Some considerations include:

1) Placement of computers:
    - Computers need to be spaced to allow students, working in groups of up to three, to sit and see the monitors. They must also be spaced to permit the students to be able to perform computer-integrated experiments

comfortably working with potentially a large number of pieces of equipment, probes, and reagents.

- Water splashing from nearby sinks and water taps in science classrooms may become a problem.
- The height of the computer monitors and peripherals should be placed to allow for students to work comfortably either siting or standing.
- Instructors need to be able to move among the stations and see the monitor screens. (A common design in TESSI labs is to place computers around the walls of the classroom with the screens facing the center.)

2) Electrical and network outlets should be easily accessible.
3) If sound is used, for example with multimedia CDs, then headphones or sound insulation must be considered.
4) Additional seating and space may be required for those students not working with technology.

Additional difficulties can arise from the unforeseen concerns of: damage, theft, ventilation, non-controllable lighting, lack of space, and lack of ergonomic chairs.

3.3 Maintaining the Technical Infrastructure: Technical Support

3.3.1 Technical Problems and Support

Technical problems with technology are ongoing. However, technical issues and concerns appear to be more pressing than other issues early in implementation because they represent a level of competence that teachers feel that they need to demonstrate to students.

The technical concerns and problems cited by TESSI teachers increases with changes in the number of computers used and the networking of computers. Even teachers with a relatively good level of technical expertise require access to a higher level of technical expertise on occasion, but this support may be difficult to achieve in a School District where technical support is a low priority for teachers. Finding sources of technical support, however, is the key to moving forward technically (and increasing teacher morale) and usually students or other "techie" peers may be the first or only sources of technical support.

3.3.2 LANs

The advent of local area networks (LANs) and security concerns marks an important stage in the technical development for teachers in this study. While the technical aspects of networking are a new challenge, TESSI teachers agree that LANs made their lives easier. LANs provide many worthwhile advantages, such as the ability to quickly install software and access files from a central location, screen sharing, desktop profiles and security, and facilitating interactive testing that became a classroom staple for most teachers.

3.4 The Student Resource Infrastructure and Issues

3.4.1 Evaluation and Use of Student Resources

In technology implementation, a pervasive infrastructure concern that is parallel to the technical concerns is the availability and appropriateness of resources, especially software. With limited experience using technology for instruction, teachers can be initially uncertain as to what types of technologies could be used effectively within the curriculum. Ample time is essential to actively seek out courseware software and test it for use in the classroom. The diversity of potential programs and the need to evaluate existing products require significant amounts of teacher time before implementing them for student use. When evaluating software and hardware pieces to use for student learning, teachers rely on their professional judgement and upon their tests of using the software with their students.

Using the best commercially available software may minimize software development work or adaptation, but some student resources still have to be modified or designed. Because students require time to adapt to different interfaces, another issue for some TESSI teachers is finding a small number of software interfaces or styles that can span the different teaching units with some continuity.

3.4.2 Enhancement of Learning and Curriculum Match -- Problems with Student Technological Resources

A large percentage of available science education software has been evaluated by the TESSI teachers, but less than twenty percent of that software has been judged suitable for use in the classrooms, and even less has actually been integrated. The three pervasive problems of student technological resources can be summarized as:

1) the lack of correspondence or relevance with the required course curriculum or content,
2) lack of student learning enhancement, and
3) poor design with respect to interfaces and/or student instructions.

Small or subtle differences in content or presentation discourages the teacher's use of the software because it creates problems such as representing an idea in an unclear way, leading students to miss a more important point, or assuming students understand a particular representation. The availability of quality software and other student learning materials has been a constraint to what teachers have implemented in contrast to what teachers have envisioned implementing.

3.5 Making Effective Use of a Small Pod of Computers and the Evolution of the Study Guides

3.5.1 Effectively Using Small Pods

The eight to twelve computers that are found in TESSI classrooms are an affordable, reasonable working limit if:

- it is not expected that all 24 to 30 students would need to have access to computers at all times or for all activities. (This represents an average 2.5:1 student-to-computer ratio), and / or
- students are encouraged to work in small groups of two or three.

3.5.2 Multi-tasking and Self-Pacing

To make efficient use of a small number of computers, classroom and student activities have to be balanced with the more expensive or limited technological resources. One way to attain this balance is to have a variety of activities from which students can choose that would be occurring at the same time ("student multi-tasking"/multi-activity) or at different rates ("student multi-pacing"). Individualized learning (or "self-pacing") allows for learning at different rates though the curriculum, but self-pacing is viable only if the supporting technological and student resources, an evaluation strategy (such using interactive testing), and an organization structure are in place.

3.5.3 Study Guides – An Infrastructure and Strategy for Organizing Student Learning

One means of enabling and supporting student activity in a multi-tasked and multi-paced classroom is using the student study guide model of TESSI[12]. The TESSI study guides give the teacher flexibility to choose to implement a multi-paced, multi-activity classroom or not. Student study guides control student use of the limited resources, direct student learning through concepts and supporting activities, provide for student self-direction in addition to self-pacing and class multi-tasking. At the outset, some students need help to develop the self-management skills required by this format.

3.6 Administrative Support from School Principals and Districts

School principals can play key roles in contributing to the integration process by providing support for funding, moral support and advocacy, understanding, and communicating the experimental nature of the pilot projects to staff and parents. In addition to ongoing support, administrators can arrange to provide release time and/or professional development time, especially in the early stages of technology integration. Communication to parents and other staff members by administrators is critical to help parents and staff to understand the value of technology enhanced learning and the evolving nature of the technology integration process.

School Districts may also need to examine whether there can be funding for pilot technology integration sites or provision of incentives to encourage such sites.

3.7 Innovation Advocates and Facilitators

3.7.1 Collaboration

Teacher collaboration is a necessity in technology integration initiatives. Collaboration with peers needs to take the forms of technical support, co-development work on student materials, sharing ideas, observing each other's classes, and peer criticism in various formats. Collaboration may also need to extend from peers to advocates such as administrators.

[12] See Appendix E regarding the origins of the study guide. See Woodrow (1998b) for description and use.

3.7.2 Role and Support of Advocates / Facilitators

Without technology-innovation advocates and facilitators, the likelihood that administrative support and technology integration will be realized is low. Advocates may potentially come from parent groups, from other teachers, from the School District, from universities/colleges, or from the government ministry level. In this respect, TESSI benefits from some of the critical roles Dr. Janice Woodrow has undertaken to support TESSI, including:

1) providing feedback and evaluation from a `third perspective,'
2) facilitating collaboration,
3) negotiating and liaising with the schools/School Districts for the project's operation,
4) providing credibility and legitimacy,
5) writing the majority of the grant proposals,
6) co-ordinating and conducting project research,
7) articulating, publicizing, and promoting the project's developing framework, and
8) fostering the necessary risk-taking to transform the teachers' teaching.

3.8 Infrastructure -- Conclusions

While current technology implementation and integration efforts require a supportive infrastructure that is above and beyond what a typical teacher might encounter today, technology implementation is not beyond the reach of motivated teachers. Currently, there is no avoiding the initial issues of funding, technical resources, and support that are needed. Although one would think that the broad and important concerns of curriculum goals and student learning should be especially important to teachers who will be teaching in an innovative way with technology, teachers seem to focus on, and need resolution of the issues of infrastructure early in the implementation process. Planning for learning should precede hardware purchase (Bork, 1995) but mastery over the physical implementation of resources is equally important before the focus of the teacher shifts to fine-tuning the effective integration of resources for students. This finding suggests that infrastructure must be dealt with first in contrast to educational goals. Yet, planning for technology integration often occurs more at the level of broad goals, perhaps at the education ministry level, far removed from teacher concerns about the nuts and bolts of technology administration. Infrastructure resources need to be in place and related issues resolved before desired educational goals can be achieved. In the planning and design of the educational infrastructure, technology should not be viewed as the `thing of the future.' Technology is the tool of science, of learning, of society – today.

The installation of LANs marked a significant technical milestone in implementation for TESSI teachers, ushering a new set of technical problems. Despite this point, serious consideration should be given to the wiring and the benefits of a local area network (LAN). A LAN's power in information management and support of technological activities becomes essential. However, decisions need to be made about how such networks and other sophisticated resources will be maintained in the educational system. Ideally, hardware and software concerns and other essentially technical concerns should be relegated to someone other than the teacher. This would allow technology implementation process to proceed much more efficiently and permit the teacher's focus to shift earlier. It should not be the function of the teacher to install the network --- just to use it effectively.

Currently, a broad range of better student TEI resources still needs to be developed. How resources can be used to enhance student learning and where they might fit into the curriculum in terms of content and pedagogy should be at the forefront of their design and integration. Ideally, student resources should be transferable and easily modifiable to suit the purposes of the teacher and curriculum. Software programs should also do more than just present content as an electronic textbook; they should be able to demonstrate some enhancement of learning unique to advanced technology. The TESSI study guide model (c.f. Woodrow, 1998b) exemplifies how student learning can be effectively organized to provide both structure and freedom in learning to maximize the efficacy of technological resources and pedagogy. The study guide model has also proven to be transferable and scalable to different subject areas and to different teachers.

From transforming classrooms into wall-less entities to changing the way that the whole school views teaching with technology, technology integration affects the larger educational infrastructure. While technology integration may seem to focus on the development of an infrastructure to support the integration, the pedagogical and technological effects may be felt throughout the school and even in the School District with mixed results. TESSI teachers have helped put positive pressure on the school or School District to evolve technologically, changing the way that their School Districts view technology integration and the funding of technology in many instances. Taken together, these are signs of the transformative nature of an effective innovation in education.

Field-based, longitudinal collaborative research and development projects, such as TESSI, demonstrate the strengths that each participant can bring in terms of a wealth of practical knowledge and experience. However, the participants do not just consist of the teachers, or administrators, or educational technology advocates, but the combination of all these stakeholders. Teachers must ally themselves with principals, parents, other teachers and advocates who share their vision of technology integration. Expectations should be established and communicated on an ongoing basis. Administrators and parents need to understand the technology integration process from the point of view of the teacher in order to provide effective support. Administrators and parents need to understand the student perspective of technology integration in order to realize that the results of technology integration may be more complex and exciting than just achievement scores on traditional exams. Hopefully the day will come when the essential roles of advocates and facilitators of technology integration will become, well ... just legendary.

B. The Phases of Technology Integration and Interactions in the Student-Teacher-Infrastructure Triad

1. A Conceptual and Practical Framework for Understanding and Implementing Technology Integration

The purpose of this study is to examine the conceptual, the accompanying practical issues and the interplay among these issues in relation to technology implementation and integration concerns in terms of curriculum development, technological roles, teacher roles, and student roles from the perspective of the teachers. One outcome of this study is the construction of a conceptual and practical framework for technology integration into the existing secondary science curriculum.

The domains of the student-teacher-infrastructure triad form a basis for discussing the praxis of technology integration as experienced by teachers. Each domain can be discussed with respect to its representative stakeholders: students, teachers, and administrators. Though each stakeholder may be transparent to the other in the technology integration process, in reality they are in fact in a multi-layer, dynamic relationship. In order to understand and inform practice, conceptions of instruction, learning and technology must be addressed: those of teachers as well as students, and indeed all stakeholders in the educational process. In other words, the learning focus, the supporting infrastructure and the teacher changes should not be discussed separately because these are interdependent and impinge on each other. To understand what technology can or cannot do for education requires an understanding of how the traditional conceptions of student learning and notions of teaching and instruction are transformed, how each domain of the triad negotiates and interacts in new ways. Thus, understanding this technology integration triad with respect to its potential *progression*, and supporting the *relationships between* the domains is critical to successful technology integration.

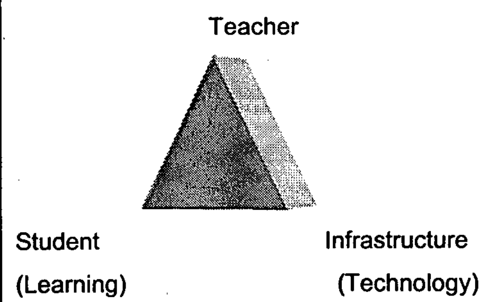


Fig. 5.1 The Teacher-Student-Infrastructure Triad. Although technology integration can be viewed from the different domain perspectives, the three domains are critically interdependent.

What does technology integration entail? This study suggests that technology integration is both a practical and a conceptual process. These processes can be delineated in terms of the student, teacher and infrastructure domain changes experienced by each teacher studied. In Table 5.1, entitled "Phases of Technology Integration in the Student-Teacher-Infrastructure Triad," the integration process experienced by the TESSI teachers is summarized in terms of six phases. This summary is based upon the overlapping critical or dominant themes that have emerged from this study of teachers at different phases on technology integration. Elements from the Three Levels of Technology Use perspective (see Chapter 4, Table 4.1) are incorporated into Table 5.1 and the ACOT (Dwyer et al., 1991) conception of stages is significantly expanded.

TABLE 5.1: Phases of Technology Integration in the Student-Teacher-Infrastructure Triad

PHASE	***DOMAIN*** ***(Perspectives and Characteristics)***		
	Student	***Teacher***	***Infrastructure***
1. Exposure	• No advanced student technology use • Technology for learning is viewed as not required • Teacher-centered instruction	• Exposure and exploration of educational uses of technology and evaluation of resources (e.g. reviews of software and correlation with curriculum) • Inward professional development • Technology used as support for teacher functions only • Traditional pedagogy in place	• One (or no) computer classroom • Serious negotiation of infrastructure begins: funding, acquisition and support in preparation for next phase • Collaboration: none or limited to advocates
2. Initiation	• Minimal student technology use: limited students and opportunities or students observe teacher use of technology • Technology used for traditional or low level applications • Technology viewed as "add-on" to student learning or special project status by teacher and students	• Initiation into technology implementation • Personal concerns begin: elation, ownership of the problem and anticipation • Experimentation with technological applications and strategies • Questioning regarding pedagogical role of technology (e.g. when to use technology) • Professional roles may expand	• One computer-use evolving into multi-computer classroom (pull-out class use or occasional use) • Physical and technical resource concerns begin (e.g. set-up and troubleshooting) • Potential isolation from traditional (non-TEI) peers
3. Infusion	• Whole classes may experience limited (30-40% class time) or low level of use in controlled (or lock-step) access • Technology-affected student management issues begin; student responses mixed; tensions in classroom dynamics • Technology viewed as student learning tool: teacher and some students	• Personal "survival" concerns: time, frustration and anxiety • Curricular issues increase (e.g. best use of technology and other strategies to enhance learning; curriculum match issues) • Many challenges to pedagogical beliefs and classroom management issues begin	• Multi-computer classroom in place • Technical issues dominate (especially if networking used) • High technical support critical • Student learning and resources developed and/or used from traditional orientations • New / strengthened collaborations

TABLE 5.1 (cont.): Phases of Technology Integration in the Student-Teacher-Infrastructure Triad

4. Synthesis / Breakthrough	• Many examples of more advanced and productive uses of technology: use with some on-demand access • Technology viewed as essential learning tool: teacher and most students • Learning methods developing: e.g. use of study guide; style of classroom learning includes some self-pacing and multi-tasking • Shifts towards student-centered learning	• Critical point and decision-making regarding personal and pedagogical change (realization that old patterns of thinking will not suffice) • Learning issues dominate	• Technical issues decrease (but may increase if introducing system-wide changes, e.g. networking) • Collaboration critical from administrators, TEI peers and advocates • Student resources developed and/or used from non-traditional orientations
5. Integration	• Diverse activities developed and used with high-engagement, on-demand access • Learning goals and methods: very developed and may include: self-pacing, full-multitasking, • Technology is *transparent*: students and teacher view technology as a another "life-tool" • Exploration of alternative learning goals: e.g. self-management, empowerment, etc.	• Personal" relief" and celebration ("breath of stability" as perspective on changes more resolved) • New pedagogical and practice in place (e.g. teacher as facilitator status) • Evaluation issues more evident • Outward professional development roles increase • New productivity period begins	• Technical concerns stablize • Student resources developed • Synergism with collaborators (e.g. TEI peers)
6. Innovation	• Student curriculum diversification and extension • Choice in learning with multiple activities • Incorporation of alternative learning goals	• Refinement of established pedagogy • Invention or extension of curriculum • Questioning about new and alternative technology ** Cycles back to Phase 1 at macro-level or Phase 3 micro-level innovation or else maintains*	• Renewal and upgrading of technologies and resources • Curriculum may be seen as a constraining infrastructure

2. Phases of Integration as an Analysis Tool

Various time and stage analyses can be applied to the phases of technology integration using Table 5.1 horizontally or vertically to follow the evolution and relationships that take place in technology integration. Analyzing the table vertically illustrates the decline in importance of technical problems and the increasing dominance of pedagogical issues such as those related to evaluation. When analyzed horizontally, the table can be used to anticipate what parallel domain factors need to be in place before a successful phase transition can be made.

Typically, progression through the domains of change—student, teacher, and infrastructure—occurs at different rates. When progression is unsynchronized between the domains or when progress in one domain proceeds ahead of the others, whether in expectation or in reality, tensions and problems arise. Many of these tensions have been described in this study. For example, where teachers have expected quicker than realized results in infrastructure in order to facilitate learning characteristic of a later phase, teacher frustration ensues. On the other hand, if the infrastructure is set-up too far in advance of a teacher's ability to use it effectively, not only are resources wasted but the teacher may feel pressured to make good use of the resources. Another example is the situation where teachers perceive that they have 'lost control' of the learning environment, where student learning out-paces their own personal and pedagogical changes.

3. Implications for Future Implementations

Undoubtedly, there is a danger in attempting to summarize results or progressions. Charting progress is a murky endeavour; clear progress should not be expected -- it is the human way to be intuitive and unpredictable. There may be momentary regressions, looping, and new, unexpected issues. The pathway of technology integration should be considered foggy at best, but the value in knowing that there is even a rudimentary map or pathway is assuring. The potential pitfalls are more easily avoided once someone else has mapped them.

The phases of integration described in Table 5.1 suggest many implications for new TEI implementations. For example, teachers should probably start by mastering educational technology on a smaller scale, perhaps teaching with one computer, before increasing the number of technologies incorporated. Teachers need to be able to troubleshoot technical problems commensurate with the infrastructure status. Teachers should find colleagues who share similar aspirations and have access to well-developed curriculum-based resources or be willing to explore these on their own. If chosen, the transition to an on-demand technology access type classroom or a technology-integrated classroom will require the teacher to acquire new types of skills such as those for networking and student management of such classrooms, and new pedagogical approaches.

Before TEI or any other innovation can be effectively infused into pedagogy, teachers will need preparation in learning *about* technology as well as learning *with* technology (Faison, 1996) in pre-service as well as in-service training. The focus of such technology training should not only be on initial technical concerns (e.g. a technical workshop) but on the process concerns (e.g. roles and changes). For technology to make an impact in the classroom, ongoing support is required from other teachers, perhaps by using a mentoring model situated in a culture of collaboration. Lasting change will not occur simply by giving teachers the latest technological tools. Teachers will also need to come to grips with the need to take risks, and a willingness to face the potential conceptual and practical challenges that plague in innovative classroom technology integration.

Innovative technology integration needs to be *informed from* and *transformed in* the practice of teachers because they are ultimately the ones who will decide how and whether technology will be used. Teachers know their classroom contexts and will adjust technology's use and any new role technology plays accordingly (Hannafin & Savenye, 1993; Miller & Olson, 1995). "Top-down" approaches alone will not be effective in creating change. "Both top-down and bottom-up strategies are necessary" (Fullan, 1993, p-37). Any change process is highly complex, involving changes in materials, beliefs and practices and involving "an overlapping series of dynamically complex phenomena" (Fullan, 1993, p-21). Complex change needs to occur in all three domains of the student-teacher-infrastructure triad, and at several levels.

C. Limitations of the Study

This study has involved sampling teachers' conceptions at different stages in technology integration. The participants were asked to retrace their conceptions to the earliest stages of technology integration. While this method is both a strength and weakness, the potential limitation lies in gathering a reliable report of changed and changing conceptions. However, the multiple viewpoints and triangulation of sources used suggests that the data is reliable.

Secondly, it can be argued that TESSI teachers and classrooms represent a special context. This is true --- for now, but the trend towards technology integration into science classrooms is one that is becoming more feasible, and less novel. TESSI teachers were also more than implementers of TEI --- they were simultaneously developing and implementing --- a fact that magnified some of the issues in the early stages[13]. Although the confrontation with the various issues and the processes described in this study will be still be common to those who implement technology in the future, some care must be taken applying this research.

A third potential limitation of this study is the researcher's ability to remain objective while also participating as one of the teachers in the TESSI Project. When this research began, I was in year one of my own technology integration. My familiarity, while a limitation in some respects, was an asset in other ways. As a TESSI participant, I was able to gain access easily to the participants and an intimate understanding of them. The types of interactions and depth of discussions might not have developed so readily if I were a true "outsider". Not only was I able to use the information collected in this study, but I could also see my own progress reflected as the seventh TESSI teacher. The contributions of my partners in this adventure have been invaluable to me and hopefully to you.

D. Concluding Comments

What is technology implementation and integration? And to what ends? These can be problematic questions, depending on one's perspective, the extent to which

[13] Beginning in 1997, the dissemination work of TESSI to a second generation of TESSI Physics teachers suggests that many of the initial issues described in this study were absent because they were just implementing TESSI resources and not developing.

technology is considered "implemented" or "integrated," and what is considered valuable in using technology for education. This study provides one definition of technology integration for the classroom. The question of value lie beyond the scope of this study and remains unanswered, although values play a part in the developing conceptions of teachers towards technology integration. Cuban and Kirkpatrick (1998) state that there are three purposes competing for resources for technology in schools: 1) to ensure that students are computer literate, 2) to enable more and better learning via computers (i.e. acquiring academic content and skills, including higher order thinking skills such as analysis and problem solving), and 3) to alter the classroom's social organization so as to make it more student-centered. The TEI model of technology integration can attain all three goals.

When TESSI began, there was no intention for TESSI to become a model of technology integration, nor can it be declared that it is a fully developed model yet. Dr. Janice Woodrow describes TESSI as a *pedagogical* model, but it has also made contribution as a research and development model and as professional development model. The success of the TESSI project rests on its incorporation of the many aspects of good teaching, good learning, and good technology. Underlying these "good" aspects are certain principles that can help make any educational endeavour successful and meaningful: the principle of empowerment, the principle of ownership (or the Grassroots principle), the principle of collaboration, the principle of process and complex change, and the enhancement principle.

While the physical components of technology have evolved quickly, the actual use of technology for enhancing student learning in education has been slow. The integration of technology into schools has been more a mirroring of cultural expectations and applications then it should be. However, technology's potential to significantly transform learning in schools is and will continue to be realized. The stories presented here have testified to the fact that technology integration is not a replacement for good teaching, but a catalyst for better learning.

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APPENDIX A: GLOSSARY

1. AtEase	•	an Apple network security system
2. CAI	•	computer aided instruction
3. desktop	•	with reference to computer desktop, it is the operating system's main working screen
4. ILS	•	integrated learning systems – entire curriculum packages, usually delivered via a central server
5. interface	•	what a person sees and interacts with when a person uses a computer or program
6. LANs	•	"local area networks" of a small number of computers
7. MBL	•	microcomputer-based labs – activities usually designed around a computer-probe interface; example: real-time data gathering of pH measurements in a titration
8. microworlds	•	older term used to describe simulations (see sims)
9. multitasking	•	use in reference to different students doing different things in the same classroom; word originate from the idea that a computer can do more than one task or discrete program at the same time
10. multi-pacing	•	also know as variable pacing or self-pacing; refers to a class of students working at their own rates
11. probeware	•	any of the analog or digital data collecting instruments (e.g. temperature sensor) that plugs into a MBL interface
12. sims or simulations	•	computer programs that provide a working and manipulative representation of a real system, example the form and function of a leaf undergoing photosynthesis
13. TEI	•	Technology Enhanced Instruction
14. TEPI	•	Technology Enhanced Physics Instruction Project – the precursor to TESSI
15. TESSI	•	Technology Enhanced Secondary Science Instruction

APPENDIX B: SAMPLE INTERVIEW QUESTIONS & PROTOCOL

LEVEL ONE: Contexts & Identification of Issues

I. Context:

1. How long have you been a teacher?
2. How would you characterise the context of your school?
3. How did you get involved into integrating technology into your teaching?
4. Why did you decide this / allow this?
5. What types of educational goals are important to you? *How are these related to technology implementation and integration?*

II. Identification of Key Issues [From the key issues, the interview will branch into and explore these].

1. What are the key issues for yourself in terms of integration of technology now? [Interviewer will try NOT to suggest categories as such].
    - technical?
    - curricular?
    - student learning?
    - achievement / evaluation / measurement?
    - teaching style? pedagogy?

2. How have these changed from when you started? How do you anticipate these to change in the future?

LEVEL TWO: Probing the Issues - examples of questions

I. Technology & Learning/Teaching (Probing for Conceptual?)

1. What is important to you about student learning/teaching?
2. What did you initially expect technology integration to do for you? For your students?
3. What do you want technology integration to NOT do?
4. Do you think technology has enhanced your student's learning/your teaching? If so how? (How do you assess or measure this?)
5. Do you think technology has not enhanced and /or hindered your student's learning/your teaching in any way? Is so how?
6. How have your ideas change (if it did) regarding learning/teaching?

II. Implementation and Integration: (Overlaps of Practical & Conceptual?)

1. What subjects / grade levels have you integrated technology?
2. How have you implemented /integrated technology into your teaching and learning?
3. How has this changed from when you first started until now? (What process did you have to undergo?)
4. What were some of the problems? The joys?
5. Where do you hope you go in terms of integration?

6. Can you give me an example which typifies what you do?
7. What is the content of your lessons?
8. What are the different components of technology which you have integrated (e.g. sims, MBL, etc.) and how have you done so?

9. What is the role now of hands-on experiments? (and other "traditional" methods)
10. What sources inform you of how to implement technology?
11. If you could draw a diagram or picture of what technology integration what would it look like?
12. If you could tell someone else who is thinking of starting out in terms of technological implementation what would you tell them?

III. Curriculum:

1. How do you view the science curriculum before technology implementation
2. And now...?

LEVEL THREE: Evaluation of Implementation & Integration

1. How successful do you feel your implementation / integration to be? Why? (How do you measure this?)
2. What do you feel your strengths are in the process? Weaknesses?
3. What directions do you foresee technology integration to take in the future?
4. Regarding the issue of _________ discussed last time, _________________?

INTERVIEW QUESTIONS FOR PROJECT DIRECTOR

1. How and why was the TESSI project started? What are its goals?
2. How has the project progressed? What types of changes in design were made along the way?
3. Why did were these teachers and /or their schools chosen for the project? What qualities?

APPENDIX C: SAMPLE RAW INTERVIEW TRANSCRIPT EXTRACT*

* This transcript has been greatly truncated (by about 50%) as indicated by (...) and pseudonyms are used throughout. Some identifying contexts have been omitted or blacked out.

Interview with Kris No. 1

...

John: when you first started teaching, did you have any conception of how you were actually going to use technology in terms of what you are doing now?

Kris: I had no idea. I mean, when I started, you have to remember that when I started, first of all, when I graduated from high school, my parents' graduation present to me was a slide rule. Calculators in that day cost two hundred dollars, okay, and they would do what, add, multiplied, divide, and take percentages, what the cheapest calculators do now. And that was a two hundred dollar calculator in those days and we could not afford that as students. So we had no clue. And then we had the Commodore 64s , and all that kind of stuff, and that was big, big news back then.

John: So when did you first ...

Kris: When I first started using computers was in [redacted] in the eighties I guess, middle to late eighties I started using one every day, the old Apple IIe, the black and green jobs, and we started doing word-processing and stuff that made worksheet, labs, and stuff for the kids so it would look nicer. It was easier to work with a computer where you could set things up on the screens and do all your fiddling around and then not have to do "space" and stuff like we used to have to do with the typewriter, back space, whiteout, and all that.

John: So you basically used it for teacher-related functions?

Kris: Teacher-related functions, it was basically a better typewriter.

John: So when did you even imagine that needy computers should be used, or can be used, or should be used, for kids?

Kris: Later on, we upgraded. Of course when I left [redacted], the best thing we had was a Mac plus... But, we saw that there were some possibilities that you could start doing the other things besides just word processing and then it was like wouldn't it be neat if we had access to a whole roomful of these. And eventually they set up computer labs in the school, but it was always a bit of the pain, you know, in fact, I don't think I ever did. It was offered to us, that we could take a class and book them into the computer lab and do something, but I never took that opportunity because it was just too much of a hassle. It was, like, that was the bottom line, *it was too much hassle to move the kids down there, and then, what are we going to do for one period session.* So, I'll go from there.

John: If you could have your own labs at that time, what would you have done? Was there anything new available at that time?

Kris: I don't know if I knew enough about it at that time. I was just basically using them for teaching, I started from the word processing and then we moved to marks programs, and getting into doing report cards, interim reports to parents, and stuff like that.

...

John: Did you didn't take any training or a formal education in that area?

Kris: No, it was learned as you go.

John: It seems like that for everyone now. So you had a major shift, or focus from Outdoor Education to tech so how did that feel at first?

Kris: At first it was like, my head hurt every night when I came home. It was like, a new program every week and still a bit like that. I'm getting a little further along in the thing, you talked about stages before, I guess we'll get into that, I mean, I'm nowhere near where I want to be with this thing.

I'm at a stage, like one removed from where I started, that I have some stuff that's working but I'm still constantly producing new things. Like just this week, I'm doing Science 10 this year which I didn't do before, and so the new program that I tried to figure out is "Electronics Work bench", which is like, you can make circuit diagrams for the electricity unit. It's like, where's the book? No one knows where the book is. The program is on the computers, you sit down and you start and see what happens, you feel your way along.

John: What kind of stages, if you could put some labels to them, have you gone through in terms of your feelings of the whole process? This has been your third year...

Kris: This is my third year so it's like 2 years completed, 2 and a half almost.

At first it was almost like a freak out state. After the excitement of getting a job, it was like, what have I got myself into it, and just long, long hours. Fortunately, Frank was right across the hall and it was just OK, don't worry about this. The first time I ran into a roadblock, like, how do I do this? He helped me.

I don't know, you guys are all younger than I and I don't know if that means anything with more energy or whatever, but *without him, I don't think I would have made it.* At least not anywhere near coming up to speed the way it is now and then from there, once I got. ... things were developing too, so you learned so much, and then it's like, *let's throw that out now, we've got something new and better*, like the At Ease, which is our network system, and then the LXR had been upgraded as you go along, and then the network thing came in. At first it was, like, stand alone machines. And then the networking stuff, and then the networking capabilities of communicating with all the machines in my room. I don't have to run around. The first year was like, here's the media center, here's how to use the computer on the media center to teach the kids how to do programs on their own computer. That's almost ancient history now.

...

As for me, I take control of the machines in my room and say, OK kids, sit down and watch what I'm going to do on your screens, screen share, and I work through with that, and now go to it, and I walk around and help them individually if they run into problems. So that's the second stage: I'm comfortable with the technology now and I have a certain base of stuff to work with, but I'm nowhere near where want to be.

The *third stage* as I see yet, I haven't gotten there yet, the third stage, predicting into the future, would be: I have everything finished and in the sense that I can run a whole course as TESSI, with a study guide, all the stuff available, all the simulations and programs that work, and then the *fourth stage* for me would be now adding on anything new that comes through, like a new simulation decree comes, a new program comes, now this is neat, upgrade this, make this better. So that's the stages I would say.

...

John: What kind of expectations were expected of you? Were there any expectations, for example from Janice, or expectations from Frank, or School, which did you feel was the...where were they coming from, what did they have?

Kris: The expectations I felt were from the TESSI group, I guess that would be Janice and Frank primarily, and Steve, though Steve not so much, but two of them, that I would take this on at least and do my best with it as far as possible. I never got the feeling from either one of them that I wasn't doing enough. As long as I was putting in the hours and try to do the best that I can, that was good enough.

John: What did you feel their philosophy was towards implementation?

Kris: The way it was explained to me was perhaps, I would for the very first year, teach the way I had taught, or was used to teaching and try to, again, probably using the media center, and the overhead, to implement, use some technology as a lesson aide, in the sense of maybe using a computer simulation through the LCD panel on the overhead as a teaching aid. I would add computers, I don't think I had that many computers that first year, a complete class at the not arrive until last year and then to at the beginning of last year. At the end of the first year I think I had four computers for the kids. Frank was getting some, some were shipped across to his room.

John: Did you feel you were progressing too fast for you? What kind of changes were happening in your mind that were stressing you?

Kris: The stress was just that, I could not learn the stuff fast enough.

John: Where did you feel the pressure of learning the stuff fast enough?

Kris: Myself. I just wanted to do it. I could see from the stuff that Frank was showing the potential of the things I could try to do and as a teacher, you always want to make sure that you can do something yourself first before you force it on the kids because it inevitably, it blows up. That is another story. I've got away from that feeling. So it was pressure I put myself to learn all the stuff as much as I could. Aside from that, I a few little things that I developed that were not technology but helped cope with the technology , one of them was the glitches that inevitably happens to computer systems.

You want things to work and they are not working. You go to their machine and you try to fix the problem and then you're totally immersed in the machine, and you totally lose control of the class, and you don't know what's going on around you. So I very quickly figured out that that was not the way to go. So I have a roll of masking tape that I carry around with me all day. When a kid had a problem, I ripped off a piece of masking tape and said, here write the problem on the masking tape and stick it on the computer. And the kids would stick it on the computer on top of the monitor. And after school when all the kids were gone, I would go round from machine to machine and say OK this machine needs this, this machines needs that, and I would fix it.

John: Do feel like you were spending a lot of time dealing with technical problems?

Kris: I was dealing with the technical problems a lot in the first year.

John: Was it because the machines were not functioning properly or not set up properly, or you weren't as quick to diagnose problems...?

Kris: Both. I wasn't that familiar with what was going on with the machines. Often at times I would have to ask Frank about how to do something and other times it was because of the machines weren't set up that well yet. Now with the new At Ease system, I very rarely have problems. Sometimes we have network problems with the server but in general, like, I still use the same system and if I have a piece of tape on the machine once every two weeks, that's about par for the course. Whereas in my first year, every day there with a piece of tape on every machine with something written on it. But it worked, it was a system that worked for me and the next morning, all the tape was gone off the machines, and all the problems I had the day before were fixed. Granted, they had a new set of tapes on them the next night.

John: What type of time did you put into it, to solve these kinds of problems?

Kris: Well, I had to drive an hour anyways, about 45 minutes to get home, I never left work before 6. Usually I sort of made a deal with my wife one day a week I'd stay late until 8 or 9, sometimes 10 o'clock. I was putting in the hours and leaving 6:30 in the morning, getting to school at quarter after 7. So I was there from quarter after seven till six every day, at least, and then one or two days a week. ...

John: Were there any other non-technical help that you used?

Kris: The other thing is that with the TESSI thing being so student centered, it is like I've found the kids, to keep the kids motivated or working, they need constant feedback on what they have done and how well they have done on that. So in other words, the mark, and there's no way you can do all this marking.

John: So do you collect everything?

Kris: The way it works for me, and I know that everyone is a little bit different, the way I've worked it out tasks me is that the kids work on a task and I call all their assignments tasks, and then when they have it finished, they bring it to me and I talked to them about and check it over individually. One on one. So this is what I spend most of my time doing now. I might give a small lesson at the beginning of the class, and then they're working. So it's a similar kind of seatwork as you would have been in a regular classroom but then they bring it to me, and it may involve using computers or where they're producing a graph to go with their labs, or whatever, and I analyze this stuff with them and check it over and this may go two or three times, they may take it back to their seat, work on it some more, bring it back to me, we'll talk about it, this is still not quite right, this point you might want to fix, back and forth, until finally it's pretty good, or basically, looking over quickly, I can't see a lot of mistakes. ...

At first, another interesting thing, but kids thought I wasn't doing any marking, and they said, "Why do we have to mark everything?" that's where they go and they put the check marks on their thing, they add a the number of right and they put it at the top of the page, "why we have to do that ? " think about that, haven't I marked it when I looked at it with you maybe two or three times? Oh, Yes, you did sort of mark it, you checked it, but you did not put any marks on it--we do that ourselves. Once I get over that hurdle, they don't mind it. In addition to that, if you had handed it in the first time, I would have marked it, and you would have got a whole bunch wrong, in which case, you would have gotten a poorer mark then if we had checked it, talked about it, you fixed it, and ultimately, you get a better mark, right? I don't know if that's artificially inflating their mark, but I have a feeling that they are actually probably learning more.

... They are actually doing the work. There are always kids who circumvent the system, one kid copies of another, and hands it in as his own work. I use an analogy, a sports analogy, where I say: Look, this is team work and we're trying to get ready for a big game. If your buddy does all the practicing for you, whatever the game is, basketball or hockey or whatever, and then the game situation comes and you have just been sitting on the bench the whole time, and now it's your time to get up and play, how well will you do? And they sort of, oh yes, I've got to practice my own if I want to be good and ready for the test. For some kids it works, for some it doesn't.

...

John: But their marks really didn't change that much from what they marked themselves, right?

Kris: Yes but they had no clue, particularly younger grade kids in grade 9, when they had no clue as to what's my letter grade, how well I'm doing, or anything like that. Once I cranked out the marks and to post them on the board, then they would know how they were doing, but it was still a bog down system...

...

John: What are you doing .... When you first started TESSI a few years ago you just did it with juniors not ...?

Kris: I did it with juniors primarily, I was supposed to, Edward and I were just starting on the twelves, and Edward, working on his Masters and stuff, got a whole pile of work done in the summer, for his courses, and stuff, he just got a big jump on it. And again, it's the old guy vs. the young energy thing. I couldn't keep up. I'm data testing for him primarily and developing the junior stuff. I've done a fair bit of junior stuff that's new to me. Frank's done a start, like a first go-through, and then I've been working on it and fixing it. The grade 9 stuff is primarily mine now. The grade 10 stuff, Frank has done one go-through, and I've doing the second go-through now this semester and I'll do it again next semester. The Bi12 stuff, I've taken Edward's stuff, and this is my second go-through, I guess.

John: Just for the record, when you're doing junior science, you have to teach all the different units, right, not just biology?

Kris: right.

...

John: So you actually did use interactive tests at that time.

Kris: Yeah. I tried to use those as quickly as I could.

John: So what did you get the students to do besides, you said students use the media center to look for answers, LXR, what else did you get them to do in the early years?

Kris: Some of the kids used the word processing programs to type and up their labs, cricket graphs I used right away as soon as I was comfortable with it, I saw the beauty of that rather than plotting stuff on graph paper. It was not much more that that.

John: Why did you get LXR up as quickly as possible?

Kris: LXR was one program I was really familiar with, well not really familiar but I had used it even back in [redacted]. It was something I was comfortable with so I could get going. I knew it enough to be able to get in on it. Cricket graph was one that I did not know before it came here, but I saw the potential of it and jumped on it and it was one of the first ones that I spent a lot of time learning, not that I know it completely yet. Well, we do have a manual somewhere but who's got time to read manuals, right?

John: I asked you that question about LXR because Steve said he would start with that because it's easier, well not easier, but more interesting to students. Did you find that?

Kris: Well the kids never said. Some of them don't like it. They wish it were on paper -- some of the kids -- wished the test was on paper. Some of the kids I had, particularly if I put on it a practice test, they say can I print this off and take it home? No, I said you can do it as many times as you want on the computer. Why would you want to take it home? Why should we waste the paper? It's here. You can come in any time you want, you can do it as many times as you want, just go for it until you feel fine about it. They find it interesting but none of them said they find it that.

John: So you did LXR, word processing, cricket graphs, what else? Any simulations or anything like that?

Kris: Not yet. I haven't. ... and tried to make of simulations. No, I just got this year Adam the anatomy stuff. Those are simulations of I will use both in the grade 9 and the biology 12 this year. That's it really powerful program. Unlike that one

John: What other programs have you implemented besides the ones we have talked about? You used cricket graphs, word processing, LXR. Do you use MBL stuff?

Kris: That's the key thing. That's another new one that I want to get into in the biology twelve, the chemistry in the junior Sciences I think I can apply it and in the physics, the gates and stuff, the philosophy, right now I haven't done that yet. Again it said the potential and what I have time, the bottom line is that the equipment is not in our school either. We don't have all the sensors. Once it's all available I guess I would use it more. What else? Logal -- used the stuff on photosynthesis for biology 12 and the cardiac-pulmonary, but the date photosynthesis one is gone now, it has gone out of what the curriculum. There's the Logal one for genetics that works well in grade 10 so I will be using that for the first time this year.

John: So on the background work I guess you are concentrating on setting up networks on stuff. Did Frank do a lot of that for you or did you have to do a lot ...?

Kris: He has it organized in the sense that he had the electricians in to pull the wires but then once the computers arrived, he showed me how, and I had to learn how to do it too.

John: Do feel there was a big change after that point when you got the network in?

Kris: Yes, it made things of lot easier. Once the network was up and running, it was a headache to get all the bugs out but it's great. I just love that. When it works, it works great. And most of the time it does work now.

John: What are the best things about the network?

Kris: The fact that I can sit down at my computer and do a couple of things. If I need to put a program on that the kids are going to use, I can do that from my machine to their machine in a matter of seconds, minutes of the most. I've got whatever program I want on all eight computers. The teaching of thing which I said before where I can screen share and they are sitting at their machine watching what I'm doing, that's great. Then the server part of it with the kids can store stuff on the server and I can go and see what they have stored in their folders, they can actually hand stuff and I can look at it. That's great. Sometimes kids are working together on one machine and they produce a good product and I watch you both. Oh, no, do I have to do this all over again? " "No, no problem. Just pull up the server, copy it from your folder to the other kids it folder, boom, there it is. Things like that are just amazing.

John: Were there any negatives about the network? Was it tough to set up? Was it tough to deal with?

Kris: It was a little tricky to get set up and understand how the thing worked. There are separate programs: there is the networks assistant and with the AtEASE administrator. One of them handles the program, like moving the programs to the machines. The other one handles the students and their work, and the work group that you put them on. For example, a kid has his name on the server and he can then be a biology twelve workgroup with me, or he could be in a physics 11 work group with Frank. When he signs on, he can sign on as a Biology 12 student or a Physics 11 student or a Chemistry student if he's with [redacted].... She only has her own computer, but she's really interested and wants to get in as much as possible. She has our kids come to my room when I have a prep block and they work on my computers. That's a whole other aspect of how your room becomes "wall-less", how kids just drift in and out all the time. That's something really weird I had to wrap my mind around. You are used to closing door and you have your own little empire, well, ... You cannot close your door because constantly someone is knocking on at wanted to come in and pick up something from the printer or they want to use the computer or they want to see if they can use the computer if your kids are not using them all. It is neat. It has a spill over effect.

One of the neatest things that happened in the first year I taught kids Cricket Graph, some of them were doing a population growth occurs in social studies and a kid comes up and says " Hey, Mr. A, can I do this on the computer?" I said, "Sure, go right ahead." then the social studies teacher comes up and says, " Boy, that was a pretty neat graph that the kid produced. How did you do that? " They didn't even know that this was a possibility. They were working with their old graph paper. So it has some positive aspects of that way where it spills over to the whole school.

John: What other kind of changes did you notice that was happening around the whole idea of teaching for you? Was there a movement in any direction that you felt was?

Kris: The whole control thing goes away in the sense that you were not the center anymore. You are not the center, you are not to dishing it out at the front teaching, lecturing, whatever. It was freaky a little at first but you say, ok, normally you lecture on a certain topic and it you know you "covered" this section of the course. When you are doing it TESSI-style, you do not have that feeling. OK, have I covered it? Has it been done? I have given out the stuff, I have seen the kids doing some work, it is cutting back, but do they really have it? In a way, you are falling yourself lecturing and thinking that they really haven't just because you told them. It's just a false sense of security that you have covered the course. You have said that, if you have covered it. What makes it that you have covered it any better than the system?

John: Is this quite a change in your teaching style? Were you quite a traditional teacher before?

Kris: Yes. I'm still not comfortable with that because my big strong point is that I can lecture. That's why kids love to be in my course is because I can make analogies, I can tell stories, I can bring in anecdotes, I can make them laugh. All the kids I have ever had back, "x" number of years have come back and said I was one of the best lecturers they ever had. For me to give that up, which is one of my strong points, is really, really, tough. That's something I haven't completely figured out yet. This will be my third stage when I can get the course to the point where I ...a really strong lecture that I've used for years and years and I know it works and gets the point across. To set up the TESSI, and say that this part will be set up on the media center, but this piece will be mine. I'm going to lecture this piece, even if I have laser discs and other stuff kids can use as a backup, this is a piece I'm not going to let go of because I know this is something I can turn them on with, and that's a big part of our job, to turn them onto science.

John: Definitely, that's something I'm wondering about is where do you balance your strengths, like maybe lecture vs. TESSI, and for yourself, what do you feel is driving the direction towards more student- centered, is it something that you feel that they said this is the way go towards or do you really believe that this is the way to go?

Kris: I really believe it. I don't think I would be doing this if I really didn't believe it. I think that there is a happy medium that would be the best for both worlds. There are things out there that I cannot do on the blackboard or white board with still pictures even if I am the good artists that I just cannot do that they can see much better on a video or laser disc or simulation or CD-ROMs or whatever. And yet I still think there is a large piece that needs to be done by the teacher and this is the whole motivation and excitement part. Now as far as getting to that point, like what has been happening this year and last year, is that I have tried to use TESSI, and again I am in a semestered situation, so what has happened and it is happening again is that I'm using the TESSI as much as possible but I find that I'm running out of time. This is where a lecture is a forte. When you need to make up time, lecture is the way to do it. Now towards the second half of the course, I will be falling back to my old mode more. I personally enjoy it a little more because I'm used to that system. That is where I am not at stage three yet. Things are still a shuffling around together around.

John: That brings me to the question of what do you feel technology has enhanced, or what has it enhanced in your students' learning? You mentioned that they can see things that you would not be able to draw, no matter what. What other ways do you feel, or think, it has helped?

Kris: Ultimately I think that the more different ways you can present something to somebody the more easily it will learn or understand it. Either because they have seen two or three or four or five ways of presenting the same concept or that one of the five is something that stays with them whereas the others didn't. I think the more way as you can hit a kid with something the more likely it will be to sink in.

This is something that I have been teaching since I started teaching. I said, biology in particular has a lot of diagrams. Kids traditionally take the diagrams you might hand out as a handout and memorize the labels clockwise fashion a round the diagram for example and then wonder why on the exam you give them a different diagram, they get totally screwed up. That has always been my point. You need to take two or three or four different diagrams of the same organism or the same concept or whatever it is and put those together in your mind. Once you can do that, you really understand it. I take that is where technology comes in. It allows that to do that even more. Particularly where you have processes in biology or something it's moving across a membrane, you can see this in an animation which shows that concept much more brilliantly and you could ever do on a diagram.

John: How do you know?

Kris: I preach it, yes. Number one, I preach that fact that the need to look at more than one way of looking at things. That is one of the things that I tell them. The more ways you can look at something the better way you can understand it. The best kids pick that up. They come in after school to go through the laser discs and find stuff that I didn't even know was there. I think, hey that is pretty neat because I haven't had time to do the whole darn laser disc. This is where before I said was never started, I had to learn all the stuff. I just used Electronic Workbench. I started. Yesterday it with the first time I opened this program. I knew it was there but I had not got a round to it, the electricity section in grade 10. Yesterday I spent a half-hour with that, playing with it, so I could make a quasi-diagram and do something with that. Today I said to the kids, this is it, let me show you what I figured out, and chances are you'll figure out numerous other things that I did not know about and we will learn together. This is where I sort of backed off from where I was before and I felt I had to know it all before the kids knew it.

I think that with technology, you quickly find out that the kids know more way more than we know or ever will know so why hit your head against a brick wall. Just tell the kids, Hey I am new with this let us learn about it together. If you find something new, tell me. I want to learn with you. And they find that neat that they can do something that the teacher does not know. It is a trip for them, sort of a power trip. He doesn't know all the answers. One of the worst things teachers can do is know all the answers. But with this technology is it is definitely like that.

John: Multiple representations, new things that they picked up that they didn't expect to and you didn't expect to. What other ways do you think that technology has enhanced your students' learning or your teaching?

Kris: For some of them it is, I shouldn't say this on record, it's a policy thing we are not supposed to give marks for neatness or this kind of work habits. Work habits are a different category. It is marked on a E,G,N system but I just give, it's just trivial but it's just less than one percent, but the kids always think it is a big deal if they get one extra mark on a that if they type it up. I find that a lot of kids latch onto that one extra mark. What is one mark out of 40? But they go for it and what it does for them is:

1: It produces a nicer looking product.
2: They can read it, I can read it there's no problem reading a printed page.
3: And this is probably the most important thing, I think it helps them in an organizational way, that if they can organize something on the computer then they are also helping them organize it in their mind, which is probably the most important.

I do not regret giving that extra one or two marks if they have typed one or two pages in their lab where before they may not have. So that is another thing that I find it really helpful in technology that it helps us as an organizational tool. Sometimes kids produce something that they are really proud of because the looks nice. It is a pride thing. All that other stuff that is out there, aside from just learning it, there's a sense of self esteem. "I have produced this, it looks nice". On Parents Night, I have the file folder with all the kids stuff in it and parents are really impressed by it. My kids did this? I didn't even know he could type.

John: That is neat. Really neat. Would you say that that is one of the unexpected things?

Kris: Yes, exactly. One of those unexpected little things that I never thought would happen. Another one of those unexpected things it is you expect kids to take the laser disk down and look at the stuff you want him or her to look at that goes with the lesson, but that's not going to happen. We do that but they soon realized that this laser disc is full of a whole bunch of other stuff and it may lead to various areas that are way off the map and things that they could get interested in, you never know where it is going to go, like the Internet, who knows? Just sort of an expansive tool.

...

Kris: For some of the kids, not all them, there is some phobia amongst some of them, computer phobia, but in general, the majority I think, it's cool to work on a computer. That is sort of a positive thing too. It is a motivational thing. One of the things that I found, even for kids who do not want to do it, they work. For the testing of LXR, the way I have it set up is, I give them a practice test that they can do as many times as they want, and when they are ready, they take the real one. I found that if you do test and retest, they don't take the first one seriously. Instead of test and retest, I've gone practice test and the real thing. You'll get kids who say there is 15 min. left in class and I don't want to do anything anymore, and I'm on their case, get to work! Why don't you just go to a computer with a practice test and they're, ok, that's cool. So they'll go and sit down and go through a practice test. Hey, they're learning something. It's the old catechism approach -- catechism being a question and answer type of learning system where you have a question and you answer it. Well, if you take a test, and even if you're guessing at an answer, then you mark it on LXR, okay that's the right one, so they're learning. I found that works for kids who can't motivate themselves, they don't want to do anything for the last 10 min. of class. Something is going to happen if they sit down and go through that. They are learning in spite of themselves. You know the kind of kids I mean: hard to motivate. They won't write anything but they will click a button. It is better than nothing.

John: I'm going to finish off by asking you about the pace the last few years. You mentioned that most of the motivation for the stress to do well came from yourself and I hear that a lot from the other guys. I'm just wondering, if you could do it all over again in terms of the last two years in terms of pace, what would you change about or would you have thought about it in a different way now that you can look back? Or do you still feel you can't look back because you're still on the go?

Kris: I don't know if I would have done something different.

John: Could you say that I would have looked at the way I approach this, in a different way?

Kris: You pretty well have to go and try things. You are going to run into roadblocks. Looking back on it, you say, I wasted a lot of time doing this because it took me so much time to figure it out but the point is now you know you learned by doing it the hard way. I don't know if I would have done anything different. I mean, there is only so much time in a day.

John: So you have to try and get rid of things.

Kris: You just have to jump into and you sink. Gradually you come up for air. That is all there is to it.

John: That is funny how you use that analogy. Harry and I, when we first started we said that we are jumping into the deep end and not knowing how to swim.

Kris: Exactly. That is exactly the feeling. You are walking on the bottom. That is exactly right. Once we get this stuff all prepared and "canned", like Frank is always asking me this question, how long do think it would take if you were presented with everything, a complete package. Could you get into it in one year?

...

John: You have also had to develop your own material.

Kris: We were developing this stuff and I don't know if that is a fair question. But I think that once it is altogether and you given to someone and say, here run with it and see what he or she can do with it in one year.

...

John: One last question about the study guide: that approach, how did you come upon that?

Kris: That it was set up from physics.

John: So you felt that that was the way to go?

Kris: That's the way to go. And I have taken that and modified it a little bit myself. What I do is I put in the tasks and the assignments that I want them to do right in the study guide and that is the topic for discussion if and when it goes to print. That is what works for me at the moment.

John: Is that because the physics guys and separated the labs from the instruction in a separate booklet?

Kris: Yeah as they have it all separated out into booklets now. They're actually four different booklets.

John: Did you feel that, were you all for the study guides or were they just the thing that you thought this was the way to facilitate it, or how did you feel about that? Even now?

Kris: I think that it is a good idea. They all need work but I think the concept of it leads the kids through the course. It is the roadway through the course and then you are doing all these little stop-offs on the road. You pull into this restaurant, you pull into that gas station or whatever and you look at this, if you try that labs, and you go and pick up this simulation. It is like a roadway. To me it seems like the center.

John: Has that helped you through your previous teacher-centered thing to a student centered thing?

Kris: It is the student centered piece and it is the main organizational tool. I guess there would be other ways of doing that if a teacher could still be teacher centered with the teacher would run the thing and say, now we're going to do this lab and it could still be technology enhanced. You could do it differently. I don't think you ultimately need... the study guide would ultimately be replaced by the teachers learning plan that the teacher keeps in his or her book. I guess you would not need it but you need some kind of central organization obviously to binder course and the study guide to provide that and it provides it to the student which I think is a better way than if it's a hidden agenda that the teacher has. Basically the study guide is like an over blown course as outlined. If you give it a course aligned on one piece of paper at the beginning of the course, this and then take the course aligned and says this is the road we're going to follow.

John: When do you not decide to use the pieces of technology?

Kris: Edward and I have been looking at stuff. You look at it and say it doesn't feel right. It's a gut feeling in the sense that you know what you are trying to present to the kids, you know the concept and you say does this piece of technology, program or CD, really do that? If I was a super- duper programmer and could do all the glitzy stuff myself, is this what I would produce? The answer is no way or yes. This is cool, this the way I would do it, I agree with this, or it isn't. There's even stuff that I have pulled off the Internet, shareware or free stuff, where a certain person has an idea for DNA replication or something and it is good. But if I was doing it, I would change this.

John: Do you actually using any of the Internet?

Kris: I have used to things insofar that I have actually downloaded and incorporated into the study guides.

John: But you haven't use the Internet for research or ...

Kris: No I haven't yet. We just got our telephone line into this year where I have the ability to tie the computers to be Internet. I'm just in the process of putting the numbers on, the TCP/IP numbers and all that stuff.

...

John: Do you ever imagine creating activities where ...

Kris: Yes ultimately if you want them to do some kind of project, either just straight information or even some kind of, I have two girls in a grade 9 class who were going to put together a PowerPoint Presentation. I have given them lots of time and they have PowerPoint on their computer at home. They already have 12 slides that they have roughed in and they're going to present this to the classic later on.

John: this is part of a project assignment?

Kris: Yes it was a bonus project that was one of the tasks that they could do. I am seeing how it works.

APPENDIX D: Interview Extract of Frank's Detailed Description of the Three Levels of Technology Use

J: Just describe to me what happened at each stage.

F: In the first year, we were doing it simply because of budget limitations. We only had the money to buy the equipment for a media presentation center that had a computer, a display panel, high-power overhead, VCR, laserdisc. We had a year to explore the simulations and the software ourselves so we became comfortable with it and used it to enhance our lecture. It really did promote some higher-level questioning from the students, and much more involvement. It was interesting, it was new, it was different.

That was fine but we did get another burst of money. It wasn't a conscious decision to go to a Level 2. It was just that we got some more money so that the students can try this. Okay, great. So that brought us to Level 2 in the second year, not through any planning, but just because we had some more money and some more computers. Then the students started using it and then all hell broke loose because everybody started pursuing different ideas and different passions. Some students hated simulations and loved multimedia. Some students wanted to guess and check, some just wanted to find the answer. So, very, very quickly, we had a management nightmare on our hands. How do we control this because we couldn't put the kids into their nice little boxes in a nice, controlled way.

So Level 2, when the technology came in, we saw we needed to orchestrate that very carefully. We needed to activity guides developed first that directed the students along a particular path when they were using a simulation or a multimedia analysis. We didn't have those, of course, so students were exploring simulations much more free-basing, for a lack of a better word, and it became very difficult to manage. So it evolved, we could see a Level 2, but you needed resources there to facilitate the Level 2. By resources I mean the activity guides to be developed first. That's when study guides started to evolve. The study guides were pretty much based originally only on the overhead transparencies we used to use in our lecture. So we took our notes, we slapped it into a text-based format to photocopy to give to the students. In the midst of the notes, we inserted a line saying: "go to the computer and do a simulation". But there was no activity guide for that simulation. The students would just go amuck with it.

And then in the third and the fourth year, the study guide started to evolve to much higher complexity. We started taking a Master's program and as we took some courses, we were refreshed about learning styles and learning theories, individualizing instructions, outcomes-based education, all those pieces of theories started to come into our heads and we were really overwhelmed. We saw that just about any theory that we were shown in our graduate classes, we could do. And it was a really daunting thing. And this isn't an egocentric comment, but it's just this bizarre sense of potential that we could do anything! You want it? Sure. Change the curriculum? Fine. Student-centered? No problem. Outcomes-based? Yup! All of a sudden we hit something very close to burnout because we tried to do everything because if we could do everything, that would be good, right? I think that's one of the strengths we have learned from in

TESSI is that you can do anything if you choose to. The important thing is to make some decisions.

It wasn't until the fourth or fifth year that we discovered something through our CUST course, something called "Berlaks' dilemmas" which finally gave us permission to say "No!" to some things. In teaching, that is a very difficult thing for us to say. "No!" You're always supposed to be able to help students. You're always supposed to create opportunities. This was the first case we had seen something formal that was educationally sound that we could say that even though TESSI could do everything, I am choosing to implement it in this way. And that has some positive and some negative effects ... We made a choice, and having a classroom that is student-directed has obvious strengths, especially in terms of skill development.

Anyhow, what evolved for the Level 3 was with Berlaks' dilemmas we made some decisions about how we were going to operate and we decided that the way we chose to go. If we could create opportunities for students of different learning styles, that seemed to be a crucial part, and if we create the potential for self-paced learning but not actually do it, then as educational change happened, and the infrastructure in schools happened, we could shift into that gear. We have made resources and set up our classrooms in a self-directed way but not self-paced, but it could easily take that step.

We've also tried to set up the resources in a way to address different learning styles. Parallel with that, we identified in Level 3 a set of skills that students could develop that we believe, are transferable to post-secondary, and transferable to the work place just in the way we ran the classroom, just in the pedagogy. Those had to do with time management, collaborative learning, and goal setting, and of course, using technology. So Level 3 seems to complement all of those the best. It doesn't mean that Level 2 isn't effective, it certainly is, but it just doesn't address some of the other skills. Just like Berlak's dilemmas, it's a choice. I'm going to do it this way for some reasons, which are very sound, and that means we are not going to do something else. I think that it's important in our new TESSI sites, that each teacher make that decision, and not feel the pressure that they have to do everything but to say that this is the path that I'm taking. Screw the other stuff. Yes, that can be done. Yes, that's great, but I'm not going to do it. And that's okay.

J: When you decided this, was it, "we're going to do this." Or was it more like, "we evolved to this point and we might as well make it the official approach"?

F: The latter. It's been a real evolutionary thing. There's no right answer. We also find that still now, if you look up Steve's interview and my interview, things that we emphasize and believe passionately are almost contradictory. Janice refers to that as the strength to the model. The individual can take their personality and their own individual strength and mold the model to suit that. It is not that the teacher has to mold to suit TESSI, within limitations of course. But it is an evolutionary thing. There isn't a right answer. I think that in TESSI, it's more like, here's 12 answers you can pick. Pick one.

APPENDIX E: Email Interview Extract from Dr. Janice Woodrow, TESSI Project Director*

The questions posed to Dr. Woodow (henceforth called Woodrow)

A. How Woodrow defines her role in TESSI?
B. Integration Concerns & Progression
C. The Study Guides
D. What is TESSI?

The following are Woodrow's responses.
*Pseudonyms used throughout.

A. How would you define your role in TESSI?

I see myself as performing the following functions:

i. Originating the project
ii. Providing support, coordination, maintenance, and, occasionally, arbitration
iii. Selecting participants
iv. Providing the majority of the funding
v. Negotiating and liaising with the schools/School Districts for the project's operation
vi. Arranging and chairing meetings of participants
vii. Providing guidance and "gentle" direction for the development of the project's ideas and resources.
viii. Developing and articulating the project's framework and pedagogy
ix. Publicizing the project – dissemination, journal articles, conference presentations, workshops
x. Coordinating and conducting project research.

I view myself as a project originator and facilitator. The strength of field-based collaborative research projects is diminished if the participants are subjected to "top-down" leadership. In TESSI, each teacher brings a wealth of practical knowledge and experience to the project. I bring practical and theoretical knowledge, experience and perspectives that I use to support the activities of the various participants including J and E in their early, project-related research and dissemination activities. I did not begin TESSI with a developed theory that I wished to implement. Rather, I had goals for the effective use of technology in science classrooms and a desire to see these goals attained in a practical and operational format that could make a positive difference to the learning of students and the practice of science teachers. None of the above would be possible without a good educational "idea".

B. Integration Concerns & Progression

i) How would you classify the main areas of concerns of teachers in TESSI?

The concerns of the TESSI teachers fall into three categories: technical, pedagogical and student.

At the beginning of their tenure in the project, each teacher faces a myriad of **technical concerns**. Some of these concerns are with the learning of many new software packages quickly and expertly enough to field student questions. Some are related to doing new things with technology such as setting up networks. As a result of TESSI, I now strongly recommend to teachers wanting to implement technology to first make sure that all of the technical components are fully functional before getting the students involved. Technical problems, while the first to arise, do eventually get solved and generally fade in importance although they never disappear.

Pedagogical concerns, however, tend to be more difficult to address. Pedagogical concerns include how, when and why to use technology. What is the best balance between TEI and traditional instruction?

Finally, **concerns related to the students** include ensuring that all students learn to the best of their capacity, helping students to master technology and learning skills, making sure that all stay on-task, etc. The student concerns are not particularly unique to TESSI but they do seem to get accentuated, at least in the early stages.

ii) When you say that you have seen the TESSI group go through common stages, what exactly are these stages?
One common stage is the switch from a focus on technology concerns to one on pedagogy concerns. Another is assuming that the value of using technology is apparent to the students. It is not. TESSI students have mastered the direct method of instruction. They must be "retrained" if they are to get the greatest benefit from TESSI. Thus all TESSI teachers learn the importance of talking about learning and the benefits of the TESSI instructional practices with their students. A third stage is that of becoming the technology guru in the school. One consequence of this is a major demand upon the TESSI teacher's time before the teacher learns how to handle this new status. A positive consequence is an increase in participation of professional development activities. Other teachers are very interested in what TESSI teachers are doing in their classroom and how they are doing it. Classroom visits tend to increase. Finally, TESSI teachers seem to enter a leadership role in their schools. They are viewed as doing something unique and important. Unfortunately, they are also sometimes subjected to negative comments from their peers.

iii) How and how well do you think that the teachers have negotiated the issues?
Extremely well.

C. The Study Guides:

i) How did the study guide come about? Who? Why?
The idea of the Study Guides originated with Steve. Prior to the start of TESSI, Steve was experimenting with dividing his Physics 11 classes into two sections for the second half of the year—those who planned to continue to Physics 12 and those for whom Physics 11 would be a terminal course. These two groups were assigned different units. Steve had transcribed most of his teaching notes, examples, etc to student materials which the two groups used in a modified self-directed way. Using these materials, Steve found that he could work effectively with his "split" class. When the student computers were first put into Steve's and Frank's classrooms, we searched for a method for maximizing student use of the technology. Time became a major issue. To

allow time for technology use, we realized that teacher lecture time had to re drastically reduced. The Study Guides were developed as a means of replacing the lectures and providing the necessary guidance for the students.

ii). Why is there a consistency between the subject areas? (Motivation?)

I don't think there is any special reason for this consistency expect the fact that the Study Guides worked in Physics and therefore were implemented in the other areas as we began to work on them. I view the Guides as a device that permits the teachers to operate in a specific fashion in the classroom. They may not be the only method that would permit this fashion but it is one that works – particularly if the teacher wants to implement multitasking and variable pacing. However, it does impose a "paper" load on the model. This paper load may be temporary, however, as the number of computers increases and the resources can be accessed electronically.

iii). Has anyone else challenged the use or its format?

Students often raise "challenges" to the use of the Study Guides – particularly initially. They are accustomed to the teacher lecturing and view the Guides simply as worksheets (make-work). For example, some students feel that they just have to fill in the blanks. There are surprised that they are supposed to be learning the material and that the Guides are just a means of coordinating and directing this learning. Some students are slow to assume increased responsibility for their own leaning.

Edward has made some adjustments to the Study Guides to better suit Biology and its technologies. One change that comes to mind is that when students are responding to questions related to multimedia resources (CD's, digitized movies and laserdiscs) Edward has them do their work in Word rather than on paper so that they can add captured pictures as part of their responses. He found that this procedure forced the students to watch the multimedia instead of just reading their Study Guide or Activity sheet and entering answers. In Physics, this problem was not an issue because most of the multimedia resources used in Physics require the students to collect data or make measurements.

One formatting issue that arose when we started working with Grade 9 and 10 students was that of the "density" of the print the we were using in the Physics Guides. The pages were just too busy and too packed with information for the younger students. Therefore, for these grades we include larger white spaces and more room for student responses.

The matter of the font was never raised prior to this fall.

Acting as a facilitator, I have not imposed any particular format on the materials that TESSI is developing. However, I am accustomed to editing material for readability and grade suitability and I feel that it is my role to make suggestions (rulings?) on such matters. As far as the physical format is concerned, I feel that if any participant can support modifications and these can be supported by the rest of the members or at least the subgroup of participants, then we should go with that modification. We are trying to develop something that works, not that conforms to some sort of theoretical construct. We are all trying to learn together.

D. "TESSI"

i) If there is a "TESSI Model" what is it?

While I often call TESSI a model, it is probably more properly called an exemplar of technology implementation in secondary science classrooms. Insofar as it is a model, is it a pedagogical model – a model of how to effectively use existing technology to enhance student learning. In trying to illustrate the TESSI model, I tend to use the following two diagrams. The diagram in Figure 1 illustrates the "flow of knowledge" in a direct instruction environment – also called "traditional" or "transmissive" instruction. Virtually all information is channeled through the teacher to the student. The only other source of information that the student typically accesses is the textbook. In traditional classrooms, teachers frequently supplement classroom texts with demonstrations, problem sets or assignments, and tests. The tests are primarily used to determine how much the student has learned (memorized) and are generally summative in nature.

If a traditional classroom is equipped with just one computer, technology can be used in demonstration mode to support teacher lectures. This mode is depicted in Figure 1 by the inclusion of items above CONTENT – Multimedia, Simulations and MBL. The lecture is presented via a classroom TV monitor or an LCD panel and overhead projector. In this mode of technology implementation the teacher is still the primary source of information but the range and impact of available teaching resources is much greater and can lead to better student learning. Lessons are made with presentation software, such as PowerPoint. The use of a multimedia center allows the teacher to switch between computer, VCR, and laserdisc material. Lessons presented in this manner are visually pleasing for the students. However, students themselves do not get to use the technology unless it is within a teacher demonstration. For example, a demonstration with a motion detector could easily involve a student running the software and a student performing the motion, all under the control of the teacher.

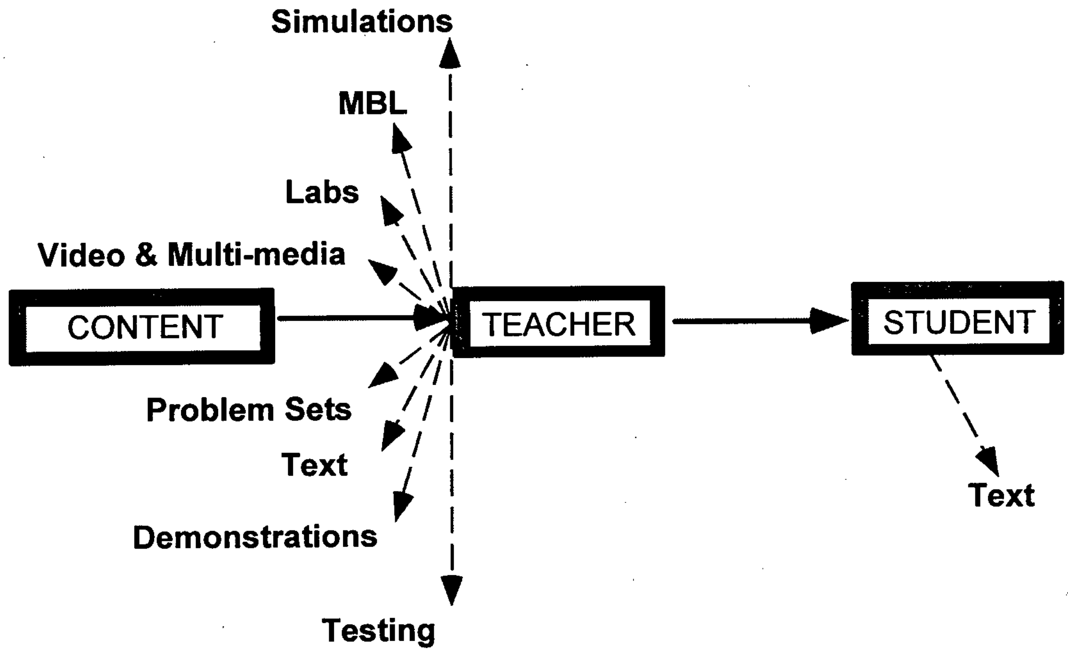

Figure 1: The Direct Instructional Model

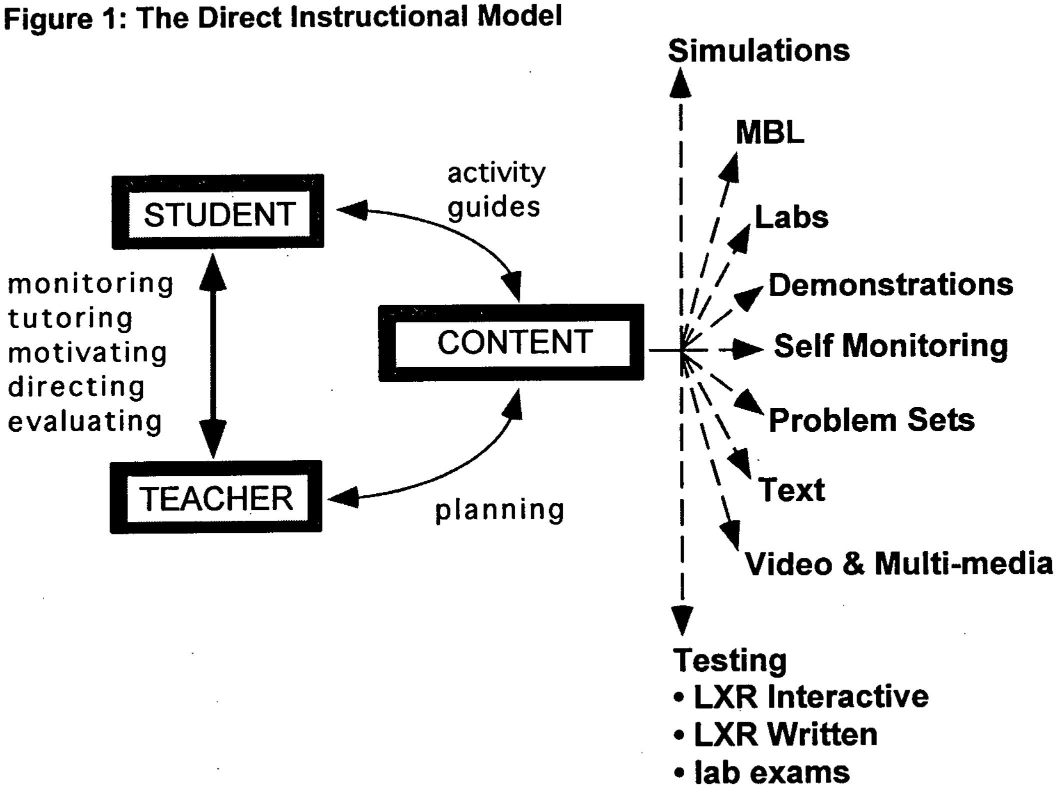

Figure 2. TESSI's Student-Centered

TESSI is not trying to replace the teacher with computers—it is creating a model of how teachers and students can use computers as tools to enhance student learning.

In TESSI, the flow of knowledge is more circular than linear as depicted in Figure 2[14]. The students, teacher and content all *interact* in a variety of formats. Students are given primary access to all classroom resources as well as to the teacher and their peers as means of promoting and supporting student learning. TESSI's pedagogy combines features of the indirect model of instruction with the enabling abilities of modern information technology. Indirect instruction is an approach to teaching and learning in which the process of learning is inquiry, the result is discovery, and the learning context is a problem. In indirect instruction, students are provided with an environment in which they engage in active learning, guided and monitored by their teacher. This type of instruction leads to learning beyond the mere recall of facts and procedures. Using the technology to present better classroom lectures in a teacher centered format is a better learning environment for students than one in which such resources are absent, but it is not the best pedagogical use of the technology. However, doing "glitzy" presentations with technology is not making the best use of available resources. Most students, when given a chance, would rather just get "on with it" than listen to a teacher talk for an hour and then be assigned an hour of homework. The more teachers lecture, the less time the students have to spend working at the computers and related technology learning the core material. In TESSI classrooms, teaching and learning is process-oriented and student-centered, placing more responsibility for learning on the student. Student-centered learning experiences help students acquire knowledge by becoming deeply involved in manipulating information and thinking about it through inquiry, problem-solving, critical thinking and communication processes, and then integrating what they have learned into their own knowledge base.

ii) What is the overarching goal of TESSI? How and why was the TESSI project started?

Why did I start TESSI? Professionally, I view myself as a teacher educator. In the 80's I began using technology to support my own teaching at UBC and became interested in learning how to use technology effectively in the classroom to support instruction and to train teachers in these strategies. At the time, there was little in the way of good research into the educational use of computers except as tools to support tutorials. I believed that computers could function much more effectively to support student learning and endeavored to find out how. As my background is Physics, naturally I began the project with Physics and then expanded into the other sciences. Initially, the project was to focus on the use of simulations – specifically Interactive Physics. The other software components were added as they became available and functional.

When I first started organizing the project in 1991, I stated the purpose and goal as:
Purpose: The primary purpose of this study is to develop, document and communicate to potential users, teaching strategies and classroom procedures that promote the best use of a specific type of technology: computer-based simulations. The following research questions are proposed for the study.

1. What are the most effective strategies of incorporating computer-based simulations into the teaching of physics?
2. What are the outcomes of incorporating computer-based simulations into physics curricula?

[14] This diagrammatic representation of the TESSI model was developed by Frank.

Goal: The ultimate goal of the study is to improve the quality and appeal of science education in BC in an effort to address rising school dropout rates and declining interest in science and technology.

Today, I would state TESSI's purpose and goal as:
Primary Objectives:
1. To develop and disseminate effective teaching strategies for the implementation of technology enhanced instruction. These strategies will be developed with practicing teachers and evaluated in real classrooms.
2. To develop complete sets of technology integrated student learning resources for Chemistry 11 & 12, Physics 11 and 12, and Biology 11 and 12 to support these teaching strategies. These resources will provide for variations in student learning styles, differentiated learning rates, individualized instruction, student goal setting, development of time, communication, collaboration and technology skills, and provide opportunities for students to control and monitor some of their own learning. To be developed in electronic form, these resources will be easily adaptable to a variety of texts and curricula, and updated as new and more powerful technology applications are developed.

Goal: The goal of TESSI is to help secondary science teachers incorporate computers and multimedia technology into their curricula in ways that support powerful new forms of student-centered classroom learning and instruction, and that enhance student learning.

Now, when asked why technology should be introduced into science classrooms, I provide the following rationale:

Why Use Technology?

- Help students learn more
  - access and control of information database
  - information processing and application
- Help students learn better
  - active learning
  - collaborative learning
  - "what-if " questions
- Help students learn faster
  - visual representations
  - self-paced learning
  - interactive
- Help students acquire essential modern technology skills

Students must learn how to find information, think about it, and synthesize it rather than how to memorize it. Underlying TESSI are the following principles:

- Students learn through exploration, collaborative groupwork, and critical examination, rather than acquiring information primarily from teachers and textbooks.
- Students must be helped to think for themselves and be able to create knowledge - constructivism

- Teachers must get out of the "information-providing" business and into the "question-asking" business, prompting students to seek information and learn to process it.
- The information explosion changes the nature of knowing from the ability to recall information to the ability to define problems, retrieve information selectively, and solve problems flexibly. Rapid advance changes the nature of learning from the need to master topics in class to the need to learn autonomously.
- Education goals must shift from facts and formulae to assisting young people to find facts and develop strategies to solve problems.
- Educators must redesign curriculum and instruction to promote problem solving and deeper understanding.
- Students learn not by listening to information presented by others, but by actively manipulating and synthesizing information in such a way that is complements and expand existing understandings.

iii) How has the project progressed? What would you say were the critical revelations and decisions made? What types of major changes in design were made along the way?

Well – they say that ignorance is bliss. Little did I realize the size of the endeavor that I undertook. Fortunately, neither did any of those who joined the project. As I stated above, initially, the project was developed to research the use of simulations in Physics. It quickly became apparent that this objective was much too limited and did not warrant the expense of equipping the classroom with the technology. Once the technology was in the classroom, Steve, Frank and I wanted to maximize its use. Thus, very quickly the scope of the project expanded to include LXR, laserdiscs, MBL and now Videopoint–any another application we could justify.

Critical Revelations and decisions:

1. The first crucial revelation was that my decision to invite two teachers to join the project was absolutely paramount to the project's success. I don't believe a project as comprehensive as TESSI would have been viable with only one teacher and myself. The two teachers provided mutual support as well as a means of distributing the workload. It was also important that the two teachers could work well together–they came to the project with a history, which helped, in the initial stages of forming the **collaborative team.**
2. Another important revelation was that the **decision to locate the project in a School District like** Q where the schools (principals) have a degree of autonomy that seems to be lacking in districts like R was critical. Q welcomed the idea of being a research site whereas R has had its fill. Over the course of the project, the support of the School Districts, first Q and then M and D was critical. The importance of this point has been reinforced many times.
3. The decision to **use commercially available software** was also important to the project. The project was able to focus on the development of TEI teaching and learning strategies, not the development and testing of software. In fact, I suspect that Q would not have approved the project had its main purpose been the development of software.
4. **The hardest part of implementing TEI is the change in the requisite teaching and learning strategies**. Clearly, for the developers, there are other challenges

such as the need to develop (by trial and error) these strategies and the supporting resources, but for the teachers that follow, the implementation of new teaching practices will be the most challenging aspect of using technology. An important consequence of using the commercial software is that once the instructional/learning processes are in place, they can be easily adapted to accommodate new forms and levels of technology.

5. **TESSI's assessment practices** are important to the success of its model. Interactive assessment promotes self-monitoring, improved learning and enhanced student responsibility. The ability to develop and mark tests quickly is important for the teacher.
6. The **nature and scope of the project changed with the inclusion first of Biology teachers and then with Chemistry teachers**. The increased breadth has strengthened the foundation of the pedagogical practices and provided an opportunity to discern which practices are general and which are subject-based.
7. The **timing of the project** seems to be optimal-with the development just ahead of major interest in injecting technology into the educational system.
8. The development of this model was **guided by the following principles**: instruction must be learner centered (i.e., task/learning oriented), technology must be classroom-based, software must be commercially available, software must be used as a tool as opposed to a tutorial, technology must be used to enhance student learning, and the model must be functional, feasible, flexible and transferable to other teachers.
9. **Technology became viewed as a means of addressing variations in preferred learning styles**. Thus TESSI started developing alternate means to helping students learn fundamental concepts.
10. **Technology should replace hands-on activities only if its use enhances student learning**.

<u>iv) What types of major changes in design were made along the way?</u>

1. The project was expanded to include more science areas and more teachers.
2. J and E were invited to join as researchers
3. The development of the Study and Activity Guides increased in importance.
4. The opportunity to publish the TESSI materials arose.
5. The experienced teachers became increasingly involved in professional development activities.

APPENDIX F: STAGE ANALYSIS OF INDIVIDUAL TECHNOLOGY INTEGRATION PROGRESS

Phase	*Frank*	*Steve*	*Edward*	*Kris*	*Harry*	*Lawrence*
1 Exposure	Teacher: • Conception of technology as tool only, not change in pedagogy • Minimal preconceptions • Conceptions of course (Physics) as elitist • Conception of engaging students, esp. all students as important	Student: • Not all kids involved • Choice for students - as optional activity Teacher: • Limited formal training / no training • No real student goals • Word-processing • Spreadsheets / Marks • HyperCard Programming Infrastructure: • Problems with access (numbers, times, other rooms)	Students: • Limited, if any, computer use Teacher: • Experienced with some technology • Conception that didn't agree with the way Science was taught • Station approach to teaching • Word processing • Marks Infrastructure: • Problems with resources	Student: • Limited computer use • Some computer phobia Teacher: • Minimal preconceptions • Technology as part of job requirement • Word processing • Marks Infrastructure: • Problems with access (hassle to switch rooms)	Student: • Limited computer use Teacher: • Experienced with Apple IIe, LC630 • innate, raw interest in technology Infrastructure: • Apple IIe, LC630 • Problems with resources	Student: • Most have computer experience and are computer educated in other courses • Word processing Teacher: • Self-taught Apple II and Apple IIe • Word processing • Marks • Did some station work • Use of temperature probes Infrastructure: • Problems with access

Phase	***Frank***	***Steve***	***Edward***	***Kris***	***Harry***	***Lawrence***
2 Initiation	Student: Teacher: • Teacher as a virus • Change in relationships with students: more engaged academically, tutoring, mentoring, motivating, but NOT in terms of responding in terms of group dynamics, charisma-style -	• Student: Practical Bottlenecks – whole class can't get on _. Solution: groups and different activities -> other problems -> student self-direction • Diversity of students Teacher: • Excitement • Concern over viability • Concern over expectations over success • Concern over time • Concern over justification for funding • Change in teaching style hinted at • Want students	Student: • Felt they were involved in a new and special project • Not accepting of the new technologies • Complaints, reluctance • Watch teacher demonstrate Teacher: • Excitement • Technology for demonstrations • Concern over time • Change in relationships with students: more engaged academically, tutoring, mentoring, motivating • Change in teaching style	Student: • Students observe teacher through screen sharing Teacher: • Excitement, shock • Concern over viability • Concern over time • Expectation from Janice and Frank to do his best • Felt couldn't learn the technology fast enough • Pressured	Student: • Didn't care? • Complaints • Felt they didn't benefit from using technology • Felt they weren't learning as much Teacher: • Excitement • Apprehension • Concern over time • Change in relationships with students: feel forcing students to do activities they don't enjoy • Frustration over technical problems • trial and error	Student: • Excited • Very accepting of new technologies • Novel Teacher: • Excitement • Apprehension • Concern over time • Felt no pressure from administration or expectations from Janice • Computer as data collector • Difficult to organize materials, equipment,

	> not seen as teaching (considered as loss) • Function of teacher style and control • Change from performance in teaching and the enjoyment of this aspect; loss due to time and other responsibilities • Hope for student learning: relevancy (measure or model / simulate situations) & motivation (student control vs. passive watching) Infrastructure: • Good candidates = willing to work to change • Administrative	to learn better • Want to make teaching easier! (Ha)-> But doing more different things • Frustration over technological problems **• Classroom activities as supplementing lectures and the demonstrations** Infrastructure: • Funding & grant processes • Teacher computer, LCD	• Want students to me actively engaged • Wants student-directed learning • Frustration over technical problems Infrastructure: • Colleague support critical • Limited resources: big screen TV,	himself to learn quickly • Frustration over technical problems • Change from performance in teaching and the enjoyment of this aspect; loss due to time and other responsibilities Infrastructure: • Colleague support essential • Limited resources: 4	method • sometimes changed what was taught to fit SIMS Infrastructure: • 8 computers: 6 LC3, 2 5200, Ethernet, 12 meg RAM, probes	safety Infrastructure: • MacJanet network already at school • At Ease network difficult

	support for innovation • Allowed to make mistakes • Debriefings crucial • Budget possibly limiting (depends) therefore one system • Allows for initial exploration into new resources • Technically based problems • Training to do good simulations • Resources & development • Time -> personal toll	Panel Laser disk -> 8 computers, software security system • Funding concern & justification – limit to eight computers • Technological problems & time (e.g. installing)	Apple Presentation System, Mac LC630 • Technological problems & time	computers (stand along machines) • Technological problems & time	• no network or wiring • support from school computer science teacher • funding from TESSI project and technology grant • no funding from own school • lack of administrative support in funding • problems with placement of equipment in the room	to work with • Frustration over technical problems • Technological problems & time • lot of computer expertise at school-colleague support essential • good administrative support • block provided for implementation • Limited resources and software • no support from TESSI teachers taken

Phase	Frank	Steve	Edward	Kris	Harry	Lawrence
3 Infusion	Student: • Problem: students learning things not Provincially Examinable Teacher: • Level 2: Management nightmare begins -> one solution - study guides REQUIRED • Transferable skills: "those had to do with time	Student: • Phenomenon: Mobilising students to take care of computers Teacher: • Increase /new level of technical expertise: Networks	Student: • Students follow teacher's example • unmotivated students less detrimental to others • students more involved Teacher: • Organizer, reinforcer • Role of manager-coach • Increase level of technical expertise • Curricular issues increase	Student: • Some students wanted "paper" tests, rather than interactive Teacher: • Using technology as a lesson aide • Increase/new level of technical expertise: networks • Study guides help facilitate the course • Technology-	Student: • Some students have taught teacher technical installations • Variety of activities Teacher: • Using technology as an add-on and replacement • Technology hasn't changed teaching method; still teacher-centered • questioning	Student: • Like the instant feedback provided • Can take risks with the computers • Work co-operatively • Have more time to address questions rather than data collection • More motivated • Pride Teacher: • Curricular issues increase • Increase level of technical expertise • Attended workshops for personal pro-d • Giving workshops on Internet

	management, collaborative learning, and goal setting, and of course, using technology." :	Infrastructure: • Networking: learning software, "making things talk another" • Advanced computer maintenance - e.g. rebuilding desktops, backups,	Infrastructure: • Networking: learning new software • lack software, chairs • colleague support essential	affected management issues begin • Implemented LXR early • Cricket graphs • Student management problems Infrastructure: • Networking: new software • Lacking MBL equipment • Colleague support in wiring & collaboration essential	integration; when to use what • questioning curriculum match • questioning value of certain sims • Increase level of technical expertise • Trained staff; led workshops • want students to be better logical thinkers, enjoy science, enjoy teacher-student relationship, learn about life Infrastructure: • still lacking resources	Scavenger Hunts Infrastructure: • Learning new software • Using the Internet • Lacking software

Phase	***Frank***	***Steve***	***Edward***	***Kris***	***Harry***	***Lawrence***
4 Synthesis/ Breakthrough	Student: • Style settled Teacher: • Realization point that TESSI could meet different perspectives of learning, learning styles (Master's Program => CHOICE / DECISION MOMENT! TESSI could take you any which way?	Student: • cont. study guides	Student: • responding much better Teacher: • Realization point that TESSI could meet different perspectives of learning, learning styles	Infrastructure: • Spill over effect: room becomes "wall-less" • Realization that with multiple representations, it is easier for them to learn or understand it		

Phase	***Frank***	***Steve***	***Edward***	***Kris***	***Harry***	***Lawrence***
5 Integrated	Teacher: • Make take more time for students to do course because it's learning by doing not by lecture • Resources for	Teacher: • Test analysis & feedback to students, mastery reports, LXR Retests? & self-pacing -> benefits &	Student: • Learn things they didn't expect to • Learn higher-level skills that aren't tested on exams • Collaborate, help each other • Top students worked by themselves • Self-directed • Learn time management skills • optional assignments they can choose Teacher: • Addresses different learning styles (multiple representations) • Test analysis & feedback to students, LXR retests	Student: • Learn things they didn't expect to • Produce more aesthetically pleasing projects • Become better organized • Pride • Increases self-esteem • Self-motivation Teacher: • You are not the center anymore • Test analysis & feedback to students, LXR retests • Limited Internet use		

	evaluation - e.g. LXR test has to be substantial • Don't give up "traditional labs" • Introduce pedagogy, deal with management issues, then technology	problems • Limited Internet use Infrastructure: • Technical problems continue, but more experience in dealing with these	• Balance between personal strengths and traditional teaching styles and TESSI • More aware of what students know and don't know • Using sims, animations, NIH activities, MBL labs Infrastructure: • Technical problems continue, but more experience in dealing with these • interfaces need redesign - to be more user-friendly	• Balance between personal strengths and TESSI • Technology as an expansive tool Infrastructure: • Technical problems continue, but more experience		

Phase	***Frank***	***Steve***	***Edward***	***Kris***	***Harry***	***Lawrence***
6 Innovation	Student: • Developing choice in learning with multiple activities Teacher: Innovation and questions in evaluation - e.g. formative and summative • Broader academic issues - e.g curriculum role; mastery vs. content; depth vs. breath; specific skill vs. general	Infrastructure: • upgrades	Student: • Developing choice in learning with multiple activities Teacher: • Innovation and questions in evaluation • Want to include optional activities to key on different learning styles			

APPENDIX G: VEE HEURISTIC*

*AS ORIGINALLY COMPOSED PRIOR TO THE STUDY

Title: Technology Implementation and Integration from the Experience of TESSI Science Teachers

Focus Question: What are the experiences & perceptions of TESSI physics, biology and chemistry science teachers at different stages of technology integration towards technology implementation and integration?

WORLD VIEWS:	VALUE CLAIMS:
WORLD VIEWS: ▪ Constructivist: individuals construct their own understanding of the world as they acquire knowledge and reflect on their own experiences ▪ Contextualist knowledge is nothing without context ▪ (Interpretists-Criticalists research paradigm) THEORIES: ▪ Innovation and change (& school reform?) ▪ Conceptions of Science Teaching ▪ Technology ▪ Educational Technology (views on technology's role in education) ▪ Technology in Science ▪ (and the conception of integration) ▪ Reflection (& Other methodology) PRINCIPLES: ▪ Technology integration requires that teachers play the central role (Teacher expertise) ▪ A change in teaching beliefs ▪ Technology & its tools in the classroom: ▪ Can be effective in promoting different forms of learning & changed class interactions ▪ The combination of conception and experiences of innovation implementers determines the form that I & I takes and this in turn can inform professional development and future	VALUE CLAIMS: ▪ Technology integration into secondary school science is can be valuable but requires applications of the analysis of issues in learning, teaching, curriculum and the implementation process? ▪ The value of studies of *unique but evolving to ubiquitous* case such as this one can inform theory as well as practice? KNOWLEDGE CLAIMS: ▪ Recurring key themes and issues in technology implementation and integration (PROCESSES & APROACHES?)? (this leads to a need for a framework of I & I?) based on? ▪ Predictable & unforeseen practical and conceptual issues (multiple profiles) ▪ Human factors: e.g. discernible "patterns of concern" & change ▪ Interplay of human factors and other issues ▪ There are differences in how technology is integrated (MULTIPLE PROFILES) -- depending on: ➢ subject areas ➢ view of educational technology ➢ beliefs and type of change to pedagogy / conceptions to learning ➢ conceptions of the curriculum ➢ resources ▪ Technology I & I can be viewed as both an approach and a process (in a complex system)

implementations CONCEPTS: ▪ Technology (& examples) ▪ TESSI ▪ Curriculum innovation and change ▪ Implementation &. integration ▪ Reflection/perspective/perceptions vs. experience	TRANSFORMATIONS: ▪ Levels: ▪ transcriptions of data ▪ coding, constant-comparative methods ▪ category grids/charts / matrices ▪ member checking ▪ 2-4 Cycles of the above RECORDS: ▪ 2-4 in-depth, semi-structured interviews with TESSI teachers spaced throughout one school year ▪ Journals of TESSI teachers ▪ School visits & field notes on: ▪ group meetings ▪ school context ▪ e-mail conversations / mini-surveys? ▪ Past data ▪ Other data?

Events/Objects:
A cross-section of 6 teachers (2 physics, 2 biology, 2 chemistry) (at up to 7 schools) at different stages of technology implementation and integration into their science curricular areas as part of the Technology Enhanced Secondary Science Instruction (TESSI) project

(plus 1-3 teachers not in the secondary TEPI sites?)