THE QUEST FOR THE MOST EFFECTIVE TECHNOLOGY-BASED INSTRUCTIONAL MODEL: THE OPERATIONAL DEFINITION OF TECHNOLOGY ENHANCED INSTRUCTION

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Abstract

Educators need access to a technology-based instructional model that provides opportunities for students to develop an expanded set of skills, accommodates students' unique learning styles and rates, and which allows teachers flexibility in adapting the model to their own instructional styles. The thesis presents a concise operational definition of Technology Enhancement as it applies to instruction in secondary school classrooms. The definition of Technology Enhancement then forms the basis for developing criteria that can be used to establish and evaluate Technology Enhanced Instruction (TEI) programs in secondary schools. These criteria will also enable educators to ensure the longevity and continuity of the program in their schools, thus maximizing the educational benefits afforded by technology, while minimizing the potential capital costs. Technology will continue to pervade all aspects of educational institutions; educators are faced with the challenge of making effective use of technology and helping students to develop life-long learning skills *without* discarding established, effective educational strategies.

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Dedication

This thesis is dedicated to Dr. Janice Woodrow, whose vision, support, and patience have made the development and evolution of the TESSI project possible. Janice, you have left a legacy that will impact students and teachers world-wide. Your leadership, encouragement, and advice have also been fundamental to the completion of this document, which may, perhaps, provide some definition for the legacy that you leave. Thank you for the opportunities you have created; you have had, and will continue to have, a profound impact on my career.

Aubry Farenholtz

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Les Dukowski and Cam Gesy had the vision to support the development of the TESSI model in their schools, and have furthered my professional growth at every turn. For the last ten years, Gordon Spann has been a mainstay in TESSI's growth and expansion; his patience, determination, and passion for excellence in education have been an essential contribution to the project's ultimate success.

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Context and Purpose of the Study

The expectations of our educational system are changing rapidly in response to societal pressures and technological advances. Schools are expected to equip their graduates with the skill sets needed to contribute in a competitive, technology-based, and rapidly changing workplace. As *technological* literacy has become one of the essential skills for high school graduates, educational leaders are allocating significant financial resources towards the installation of computer related technologies into schools - but they are doing so with little consideration of, or research into, instructional models that effectively integrate technology in a variety of academic disciplines. The majority of technology funds to date have been directed towards upgrading computer labs or towards installing local area networks for school-wide Internet access. This allocation of technology has, in effect, reduced the opportunities for teachers to integrate technology into their classrooms within the context of existing curricula. The technology that has been installed in classrooms to date has generally been for teacher use, primarily for traditional instructional resource development and electronic reporting (Bitter, Camuse & Durbin, 1993); the technology has rarely been dedicated for students' use outside the confines of computer science or business education programs. The fact that technology is not being used to its potential may be due to the fact that teachers are not aware of instructional models that effectively integrate technology within their own curricular area, or of the pedagogical requirements that make the most effective use of technology: *wherein pedagogical awareness requires an operational definition of Technology Enhanced Instruction (TEI) as it applies to secondary school classrooms.*

A precise description of the TEI classroom can provide teachers with a working instructional model for reference as they integrate technology into their own classrooms. Educators need to have an understanding of the issues that can impact their success when implementing TEI. Both students and teachers will experience a steep learning curve associated with technology, and will need ongoing support and training. Teachers will also need access to pedagogical support as they develop strategies for classroom management and evaluation better suited to a transactive environment[1]. In addition, in order for educational leaders to make informed decisions regarding the establishment of technology-enhanced classrooms in schools, they need to be apprised of proven, reproducible, and *scaleable* instructional models that effectively integrate technology into the classroom.

Educational leaders who research technology-related instructional models find that the majority of published literature focuses on Computer Directed Instruction (CDI) models. CDI models are based on the premise that computer-related technologies are best used as *replacements* for direct instruction. For example, the PathFinder™ program, which is based on the CDI approach, is used extensively in British Columbia schools. PathFinder's™ computer-based courses offer an economic solution to the organizational challenges faced by administrators by allowing small groups of students to work through different subjects within one classroom. The students are supervised by one teacher, who may have limited expertise in the course content being delivered. PathFinder™ and similar CDI programs have not, however, provided an effective educational alternative for the enrolled students. CDI models have proven to be effective tools for reinforcing rote learning, but do little to develop higher level thinking skills or to develop skills that are transferable out of the context of the CDI program itself; CDI is a very limited instructional model.

[1] See Appendix 1 for a discussion of the three curricular orientations: transmissive, transactive, and transformative.

Alternatives to the CDI model have been explored in some schools in North America, where technology has been dedicated for students' use and has been available within the classroom setting. The majority of these projects have suffered inherent limitations with respect to their scaleability, transferability, or effectiveness. For example, projects such as ACOT (Apple Classrooms of Tomorrow), where each student and teacher had two dedicated computers, one for use at school and one for use at home, require disproportionate financial commitments and cannot be scaled beyond the pilot sites to typical public schools. Other ventures, such as the Computer as a Learning Partner (CLP) project, (Linn, 1992, 1997) in Berkley, California, where computer based probes were used for data collection and analysis in junior Science classes, were not transferable to other disciplines because they were designed around a particular piece of software and hardware. The majority of smaller scale projects involved teachers using technology in a very limited way to supplement activities in a primarily transmissive setting[2]; in these classrooms, the technology had little impact on the structure of the learning environment, and was used primarily to enhance a lecture or demonstration, or by a select few students for enrichment or remediation.

What is lacking in the majority of projects which explored alternatives to CDI is the goal to develop a pedagogical framework that can integrate technology into any academic discipline at the secondary level. The few projects[3] that have *pursued* this goal have contributed to the development of an instructional paradigm known as the Technology Enhanced Instruction (TEI) model, which is based upon the premise that technology should be fully integrated into a student-centered, experiential learning environment - within the context of existing curriculum.

[2] When technology is used to supplement teacher directed activities, the model is referred to as Computer Assisted Instruction, or CAI.

[3] Apple Classrooms of Tomorrow (ACOT), Technology Enhanced Secondary Science Instruction (TESSI), Computer as a Learning Partner (CLP), Learning Through Collaborative Visualization (CoVis)

In TEI settings, the technology does not act as a replacement for the instructor, but instead is used as an integral learning tool that enhances the learning process. The TEI model is not restricted to a particular piece of software, computer platform, or hardware product, as is the case of most CDI models. TEI is comprised of an instructional approach wherein the teachers and students use aspects of technology to explore, illustrate, simulate, and evaluate their understanding of a concept. Full implementation of TEI may also include a pedagogical shift on the part of transmissive teachers to a more transactive approach. In order for educators and students to realize the benefits associated with TEI, they must have access to detailed descriptions of the classroom model - descriptions which are currently not readily available. When courses are taught using a TEI approach, students as well as teachers have to adapt to the new instructional design. Once students reach their senior years in high school, most have developed strategies for success in the more traditional, transmissive settings, and are faced with personal challenges posed by this new classroom model. In the TEI setting, students develop their knowledge through interactions with a wide range of resources in their environment; these resources can include computer simulations, video analysis, traditional hands-on experiences, and interactions with peers and/or their teacher, *as opposed to passively receiving the knowledge in a more transmissive setting*. Students move outside their 'comfort zone' and into the realm of a 'construction zone' to formulate new relationships and thus, knowledge. In student-centered TEI classrooms, students are taught to assume a more proactive role in the learning process; students make their own choices regarding the type of activity and, within limits set by the teacher, control their pace of working through the course materials.

The best illustration of an effective TEI model is the Technology Enhanced Secondary Science Instruction (TESSI) project, which was conceived of and initiated by Janice Woodrow, Professor, at the University of British Columbia (1987). Woodrow has directed the project's development and, subsequently, working in partnership with physics teachers Spann and

Farenholtz, Woodrow has established a TEI model which provides an instructional framework that successfully integrates virtually any new technology without discarding effective established instructional tools.

In the TESSI classroom, computers are used to introduce, explore, simulate, and evaluate science concepts. This utilization has dictated a pedagogical shift for the teachers from the transmissive to the transactive approach. TESSI has been in operation for seven years in schools in south western British Columbia, and is currently expanding to seven more sites in British Columbia. The TESSI model has also been selected as the national model for Physics education in Mexican Secundaria schools; it has been established in 36 sites across Mexico over the last three years. In British Columbia, the model is currently applied in both junior and senior science: Science 9 and 10, as well as senior Physics, Chemistry and Biology. The TESSI group has developed unique instructional resources that cater to a Technology Enhanced, student-centered, experiential approach to learning; these instructional resources for Physics have recently been published[4], and are currently being used as a resource development model by the Mexican Ministry of Education. Because the project has proven to be scaleable to other schools on an international basis, it will be used as an exemplar of the definitional aspects of TEI.

By providing educators with a concrete description of the essential constituents of the TEI model, and through a discussion of the challenges that both students and teachers face when establishing a TEI classroom, this study will identify critical definitions and issues that students, teachers, and administrators should address in order to help the participants make a successful transition to a Technology Enhanced, transactive classroom environment. A subsidiary outcome

[4] Prentice Hall, Canada, 1999.

of this study will be the identification of the key factors that influence the success and longevity of established TEI classrooms in schools. Assuming that educational leaders have access to a synopsis of the instructional model and are aware of its advantages over CDI and CAI, they may choose to redirect technology funds towards supporting the integration of technology into classrooms adopting the TEI approach. TEI can act as an agent of wider educational change in schools, and it will fall to local administrators and teachers to implement the approach in an inclusive and receptive manner.

In summation, the objective for this study is:

> *'To provide an operational definition of Technology Enhancement as it applies to the instructional process in secondary school classrooms.'*

The defining elements of TEI will be based on personal experience in the development, dissemination, and teacher training aspects of TEI, as well as on documentation of projects that emulate aspects of the TEI model. The author (Farenholtz) is in a unique position to be able to identify and discuss definitive aspects of TEI, and to explore the issues which will impact the longevity of a TEI classroom. He was one of the initial *in situ* developers of the TESSI model and its instructional resources, and has collaborated with and trained educators at each of the expansion sites in British Columbia and Mexico. He has been successfully applying the TEI model in his classroom at the junior Science and senior Physics levels for the past seven years, and has given presentations on the TESSI model and a variety of topics related to the educational use of technology, at numerous national and international academic conferences. The author is, therefore, acting in the capacity of a participant/observer/researcher in this study.

Importance of the Study

When a technological innovation becomes widely available, its ramifications seem to spread through all elements of society, including educational institutions. The invention of the printing press and the advent of affordable books, for example, made the concept of universal literacy through public schools possible, and led to the de-emphasis of teaching the art of memory (Boorstin, 1983). The impact of mass media and video technology is already evident among children, as an increase in visual resources appears to result in a loss of innocence and lower attention spans (Postman, 1982). Similarly, computers and multimedia technology are likely to have a profound effect on the way we teach and the way students learn; if there is little discernable change to the students' and teachers' roles in the learning environment, it is indicative that the technology has not been well integrated and used to its potential. The question for educators in the 21st century to address is how to effectively incorporate these emergent technologies into the classroom.

There are several issues regarding the role of technology that need to be considered before institutions should commit the financial resources to purchase the technology or to provide on-going technical and pedagogical support. These issues include the challenge of identifying appropriate software designs, such as the structure of the computer interface that is best suited to concept development (Reigeluth & Schwartz, 1990), the anticipated impact that computers will have on the structure of schools, such as a shift towards cooperative learning, small group instruction and individualized learning plans (Collins, 1991), or adopting alternative pedagogical approaches dictated by TEI models (Cuban and Kirkpatrick, 1998).

The majority of the research to date on computer use in education falls into one of four broad categories:

1. reporting on the findings of short term, isolated pilot projects, often assessing the effectiveness of a specific software package,
2. assessing the effectiveness of CDI or CAI models (Lockard, 1994),
3. reporting on the results of projects that emulate aspects of TEI,
4. describing the philosophical ramifications of technology and the role it would play in the restructuring of schools (Pearlman, 1989).

Those research projects which emulate aspects of TEI have attempted to fully integrate technology into the classroom, and have been faced with the challenges related to experimenting, developing, and researching, while still providing a viable educational program for students. The teachers in these research projects faced technical problems, increased parental pressure, and concerns regarding the accountability of the research; these risks have restricted most technology-based projects to operating on shorter treatment times, often less than 10 sessions. Only in rare cases have teachers been able to integrate the technology into the classroom routines on a yearlong basis with their classes. These long-term studies generally reflect classrooms with limited integration of technology, where computers may only supplement one aspect of the teacher's practice, as opposed to producing any significant changes in pedagogy (Hennesy et al., 1995). It would be difficult to support the case-to-case transferability of such findings to classrooms that use technology as an integral learning tool.

Although they are not widely publicized, effective TEI models such as TESSI *do* exist. Their success is evidenced by the fact that in these settings the technology is imbedded within the learning processes in non-technology-based curricula. The technology *has* had an impact on the structure and function of the learning environment, while maintaining - if not improving -

academic standards and participation rates. Students are also learning skill sets beyond the scope of subject specific course outcomes. Research on students' perspectives on learning in TESSI classrooms (Pedretti, Mayer-Smith, & Woodrow, 1998) concluded that the integration of technology was preferred by the majority of students[5], although it had a significant impact on the roles of both the students and the teachers. Students articulated that they were developing learning skills beyond those developed in traditional transmissive classrooms, including time management, working in collaborative teams, using technology as a learning tool, goal setting, and reflecting on their own learning processes. The majority of students in TESSI recognized *"the importance of the teacher assuming a different type of role in this technology enhanced setting"* (Woodrow, Mayer-Smith, & Pedretti, 1996). They used terms like "facilitator", "guide," and "helper" to describe the teacher. Research by Woodrow, Dwyer and Linn has begun to address the need for more descriptive literature for teachers in technology-enhanced classrooms such as TESSI, ACOT, and CLP respectively.

What is still lacking in the literature, however, is a more prescriptive summation of what constitutes an effective TEI model. Educators considering the implementation of technology in secondary classrooms need access to a definition of Technology Enhancement and to operational criteria that are evident in effective TEI classrooms. Without the ability to operationalize the TEI model, teachers will be unable to realize the educational benefits afforded by the integration of technology.

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[5] "86% of the students surveyed enjoyed using the technologies in the classroom...64% preferred taking interactive tests on the computers...71% preferred learning science in this setting (Technology, Text and Talk: Students' Perspectives on Teaching and Learning in a TESSI Classroom, 1998)

Literature Review

Overview

The majority of the current body of research into the role of technology in education falls under four general categories:

1. The analysis of particular pieces of software or hardware that supplements instruction for one unit of study (Hennessy *et al.* 1995). These studies typically involve a small sample size (fewer than 15 students) and are usually done at the elementary or post-secondary level. The technology is not used as a daily tool in the classroom - it is actually an aberration of the normal instructional routines.
2. The analysis of Computer Directed Instruction and Computer Assisted Instruction models (CDI and CAI), where the technology has been used as a replacement of or supplement to the classroom experience (Lockard, Abrams, & Many, 1994).
0. The analysis of projects that emulate the Technology Enhanced Instruction model (TEI), where technology has been fully integrated into the learning experience for the entire course of study. The majority of these projects, with the exception of the TESSI model, are rarely reproducible or scaleable, because they have not developed an operational pedagogical framework that is economically viable; the projects are reliant on disproportionate allocation of funds, resources, and personnel.
4. A discussion of the philosophical ramifications of technology in our schools, such as on students' attitudes towards computers (Boone & Edson, 1994), or the impact on instructional methods (Melzer & Sherman, 1997). The literature included under this category illustrates the need for full integration of technology in the classroom and a new pedagogical approach for teachers in order for technology to have a meaningful and lasting impact on education, but does not specify how to accomplish these changes.

The following literature review will examine exemplar studies with respect to the use of technology in secondary schools, illustrating the need for an operational definition of Technology Enhanced Instruction. Many aspects of the literature provide valuable insights into the benefits and limitations of integrating technology in education *outside* of the context of TEI classrooms.

The Analysis of Software Designed to Supplement Instruction

One of the best applications of computer technology involves the use of simulation software to model, illustrate, or explore concepts and their interrelationships. Well designed simulations are useful tools for technology-based instructional models. This section of the literature review discusses the merits of two frameworks used to classify, design, and evaluate simulation software.

Two organizational schemes for computer simulations are evident in the literature: a classification scheme based on the instructional goal of the activity (Van Berkum *et al.*, 1991), and a developmental framework for designing and evaluating computer simulations (Reigeluth and Schwartz, 1990). In the article 'Aspects of Computer Simulations in an Instructional Context', Van Berkum *et al.* describe four aspects of simulation-based activities: simulation models, learning goals, learning processes, and learning activity.

1. *Simulation Models:* Interactive simulations are first categorized according to their quantitative or qualitative nature. Quantitative simulations are further delineated by the nature of the variables (discrete or continuous) that can be controlled in the simulation.

If one of the variables is time, the simulation can also be described as a dynamic or static simulation. The "General Model for Simulations", presented by Reigeluth and Schwartz, expands on Van Berkum's model by identifying four essential components in the design of an effective computer simulation: the introduction, acquisition, application, and the assessment.

2. *Learning Goals:* Simulations can be classified according to the intended learning outcomes addressed in the activity. The simulations are grouped according to the knowledge level (Bloom, 1981), method of knowledge representation, and the scope of knowledge that they are designed to address.
3. *Learning Processes:* Learning processes are defined as the cognitive actions of the learner. Learning processes are classified into four categories: orientation, hypothesis generation, testing, and evaluation.
4. *Learner Activity:* Learner activity is defined as the physical interaction between the learner and the computer, as opposed to the mental interaction as described above. Learner activity is classified into five categories: defining experimental settings, interaction processes, collecting data, choice of data presentation, and metacontrol over the simulation.

The algorithm that Van Berkum *et al.* (1991) have developed can help educators to exploit the strengths of each type of simulation by correlating the simulation features with a type of learning activity or learning outcome. Van Berkum *et al.* recognized that there were potential limitations to their model, however, as their interpretations were based on studies conducted in transmissive classroom settings where simulations were used for short treatment times, usually less than 12 sessions. Their results would be more viable and transferable if their study had been conducted in a Technology Enhanced classroom, where students' technological literacy would not factor as significantly as in projects with shorter treatment times.

In the article 'Developing a Framework for Delivering Technology Enhanced Physics Instruction' (Woodrow, Farenholtz, and Spann, 1994) the authors identified four types of simulation-based activities used in the TESSI classroom[6]. These types of activities, which also correlate with Van Berkum *et al.*'s model, include: teacher-led demonstrations, concept introduction and exploration, reinforcement and enrichment, and assignment reference or problem visualization. The simulation interface was tailored to each type of activity by varying the complexity and number of controllable variables, and by changing the detail in the activity guides and support materials. For example, simulations designed to be used in teacher-led demonstrations had several hidden features that were only referenced in the support materials, or simulations designed for the open-ended exploration of a concept had a larger number of controllable variables to allow students to explore "What If?" scenarios. The TESSI developers found that they intuitively applied aspects of the general model suggested by Reigeluth and Schwartz (1990), illustrating that the TESSI resources have a strong correlation with the operational pedagogical framework.

The Analysis of Computer-Based Instructional Models

This section of the literature review identifies the merits and inherent limitations of the CDI and CAI instructional models; it also includes a description of those research projects which

[6] The TESSI project developers (Spann and Farenholtz) created the majority of the Interactive Physics™ simulations for the Physics 11 and 12 resources.

attempted to extended the CAI model and fully integrate technology into the classroom on a long-term basis.

Over the last decade a considerable investment in time, energy, and money has been made to determine how to best use technology in the classroom (Levin, 1986). The majority of the work that has been done falls within the realm of what is referred to as Computer Directed Instruction (CDI) (Schofield *et al.*, 1994) and Computer Assisted Instruction (CAI) (Steinberg, 1991; Fletcher-Flinn *et al.*, 1995), also known as Computer Mediated Instruction (CMI). CDI describes a model of instruction whereby the computer is the focus of the learning environment; that is to say, it prompts, directs, presents, monitors, and tests the student. CAI refers to the case where the teacher uses aspects of technology to better illustrate or model a concept. In their publication "Restructuring Schools With Technology", Knapp and Glenn (1996) note that *"Most teachers use a variation of the teacher-centered model of instruction...this approach is (more) comfortable because there is a great deal of predictability – it gives teachers control over the process."* (p 217).

In most computer-based classrooms, the computer is used in six potential ways following a CDI or CAI approach:

1. *Computer as Tutor:* students work through a predetermined sequence of events, usually with regularly scheduled tests that may redirect them back to an earlier place in the sequence. This cyclical pattern, where students practice and retest, is repeated until the students demonstrate that they have mastered a particular outcome. This process focuses primarily on low level skill development or rote learning.

2. *Computer as Data Collection or Analysis Tool:* students use the computer on a regular basis to measure or analyze the results of an experiment. In its most limited case, this application of computers may involve the use of a word processor or spreadsheet; in more sophisticated cases, the computer may be connected to electronic probes that take measurements directly and export them to the computer for analysis and presentation.
3. *Computer as Research Tool:* students use the computer to sort through data bases, either on a local network with library resources or using the Internet to access global databases.
4. *Computer as Presentation Tool:* teachers and students use the computer to enhance their lectures or presentations.
5. *Computer as Special Treatment:* students use a particular piece of software that links well to a particular curricular outcome. The activities often span a period of weeks, and the computers are normally located in the computer lab or library.
6. *Computer as Development Tool:* teachers use the computer to generate word processed assignments and tests for classroom use.

In CAI models, the technology does not have a significant impact on the structure or culture of the learning environment. Students are learning in the same ways, albeit with a different tool, and are learning essentially the same skills and concepts as in a teacher-centered classroom without technology.

Salomon (1991) suggests that in order to better understand the educational impact of embedded technologies in the classroom, researchers should *"Study the whole learning environment and the way it and the individuals in it interactively change"* (pg. 171). Several studies have been done in classrooms where technology has been used more extensively than in the CAI models.

Based on literature review, Collins (1991) identified eight trends that were evident in classrooms that adopted a more complete use of computer-related technologies.

1. A shift from whole-class instruction toward small-group instruction.
2. A shift in instructional orientation from lecture towards coaching.
3. A shift towards individualizing instruction, allocating more teacher time to weaker students.
4. An increase in students' engagement time.
5. Assessment became more performance-based; students' products, progress, and effort became an integral part of their evaluation.
6. Students worked collaboratively with their peers and the technology; there was less of a focus on competition.
7. Opportunities for students to regulate their own pace through the course materials.
8. A shift from the verbal thinking towards the integration of visual and verbal thinking.

Cuban and Kirkpatrick (1998), completed a study of a breadth of computer-related projects, and identified a third instructional model, Computer Enhanced Instruction (CEI). According to their research, *"CEI differs from CDI and CAI ...in that its program provides less structured, more open ended (learning) opportunities for students."* (pg. 30). Although they recognize that the teacher is an essential component of the learning process in CEI, they do not demonstrate an awareness of the pedagogical impact of the effective integration of technology. As illustrated by research completed by Sandholtz and Ringstaff (1996), teachers must adapt their instructional strategies to accommodate the benefits afforded by the integration of technology; Sandholtz and Ringstaff explicitly identify the need for a proven educational model that illustrates how to teach effectively with technology.

Based upon their meta-analysis of the comparative attributes of CDI, CAI, and CEI, Cuban and Kirkpatrick (1998) concluded that CEI is less effective at "*raising achievement levels on test scores*" (in secondary classrooms), and that students' performance on standardized tests would improve by *reducing* the teacher's role in the classroom. On reviewing the citations in Cuban and Kirkpatrick's (1998) analysis, it was evident that the authors were unaware of projects that have demonstrated long term, successful integration of technology into the daily learning routines in the classroom - projects which also require the active participation of the teacher in the learning process. These projects[7] have established an effective instructional model, known as Technology Enhanced Instruction (TEI), wherein the students develop their knowledge experientially, using the computer as a tool to model, illustrate, analyze, and evaluate concepts. In TEI's transactive setting, the teacher's role has also changed to accommodate the benefits of the technology and the instructional model. Researchers such as Cuban *et al.*[8] fail to make the connection that the student-centered, activity-based learning that takes place *within* a TEI environment will make the significant difference in student performance and skill development that effective integration of technology provides.

The limitations in current research literature may be partially due to the fact that the majority of TEI-related projects in the United States may require such substantial financial investments that these projects are prohibitive for many school districts, or that the projects did not develop a pedagogical framework in a fully operational secondary classroom setting. The ACOT (Apple Classrooms of Tomorrow) project, for example, equipped each student and teacher with two computers – one for school and one for home. The ten year venture showed that technology

[7] These projects have been in operation since the establishment of the Technology Enhanced Physics Instruction project (TEPI), in 1989.

[8] "Teachers become the critical element in applying (TEI)...thus teachers become both the problem and the solution." (Cuban and Kirkpatrick, p 30, 1998)

clearly had a significant impact on the learning environment and upon the students' attitudes towards learning with technology, but the results are hardly reproducible, even assuming economies of scale. The goal of the ensuing professional development program developed by ACOT was to *"create structured experiences in which participating teachers could learn from the expertise of ACOT teachers and apply the results to their own relatively low-technology classrooms"*. (David ,1992, pg. 241)

Projects like ACOT not withstanding, plans for the distribution of computers has been largely misdirected; in many cases, technology has been installed without thorough research into the most effective technology-based educational models. The efforts to research effective technology-based models is compounded by the fact that publications on effective TEI models are not widely available. Policy makers and educational leaders concerned with educational reform seem to be searching for ways to circumvent the teacher, and technology has presented such a path through CDI. The teacher is, in fact, the crucial link for connecting the students with the technology and with the learning process. Educators therefore need access to a working definition of Technology Enhanced Instruction that illustrates *pedagogically* how teachers can effectively use technology as an effective tool within the context of existing curricula.

The Impact of Technology Use In Schools

Several research projects have examined the impact of technology on student performance and instructional practice. This section of the literature review presents the results of several of these studies, and discusses the associated implications for technology integration in secondary schools.

Research on the impact and methodology of computer use in the classroom has been taking place for the past 12 years. The majority of the research indicates that there is a positive correlation between the integration of computers in the classroom and student performance ($c > 0.7$). Bishop-Clark, in the article "Implementing Computer Technology in Educational Settings" (1988), analyzed five projects which fully integrated technology. In each project, funding was provided by private companies. In Bishop-Clark's study, five activities were identified that would help administrators and interested third parties more successfully implement technology in schools. These activities include: understand resistance, educate and communicate, encourage positive attitudes, introduce change that is consistent with environment, and encourage and support champions. Bishop-Clark's research provides a valid framework, but like many prescriptive studies in the literature, it assumes a "top-down" model for the implementation of innovative programs.

Some of the literature suggests that computer technology can transform the educational process to meet the growing demands for computer and science literacy (McCluskey,1994). Researchers are trying to develop implementation models for third parties to follow when supporting educational innovations. Research on the future direction of instructional technology, completed by Clarke (1994), indicates that available literature does not provide detailed models for teachers or teacher training institutions to follow. The role of the third parties has also been restricted to supplying hardware *without considerations for the professional development of the teacher.* Innovations will not be adopted by teachers for long-term use in their classrooms unless they have input into the structure and process of the changes. In the TESSI research project, teachers have volunteered to incorporate the technology into their classrooms, and they have direct control over their instructional strategies.

A second problem with research studies on technological innovation in education stems from the short-term nature of secondary school pilot projects. According to Clarke (1994), the average amount of treatment interaction was approximately one hour. Cronbach and Snow (1977), advised that at least ten separate sessions were necessary to aquaint learners with innovative instructional treatments. What is not addressed in the literature is the determination of the treatment time required before educational benefits are realized, with respect to technological literacy and within the context of the curriculum. The effect of treatment times would be a valuable topic for further research, particularly with respect to CAI models.

Krendl and Broiher (1992), in their study of students' responses to computers over a three year period, focussed on projects which attempted to increase the students' interaction time with technology. Students in the fourth and tenth grades were measured for their preference of learning strategy, perception of learning, and perception of difficulty; the results clearly supplied evidence for the novelty effect of computer technology, as students' preferences for using the computers and their perceptions of their learning declined steadily over the three years. Perceived difficulty of using computers, which was expected to decline, remained stable. Data analysis was done using MANOVA repeated measures procedures for longitudinal data ($p < .001$) to identify any variance in the students' attitudes. Although their research was internally valid, it is not generalizable to computer-based classrooms, because they did not control for experimenter effects and interactions of treatments. The role of the teacher is still crucial in the classroom, even if they are not the center of the educational activities.

A framework for analyzing the impact of technology in education has been proposed by Salomon, Perkins, and Globerson (1991). They suggest that it is the combination of the integration of technology within the operational context of classroom environment that will impact students' learning processes. The classroom context is comprised of the roles of the students and teachers, the types of technology-based activities, and the types of interpersonal interactions between students and with the teacher. Salomon *et al.* distinguish between the effects *with* and the effects *of* technology: effects *with* technology refers to the impact that the technology-based activity has on the learner with respect to the curricular outcome, whereas effects *of* technology refers to the outcomes that result from the classroom dynamics and peer interactions that extend beyond the context of the activity. This distinction is important because it indicates that the impact of technology integration is not merely indicated by traditional methods of assessment within the confines of the curriculum (as suggested by Cuban and Kirkpatrick, 1998).

Technology *affords* the possibility of producing change and educational benefits; the benefits cannot be *assumed* to become automatically realized only because of the technology's presence (Kimmel & Deek, 1995; Stoddart & Niederhauser, 1993). Effective integration of technology includes a pedagogical shift that develops students' life-long learning skills that are transferable outside of the confines of the classroom.

The Role of TEI in the Process of Educational Change

Many of the pilot projects related to the educational applications of technology were initiated in science and mathematics classrooms. The philosophical underpinnings developed in these research projects are, however, transferable to the most other academic disciplines in schools. This section of the literature review discusses the processes involved in the successful implementation of an innovative program in schools and the potential role of the TEI model in the process of educational change.

Technology can form an integral part of school culture once the educational community is informed of the advantages of TEI. As stated by Miller & Sellar (1990) in their research on curricular orientations, a school's strength can be reflected in the diversity of orientations of its staff. A transactive setting for TEI classrooms should not necessarily be the dominant instructional model. It should, however, have a valued and pervasive presence in all schools. Establishing a perceptual change in the educational community is a long term process, but it must begin with the educational leaders in our schools – the administrators and teachers.

According to Rogers (1962), there are five characteristics of a change that will affect its adoption by others:

1. *Relative advantage:* the degree to which the change is perceived to be an improvement over present practice.
2. *Compatibility:* the congruity between the values implied by the change and the values of the teaching staff.
3. *Complexity:* the ease with which the change can be understood and then applied.
4. *Communicability:* the ease with which the effects of the change can be communicated to others.
5. *Divisibility:* the ability to break the change into smaller, incremental components.

It follows that the administration plays a key role in managing the impact of Rogers' five characteristics through supporting teachers adapting to technical and pedagogical changes. Teachers must have a clear vision concerning the educational goals that guide the implementation of TEI, and that vision must be supported by the administration. In Fullan's article, 'Changing forces: Probing the Depths of Educational Reform' (1993), the author asserts that improvement efforts can generate considerable controversy. Effective communication is therefore essential for the development and longevity of staff support for the implementation of a new program, such as TEI. The value and relevance of the results of implementing a TEI model needs to be acknowledged publicly with the rest of the staff. Without that acknowledgement, teachers involved in the implementation will be professionally isolated from the rest of the staff (Shepard, 1967). As the leaders in the school, it falls to the administration to not only allocate the financial resources, but to communicate the value and the outcomes of the project to the staff. Where applicable, it should be communicated that the demonstrated outcomes of the TEI classrooms are consistent with the schools' educational goals. As suggested by Saranson (1982), teachers work in isolation from their colleagues, and view change as an individual activity. An important aspect of change is that, *"Teachers have a need for an objective description of the innovation itself."* Miller & Sellar (1990). A teacher's curricular orientation will affect their perception of the innovation; teachers who believe that students learn best when provided with direct instruction will resist a new transaction-oriented approach, such as TEI, because they do not believe in the basic philosophy of the new program. If teachers are not equipped with an understanding of the merits of each curricular orientation and an operational definition of technology enhancement, they will not be able to support or effectively participate in the innovation.

In Fullan's study on the meaning of educational change (1982), he states that each person has their own subjective view of reality[9] which affects how that person views a new program. As teachers have a limited opportunity to interact with their peers (Saranson, 1982), effective change must allow for the process of introduction into "the subjective world of the teacher."

[9] In a pedagogical sense this could refer to a teacher's curricular orientation, as described by Miller and Sellar (1990)

(Fullan, 1982). Fullan also identifies three criteria that will impact the degree to which the teacher will internalize the new program:

1. Does the change address a need? Will students be interested? Will they learn?
2. How clear is the change in terms of what the teacher will have to do?
3. How will the change affect the teacher personally in terms of time, energy, new skill development, sense of excitement and competence, and interference with existing priorities? (pg. 113)

Implementation of a new program does not, however, guarantee a change in practice. Fullan refers to two forms of non-change that can occur: 'false clarity' and 'painful-unclarity'.

> *"False clarity occurs when people think that they have changed but have only assimilated the superficial trappings of the new practice. Painful-unclarity is experienced when unclear innovations are attempted under conditions which do not support the development... of the change."* (pg. 28)

For schools planning to implement TEI, it follows from Fullan's description of non-change, that in order for pedagogical changes associated with the implementation of a 'new' Technology Enhanced program, *teachers must have access to an operational definition of TEI.*

Rapid advances in technology, combined with a shift from local to global economics, has forced significant changes in the structure of the international community. To remain competitive in the world market, businesses must be able to utilize the latest production methods and respond quickly to changes in the marketplace. Employees roles and responsibilities have also changed, requiring them to develop new sets of essential skills. These skills include the ability to work collaboratively, set goals, manage time and resources in order to reach those goals, be self-motivated and self-monitoring, use computer-related technologies, and be life-long learners.

These changes in the needs of our business community have in turn raised the expectations of our educational institutions; in the course of their education, students need the opportunity to develop the above skills in the context of subject-related curricula. In her article "Establishing a Research Base for Science Education: Trends and Recommendations" (1986), Linn details the foundations for change:

> *"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 advances change the nature of learning from the need to master topics in class to the need to learn autonomously. Educated citizens need to know how to revise their ideas and how to locate and synthesize information."*

Some regions have attempted to address these expectations by modifying curriculum, such as with the institution of 'Applied Academics' courses (B.C. Ministry of Education, 1995), which are intended to link course outcomes more closely with skills required in workplace environments. Another approach adopted by schools across North America involves the installation of computers, Internet access, and related technologies in the hopes that it will foster technological literacy and competency. Educational research in areas such as brain function and learning theory (Sylwester, 1995) suggests that the structure of learning environments should be changed to accommodate a variety of learning styles and rates, which are in turn dependent on the nature of the thought processes in the human brain. According to Sylwester, the chemical processes are affected by the environment in which students learn, which may not necessarily correlate with the environment in which students are tested.

> *"Educators have a responsibility to effect positive change in school and classroom structures...that (correlates) with recent developments in brain research."* (Sylwester 1995)

There is a significant body of research on specific applications of technology in schools and their implications for students, teachers, and the structure of schools. Technology has already begun to play a significant role in reforming pedagogical practices and school structure. A report by the TeleLearning Network Inc. (1998) provides a comprehensive summary of exemplary research projects that examined the educational applications of computer-related technologies on an international scale. The report provided an organizational framework to compare the impact that the integration of technology has had on students, teachers, and the learning environment as a whole. The four key elements of this framework are:

1. **T** – the teacher (ranging from a transmitter to a facilitator)
2. **C** – the content (ranging from pre-organized to constructed)
3. **L** – the learner's level of access to technology (ranging from low to high levels of access)
4. **C** – the context of the classroom and the school (ranging from low to a high level of support for innovation and resources)

The TeleLearning report then clustered projects according to their level of operation using the above framework. In one extreme case, referred to as **TCLC-**, the teacher used lecture as the primary instructional method, the content was predetermined by the teacher (or by the technological resources, such as a CD ROM), the students had limited access to technology, and the teacher had little support for instructional innovation or for the purchase of additional technological resources. In the other extreme case, referred to as **TCLC+**, the teacher acted primarily as a facilitator and the learners constructed their own understanding of knowledge through frequent access to technology, in a school environment that supported innovation and provided sufficient technological resources.

The TeleLearning report is a valuable reference that illustrates the wide range of technology applications that are being explored in schools, both at the secondary and post-secondary levels. What the report does not illustrate, however, is that there exists a pedagogical model, which has yet to be defined, that can accommodate the range of instructional techniques and types of content described in the report framework. The pedagogical model has proven to be effective given the maximization of the report's third and fourth organizers, technical and pedagogical support. That pedagogical model is Technology Enhanced Instruction, which will be operationally defined in the following chapters.

Overview

The analysis of the TEI model will be used to develop a universal definition of Technology Enhancement in the context of secondary school classrooms. The TESSI program is an exemplar of TEI, and will therefore be examined in detail in order to identify and describe aspects of TEI classrooms that are essential to the effective use of computer-related technologies in secondary schools.

The TESSI Model

The TESSI project has been in operation for the past seven years in Langley secondary schools in British Columbia. It was conceived by Janice Woodrow, Professor of Education at the University of British Columbia and, under her guidance, has developed into an internationally applied model of TEI. Researchers, teachers, and administrators associated with TESSI have identified it as a classroom model that, when compared with more traditional lecture-based science classrooms, meets the needs of a wider range of learning styles, develops valuable life skills, and allows for individualized instruction, thus increasing the opportunities for students to be successful (TESSI Video Conference,1995). The project has developed an instructional framework that fully integrates technology in a transactive and student-centered way. The TESSI approach requires a significant change in instructional orientations for many teachers, along with a change in students' roles in the classroom.

The TESSI classroom completely integrates computers and multimedia technologies into students' daily learning routines. A typical TESSI classroom is equipped with eight student computers and one multimedia station, along with one higher end computer for the teacher's development work. Computer-based probes for data collection in experiments are available at some of the student computer stations. The technology provides for a wide variety of activities which suit a range of learning styles, yet still address the same curricular outcomes. The sequencing and choice of activities are presented to students through a study guide, which also represents the majority of the teacher's planning. A summary of the types of activities available to students in a TESSI classroom and the relationships among them are shown in Figure 1. Students use the study guide to refer them to a range of activities at a variety of centers around the classroom, ranging from computer-based activities, such as simulations or interactive tests, to traditional 'hands-on' experiments or collaborative problem-solving exercises[10].

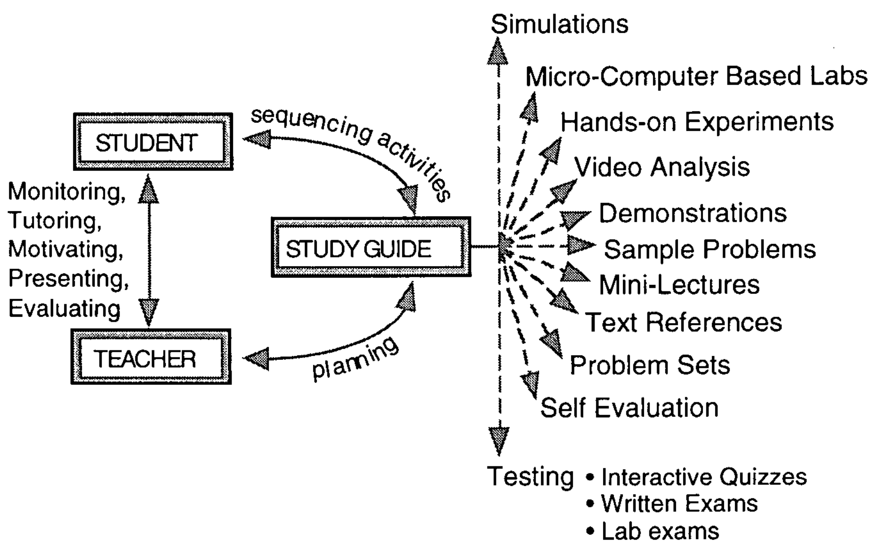

Figure 1. Role of the Study Guide in the TESSI Classroom

[10] For a more detailed description of the design of TESSI instruction resource materials, see Appendix 3.

More traditional activities, such as working through problem sets, one-on-one instruction, or group lectures still take place, but the timing is determined by the students' pace and levels of success. Because the technologies are fully integrated into their daily learning routines, students can explore concepts rather than merely complete closed-ended exercises. Students also have more control over the sequence and variety of activities than in a more transmissive classroom, because they can select experiments that may better reflect their learning style or area of interest. The teacher's role in a TESSI classroom changes from the 'disseminator of knowledge' to a facilitator who monitors, motivates, tutors, or provides 'just-in-time' small group instruction. Classes normally begin with a discussion of an advance organizer and the planned outcomes for the class. The teacher then circulates among the groups, responding to student needs as they arise; *students create the teachable moment* within the context of their own explorations.

Student evaluation is separated into formative and summative categories, and is measured relative to personal goals set by each student, in conjunction with the teacher and the curriculum. If students do not reach their personal goal on either the interactive computer-based quizzes or the paper-based unit exam, they can choose to complete corrective assignments or activities, and then retest on the specific outcomes where their scores were below their goal. A sample of a typical mastery report (produced using the LXR•TEST™ software) returned with each unit exam is shown in Figure 2. The student in this case reached the goal on two of the three objectives; the student could then choose to do some corrective work and retest on the 'Relative Motion' outcome. This feature of the evaluation software helps to identify areas of strength or weakness that may have been missed if the student had used only the total score of 80% as a indicator of their abilities.

Student: John Doe
Score: 39 of 49 (80%)

Test Date: October 20, 1995
Test Name: Kinematics Unit Exam
Instructor: Mr. Farenholtz
Class: Physics 12, Semester 1

	Number of Items	Maximum Score	Personal Goal	Percent Received	Mastery
Motion with Constant Acceleration (1-D)	7	11	80	82	
Relative Motion	9	21	74	67	
Projectile Motion	4	17	74	94	
OVERALL		49		80	

Mastered:
Not Mastered:

Figure 2. LXR Individual Mastery Report

The TESSI model does more for students than just help them to learn the course content; students are learning how to learn. Teachers have seen students develop a wider range of skills beyond the prescribed learning outcomes in the BC science curriculum (Woodrow, 1994). These skills include time management, resource management, the ability to work collaboratively in small groups, self-evaluation, goal setting, and computer literacy. The TESSI classroom setting also provides opportunities for individualizing instruction: students can work at their own rates, within limitations set by the teacher, and study unique content which allows for remediation, acceleration, and enrichment.

The TESSI model was first developed[11] in secondary Physics classrooms (then known as TEPI-Technology Enhanced Physics Instruction), where developers noted a marked increase in student participation rates. Despite working with a progressively larger sample of the graduating class, student achievement on final exams has been maintained at or in excess of the

[11] For a description of the evolution of the TESSI model, see Appendix 2

provincial average (Figure 3), suggesting that the TEPI classroom can help students of varied abilities and interests to be successful.

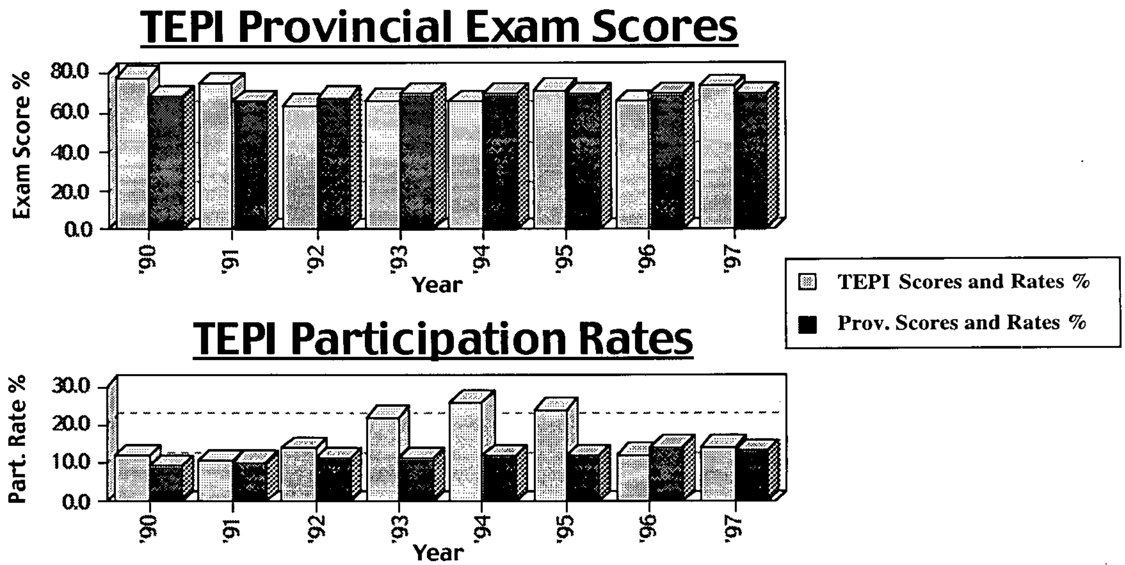

Figure 3. TEPI Participation Rates and Provincial Exam Scores

Essential Constituents of TEI Classrooms- Pedagogical Issues

Educators planning to utilize technology in secondary classrooms must first consider the impact it will have in terms of pedagogical issues[12]. TEI classrooms can address a breadth of learning styles and rates while developing life-long learning skills - all within the context of subject curricula - provided that educators are willing to reflect on and adapt their current practice. Effective use of technology involves changes in the ways teachers teach and the ways students learn.

[12] See Appendix 4 regarding the establishment of a TEI classroom.

Teachers beginning to integrate technology would typically first use the new tools to supplement and enhance their current practice; in other words, they would use technology to improve their lectures and demonstrations. Computers and related technologies are versatile tools, and although they can be used to enhance a lecture, they have the potential for much more diverse and effective applications. Over the last decade, advances in computing power and software design have increased the number of potential applications to include simulations, interactive testing, data analysis, publishing, and multimedia presentations. Access to global information through Internet search engines has also added potential uses such as research and electronic publishing. Students need the opportunity to use the technology within the meaningful context of the various disciplines in order to develop authentic technological literacy. Teachers can, however, perceive the integration of technology as a threat; CDI models are operational in many schools, wherein the technology replaces the teacher-as-expert in the classroom. As long as CDI is the prevalent model for the educational use of technology, teachers have every reason to be concerned; CDI programs *are designed* to replace the transmissive teacher and, through the application of rote learning strategies, focus only on limited skill development – skills which are restricted to the computer-based environment.

Effective integration of technology does not, however, involve the replacement of the teacher. It involves teachers assuming different roles with their students; as opposed to primarily lecturing, they can instead act as a mentor, motivator, tutor, presenter, evaluator, and designer. TEI requires that teachers adopt another pedagogical orientation: one which is more student-centered and based on experiential learning, known as the transactive approach. The perceived threat that technology presents for the transmissive teacher can be reduced by teachers developing an awareness of the inherent value of other curricular orientations[13]. Once they have an understanding that exemplary schools have a staff with a diversity of orientations, teachers will have a context for understanding the value of their own methodologies. When teachers are in command of precise *operational definitions* of the pedagogical devices they are using, teaching and learning improves. If they are committed to their current transmissive practice, they can see where it has a valued role within the school. If they are interested in exploring transactive approaches, they can also address students' skill development beyond that prescribed by subject curricula - and technology can play a vital role in making their instruction more effective. As schools establish more TEI classrooms and adopt more skills-based and outcomes-based approaches, the proportions of teaching staff who operate in the transmissive mode may be reduced.

From the teachers' perspective, a Technology Enhanced classroom would have several unique features when compared with more transmissive settings. The teachers' preparations would involve organizing a sequence of activities that students could work through individually or in small groups; students in TEI settings learn through experience, manipulating concepts, and collaborating with peers. The activities are designed to reflect a number of different learning styles, so students may have a choice among several types of activities in order to develop or demonstrate their understanding of a concept. Although teachers can prepare activities suited to several learning styles in a transmissive classroom, the activities lack the immediacy, level of interaction, and student-based control that occurs when students develop their understanding using simulations or computer-based experiments. Figure 4 illustrates how technology, combined with more traditional activities, can be used to accommodate a range of learning

[13] See Appendix 1 for a description of curricular orientations as they apply to the TESSI model.

styles. As new developments in technology become available, new activities can be integrated into the existing classroom structure.

Learning Style	Activity
Visual	Video measurement and analysis, teacher and student-led demonstrations, multimedia presentations.
Aural	Peer tutoring, teacher-directed demonstration and lecture, interactive computer-based tutorials.
Exploratory	Computer simulations, interactive data analysis, hands-on experiments.
Kinesthetic	Hands-on experiments, computer-based experiments (interactive probes), poster presentations, role play.

Figure 4. Sample Activities Associated with Learning Styles

In a TEI setting, the technology is used for a wide range of tasks, but it *is not* the focus of the learning; technological skills are taught *within* the context of the curricular-based outcomes. Technology is used as a tool to manipulate, analyze, and visualize concepts, and therefore should be as transparent as possible to the student. Technological literacy[14] often develops as an indirect result of the learning activity.

Students' roles in TEI classrooms are significantly different from those in transmissive classrooms. TEI teachers devote instructional time to developing their students' metacognitive, organizational, and time management skills. Students work towards personal academic performance goals that are set in conjunction with their teacher, and use their performance on each task as an indicator of their relative mastery of a concept. Students will manage their time

[14] Technological literacy refers to a person's ability to use computer-related technologies as a tool to research, organize, analyze and publish information. These skills include familiarity with computer operating systems, the internet, and common business applications such as spreadsheets and word processors.

and resources by varying the number and types of activities that will help them to reach their academic goals. The TEI model is well suited to a summative approach to assessment. Teachers can vary the number of formative tasks each student needs to complete in order to reach their personal goal; the student's grade will be based on their performance on summative tasks, which all students complete. Note that summative tasks should involve the use of similar analytical tools as were used during formative tasks. For example, if graphical analysis software was used in the formative experiments, then the same applications should be available during the summative lab exams. Interactive computer-based testing is an essential component of TEI, giving the students immediate feedback so that they can choose to complete corrective tasks and retest on specific learning outcomes within time constraints imposed by the school calendar and/or the teacher. The technology used in accordance with the TEI model affords a more realistic approach to outcomes-based and mastery-based learning (Eichorn & Woodrow, 1999) than in traditional transmissive classrooms. Students are directly involved in educational decisions regarding the amount and type of formative work they must complete before they can demonstrate their mastery of an outcome. As a result of these metacognitive processes, students in TEI classrooms tend to be highly motivated and actively involved in their learning (Woodrow, Mayer-Smith & Pedretti, 1998; Muldner & Reeves, 1998).

In TEI, the roles of the teacher and the student adapt to accommodate the benefits offered by the technology, but the technology does not replace the interrelationships between the teacher and the student. The focus of the learning remains on the curricular area, and the technology is used as a tool in, not the focus of, the learning process.

Essential Constituents of TEI Classrooms- Technical Issues

Once teachers make the decision to use technology as an educational tool, they are first faced with the task of installing computer hardware and software. If the physical arrangement of the technology is not well designed, teachers may encounter several pedagogical problems that are actually technical in nature. There is also an optimal amount of technology required to establish a transactive TEI classroom. The computer is the dominant tool used in the TEI classroom, and if the student to computer ratio falls below 3:1, students may not be able to use their time effectively, which may lead to 'waiting periods', which in turn may become classroom management issues (Woodrow, 1995).

In TEI classrooms, such as those exemplified by the TESSI model, the technology is located *within* the classroom, and it is dedicated for students use. It is available on a spontaneous basis as the student or teacher chooses, and as a result, it becomes a regularly used and essential learning tool. Technology-related resources such as a video center, computer-based probes, computers, scanners, and printers, are distributed throughout the room. This arrangement helps students to better manage their time, as they can readily see which resources are available; it also reduces potential distractions for their peers.

If the technology were to be located outside of the classroom, such as in a local computer lab, the students would see the technology as a special treatment, out of context of the normal instructional routines. Technology would be used as a special treatment for a specific task, not as an essential tool for learning. Teachers would be more likely to revert back to a more transmissive approach, as the computers would then become a scheduled, teacher-directed event, which in turn would eliminate many of the benefits associated with the transactive use of technology.

In the TEI classroom the computer-based tools serve several educational functions:

1. The computer can be used as an evaluation tool; advanced interactive testing software, such as LXR•TEST™ can provide students with instant feedback on each course outcome. Students can take tests at different times, within the self-pacing constraints set by the teacher. Interactive tests can include multiple choice, matching, numeric, and short answer question types, all of which can include colour graphics and movie files. The interactive tests are therefore more versatile and realistic than traditional multiple choice paper-based tests, as students can be tested on more realistic representations of concepts and their interrelationships.
2. The computer can be used as a data collection and analysis tool. Computer-based probes connect to the computer through an interface to measure virtually any physical property, and the analysis software presents the results in graphical or tabular format in *real* time. Students have an opportunity to manipulate the concepts more readily and determine or verify scientific relationships without first filtering the data through several analytical processes. Specific analytical and visualization tools such NIH Image™ or Videopoint™ are also effective for detailed measurement or manipulation of still or video images.
3. The computer can provide some direct instruction, as suggested by CDI models, but this use is most effective when used for remediation or enrichment. The effectiveness of this process is contingent on the quality and sophistication of the resource; often these products lack the flexibility to be tailored to suit an individual's needs, or to correlate closely with the local curriculum.
4. The computer can act as a research tool; students can have direct access to search world wide databases via the Internet, or use CDROM-based encyclopedias and periodicals. When students are researching subject-specific topics, they are also learning how to use search algorithms, verify the credibility of sources, and classify and organize information – all of which are essential components of *technological* literacy.

5. The computer can be used to model or explore relationships using specific software tailored to a curricular outcome or discipline. Simulation software such as Interactive Physics™ allows students to control combinations of variables to determine their impact on the motion of objects; simulations, such as the Biology Explorer™ series, allow students to trace genetic patterns through several generations of offspring, or explore the interrelationships between carnivores and herbivores in a controlled ecosystem. Students' motivation increases when they are given the opportunity to explore the concepts themselves, and as a result, they develop a more complete understanding of the relationships being explored.
6. The computer can be used as an effective publishing tool. Common business applications are used for word processing, spreadsheets, and communications, fostering transferable computer-based skills. In British Columbia, for example, TEI classrooms can address a significant portion of the outcomes in the Information Technology curriculum.
7. Technology can also be used effectively as a presentation and development tool, as suggested by CAI models. By using screen sharing or projection panel technology, students and teachers can use the computer to more effectively model a concept for a large group. Note that in CAI models, this is the *only* function of the technology and normally only accessed by the teacher, whereas this is likely the least used function of technology in the TEI model.

The proportion of use for the seven preceding educational functions will be partially determined by the discipline and availability of resources: Science students may use the computer primarily for data collection and analysis, English students may use it primarily for publishing and multimedia presentations, and History students may use it more for research and Internet access. The diversity of activities available to students may be restricted by the limited number of instructional resources that are well suited to a TEI environment. Until more resources appropriate for TEI classrooms are available, teachers may have to devote a significant portion of their preparation time to technology-based resource development.

CHAPTER 4 *The Definition of Technology Enhancement*

Overview

Technology has become an essential and pervasive tool in our society, and as part of the continual process of addressing the educational needs of the community, schools are attempting to develop life-long learning skills and technological literacy in their students. Technology is consequently being installed in schools, primarily along CDI or CAI models, which have severe educational limitations. Computers have not had the impact on student learning as technology proponents anticipated, because a concise operational definition of technology with respect to education, and technology with respect to enhancement in secondary classrooms, does not exist. The financial requirements of the complete integration of technology in every classroom can be prohibitive, but the economic/educational benefits can be maximized if we have access to operational definitions of effective technology-based instructional models. Because of the TESSI project, there is an emergent definition of Technology Enhancement that can be used in establishing effective Technology Enhanced Instructional programs. The *operational* definition of technology enhancement in secondary schools is crucial to cost effective and educationally effective integration and implementation of technology.

Most generically, technology may be defined as the means by which humans support or extend their physical and mental capabilities. With respect to *traditional* applications in secondary education, technology may be defined as a tool that assists with instruction, primarily used by the teacher: the tool is used to enhance a presentation, improve the accuracy or efficacy of a measurement, illustrate a concept, or assist with evaluation. This definition is no longer operationally relevant, given the evolution of the desktop computers and the development of the

TEI model; technology is integrated most effectively when used primarily by the student. Given the detailed description of the TESSI model (Chapter 3), it is now possible to develop the operational definition of Technology Enhancement as it applies to secondary schools.

The Definition of Technology

Technology, in the context of secondary school classroom instruction, is the use of a computer or computer-related tool to assist with students' learning processes in a task-oriented classroom environment. The tool is used primarily by the student to model concepts or to simulate and manipulate their interrelationships. It is also used for measurement, analysis, product development, hypothesis generation, and self-evaluation. The technology promotes interaction and collaboration between students and between the student and the teacher. The technology creates the opportunity for the learner to test an emergent theory in a low-risk fashion; it encourages exploratory and experiential learning by allowing students to manipulate a representative environment. The technology increases student engagement – requiring interaction, but providing immediate feedback.

In the TEI setting, the technology, of which the computer is the essential component, is used as a fundamental tool for the majority of the student-centered activities which are designed to accommodate a variety of learning styles. The technology is fully integrated into the learning activities on a daily basis, and therefore must be located within the classroom to be used effectively. Thus, the definition of technology can be applied to computers being used for:

1. The exploration of concepts, such as with computer simulations.
2. The assessment of students, such as with interactive testing, outcomes based reporting, and grade-book programs.

3. Data collection and interpretation, such as with Universal Lab Interfaces™ for electronic data acquisition.
4. Data analysis and publication, such as with the Microsoft Office™ package.
5. Research, such as with Internet search engines.
6. Illustration of concepts, such as with multi-media CD-ROMs.

The Definition of Technology Enhancement of Instruction

Technology *Enhancement* of instruction refers to the behavioral outcomes that arise when both the students' and the teachers' roles change as a result of the full and effective integration of technology in a transactive classroom. A summary of the behaviors common to all TEI classrooms are:

1. The teacher's role extends beyond that of a lecturer and evaluator. The teacher acts as a motivator, monitor, and tutor. Presentations are usually reduced in length and held for small groups of students – as their progress dictates.
2. Teachers adopt a primarily transactive orientation, although they can choose to move among orientations (transmissive, transactive, and transformative) where appropriate. The full integration of technology affords a more diverse culture in the learning environment.
3. From the student's perspective, the technology becomes transparent to the learning process. The focus is on the concept or skill development; computer skills are taught within the context of an activity - they are not the focus of the activity.
4. A variety of activities are usually happening simultaneously in the classroom.

5. Students are much more engaged in the transactive learning process than in a transmissive setting.
6. Students regularly apply metacognitive skills to assess their progress, and to make decisions regarding resource and time management. Teachers and peers are also considered as resources in the TEI context.

If any school is considering implementing computer technology, the computer uses and participants' behaviors described above are the critical aspects of the definitions; these aspects of TEI are indicators that the learning benefits have been maximized and the associated costs are minimized.

The criteria delineating Technology Enhancement have been extrapolated from more than ten years of research and seven years of development and classroom practice. The criteria act as the primary indicators of the successful and complete establishment of the TEI model in a classroom; if most of the criteria are not met then neither learning nor the associated costs will be optimized.

The Continuity and Longevity of Technology Enhanced Instruction

Effecting lasting change is a difficult endeavor in any context, and modifying educational practice is no exception. Treatment times associated with teachers' pedagogical changes are year-long ventures. An obvious concern for educational leaders is the longevity of the TEI program; the expense of installing TEI is not warranted if the program has a very limited lifetime. The fact that technology will continue to pervade aspects of our educational institutions, however, mandates the implementation of the TEI model and its successors.

The TEI criteria generated from the essential definitions of Technology Enhanced Instruction provide a most important basis for teacher/administrator decisions relating to the implementation of computer technology in a school. The criteria that impact the continuity and longevity of TEI can be adduced from the descriptive details of TESSI in Chapter 3. The operational requirements for establishing and maintaining a Technology Enhanced Instruction program in secondary schools are:

1. Implementation requires the initial and continuing support from staff, administrators, and Board.
2. Administrators need to establish a forum for regular professional communication to discuss how different programs or pedagogical approaches in the school are addressing the district's educational goals, mission, or vision. These forums should include presentations by the TEI teachers on staff[15] .
3. TEI teachers should revise aspects of the program so that it better correlates with the demographics of local classrooms.
4. Administrators should foster a 'low-risk' environment wherein teachers can explore new pedagogical approaches. If teachers have an opportunity to work closely with and be supported by administrators who regularly review the project's results, the personal risk *perceived* by the teacher would be reduced.
5. TEI teachers should maintain currency with exemplary research projects and publications by the academic community.

[15] It is recognized that innovations may often be misunderstood or misinterpreted; provisions must be made for feedback as further clarification is needed. (Watson, 1966)

6. Administrators should illustrate publicly how each pedagogical approach contributes to the academic success of the school. Educators will tend to support an innovation once they can see how the innovation corresponds with their own educational values and ideals.[15]
7. Educational leaders need to participate in an informal process of evaluation that can provide constructive feedback for teachers implementing an innovation.
8. Educators need to inform students of the benefits associated with the forthcoming TEI program.
9. Schools need to communicate the benefits of the TEI model to parents within the local community.

CHAPTER 5 *Conclusion*

The central purpose of the thesis was to provide an operational definition of Technology Enhancement in the context of secondary school classrooms. Chapter 3 has provided an explicit, detailed description of the TESSI project, as it has successfully operated for up to seven years in seven sites in B.C. schools. In addition, Chapter 3 has provided detailed descriptions of the technical and pedagogical challenges associated with implementing TEI. From these descriptions, Chapter 4 developed the logical definitions of the critical terms of Technology Enhanced Instruction. From these definitions, three sets of explicit criteria emerged, which, if a school or school district were to undertake the implementation of a successful TEI program, could be used to develop, organize, and criterion-reference the establishment and long-term success of a TEI program[16].

Those schools that decide to make effective use of technology through applying the TEI model may benefit from the inclusion of an ideal sequence of events that can impact the efficacy and continuity of their TEI classes. The critical path for events is based upon the criteria developed in Chapter 4, and is detailed in four phases below.

[16] See Appendix 4 for a discussion of the process and context of establishing TESSI classrooms.

Phase 1. ***Establish a support network for the implementation of the TEI program.***

Events	Evaluation/Indicators
1. Establish endorsement for the project from senior management at the school board level.	Documented support from the district superintendent and local administrators has been obtained.
2. Obtain project endorsement from the administration and staff.	Forums have been arranged for discussion at staff meetings regarding the role of TEI in the mission and vision for the school
3. Select at least two teachers to implement TEI[17]; in order to facilitate collaboration, resource distribution and development, these teachers should be implementing TEI in the same subject area.	At least two teachers have been selected to implement TEI after an appropriate application process. The teachers may be working at different schools within the district.
4. Establish a timeline and anticipated outcomes for the project with the TEI teachers and staff; this timeline should be reviewed at regular intervals.	Published timeline is available, detailing responsibilities of each member of the project team.
5. Determine the level of financial commitment available over the three year duration of establishing the TEI classrooms. Costs should include hardware, software, installation, and training.	Documented financial allocations to a TEI budget are produced, detailing the amounts and timelines that correlate with the TEI development plan.
6. Communicate project objectives and benefits to interest groups (parents, students, and staff).	Publication through school newsletters and local newspapers of the implementation of TEI classes is undertaken.

[17] The selection criteria for TEI teacher could include such characteristics as: attitude towards change, level of computer literacy, perceptions of alternative instructional orientations (in particular with respect to student/teacher roles), level of commitment, and the ability to participate in on-going training, evaluation and debriefings.

Phase 2. ***Develop the technological literacy of the TEI teachers.***

Events	Evaluation/Indicators
1. Purchase technology for the teachers, and install in each classroom.[18]. Technical assistance should be available to help the TEI teachers install the operating system and appropriate software.	Technology is in place and operating in each classroom. Internet access is available.
2. Provide technical training for the TEI teachers.	Teachers have the support to attend regional technical workshops on needed aspects of the technology. Teachers should be developing activities related to the topics of each training session.
3. Purchase instructional resources designed for a TEI environment.[19] Have TEI teachers develop technology-based activities following the TEI resource guidelines (see Appendix 3).	Developed activities are shared with other TEI teachers, who evaluate and revise the activities using the TEI resource guidelines. TEI teachers use release time to meet, debrief, and develop TEI materials.
4. Teachers use technology as an instructional resources along CAI guidelines, such as using projection panel technology for group presentations, and using test-generating software, such as LXR•TEST™, for creating outcomes-based tests.	Teachers are observed to be using the technology on a weekly basis to supplement lectures and demonstrations. Students' tests and activity guides have been (partially) developed by the TEI teacher.
5. TEI teachers use electronic communication methods to share resources and debrief on technical and pedagogical issues.	Teachers successfully transfer documents using email, and explore TEI-related resources available on the Internet.

[18] Technology common to each TEI teacher would ideally include a computer, printer, publication software, subject-specific hardware and software (eg. Simulations, MBL equipment, video analysis software, CD ROMs, video technology, and a projection system).

[19] TESSI's recently published (Prentice Hall Canada)instructional resources for Physics 11 and 12 serve as an exemplar model for well designed TEI resources. See Chapter 3 for a description of their function in a TEI setting, and Appendix 3 for a description of the design features of TEI activities.

Phase 3. ***Implement technology in an activity-based, teacher controlled setting.***

Events	Evaluation/Indicators
1. Adapt physical arrangement of the classroom to accommodate ideal locations for the computers, multimedia resources, and printer. 2. Purchase and install student workstations and Local Area Network.	Student workstations are distributed throughout the room, preferably at least 2 meters apart. The technology in the TEI classrooms is installed and operational
3. *In situ* technical support is available to support the installation and management of the LAN.	A district computer technician is available upon request. The teacher has the opportunity to work collaboratively with the technician in order to learn how to better maintain the LAN. Problems are documented and shared electronically with the other TEI teachers.
3. Students use the computers on a daily basis, working through technology-based activities *as directed by the teacher.*	Students are seen to use the technology frequently, working either in small groups and independently; students become technologically literate.[20] Project members, including administrators and other TEI teachers, observe the class on a regular basis; team members meet to debrief and revise activity guides and instructional strategies.
4. Students take tests within each unit interactively at the computer.	Interactive tests are used to provide immediate feedback to students.
5. TEI teachers attend pedagogical training workshops. These training sessions should include presentations on curricular orientations with respect to changing student/teacher roles, and how to apply these principles in a TEI classroom. Ideally this would also include visits to operational TEI classrooms.[21]	Release time is available to attend pedagogical training sessions. Teachers are able to visualize and anticipate the pedagogical impacts of a transactive TEI classroom.

[20] See Glossary.

[21] Alternatively, video resources of TEI classrooms could be used as a reference. See TESSI Video Conference, 1994.

6. The project status and progress is reported to the staff and senior management. Revisions and recommendations regarding project direction are developed.	The TEI project team collaboratively develops a report to schools at the end of Phase 3.

Phase 4. ***Establish the transactive, student centered, TEI classroom..***

Events	Evaluation/Indicators
1. Teachers make the transitions to a student-centered, transactive-oriented TEI classroom.	Observers are able to correlate the instructional strategies with the TEI criteria in Chapter 4.
2. Students are taught metacognitive skills to help them manage their progress through the course.[22]	Observers are able to correlate the student behaviors with the TEI criteria in Chapter 4.
3. *In situ* pedagogical support is available. Ideally, experienced TEI teachers would be able to participate; alternatively, the TEI project members would observe and evaluate each other, and debrief on a monthly basis.	Teachers have the release time available to observe TEI classes, meet, and debrief.
4. TEI teachers develop additional activities, using their experience to adapt the TEI guidelines to their own classroom routines.	Teachers use release time to develop additional TEI activities. Note that this role will be reduced as more appropriate resources are made commercially available.
5. The project status and progress is reported to the staff and senior management. Revisions and recommendations regarding project direction are developed.	The TEI team collaboratively develops a report to schools at the end of Phase 4. The results are presented and discussed with staff.

[22] Topics could include goal setting, self-evaluation, time management, resource management, and learning styles.

At the end of Phase 4, a fully operational TEI classroom would be established in at least two schools in the district. The district has also helped to develop the technical and pedagogical skills in the TEI teachers, who can now act as relatively experienced advisors as the project is scaled to more classrooms, and to more schools. Successful rapid expansion of the project is contingent on an additional number of factors, which are also extensions of the criteria for Technology Enhancement developed in Chapter 4:[23]

1. A TEI trainer, with experience in the technical and pedagogical aspects of TEI is dedicated to support a maximum of six TEI expansion sites.
2. TEI instructional resources are developed and available to teachers at each expansion site.
3. Funds are available for equipping each expansion site with equivalent technology.
4. Funds are available for the TEI teachers and trainers to meet on a regular basis through the school year. Session must include a series of technical and pedagogical workshops.
5. The process at each expansion site follows the above progression described in Phases 1 through Phase 4.
6. The progress at each expansion site is regularly evaluated and reported, as described in Phase 3 and Phase 4.

A successful TEI program is not dependent solely upon the change from a transmissive to a transactive orientation, but upon the application of the ***criteria*** extrapolated from the basic definitions created for TEI. These criteria comprise the complete operational framework for TEI; the proportion of these criteria that are addressed within the development of a TEI program

[23] These factors were also evidenced as a result of the author's role in the expansion of the TESSI project to sites in Mexico and British Columbia.

act as an indicator of the degree of successful implementation. These criteria are much more than a list of conceptual references; they create an explicit, operational guide for educators, helping them to maximize the educational benefits associated with the integration of technology in schools in a fiscally responsible fashion.

Technology will continue to evolve and pervade every aspect of our personal and professional lives. Numeracy and literacy are no longer enough – graduates must also become *technologically* literate. Computers and related technologies *will* play a significant role in education, and Technology Enhanced Instruction affords an opportunity for educators to use them effectively. The definitions and criteria developed in the thesis have the potential to enhance such effectiveness.

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Curricular Orientations & Berlaks' Dilemmas

Research by Miller & Sellar (1990) has shown that instructional strategies and philosophies can be organized into three categories called 'orientations': transmissive, transactive, and transformative. The transmissive orientation reflects an approach where students learn through listening and observing; there is primarily a one-way transfer of knowledge, skill modeling, and information. The transactive orientation involves students more directly; as they learn through individual experience and experimentation, students construct knowledge and understanding through a dialogue with the teacher and their peers. Learning is seen as both a social and a democratic process. The transformative orientation reflects a classroom environment which focuses on the development of a student's personal knowledge and intrinsic understanding of their relationship with their environment. An understanding of these three orientations can provide teachers with a perspective on alternative instructional strategies, direction when choosing alternative instructional models, a language and a framework to discuss the effectiveness of alternative instructional models, and thus the ability to reflect on their own practice. Each of the three curricular orientations can be effective, but their use is often influenced by instructional style and the nature of the discipline.

When teachers adopt an orientation, they are faced with 16 dilemmas (Berlak & Berlak 1981). These dilemmas are the inherent benefits and limitations associated with each orientation, such as choosing between processes that are controlled by the student or by the teacher, whether the class focuses on the development of personal knowledge or public knowledge, or whether learning is seen as a molecular or holistic process. When teachers are familiar with these dilemmas, they will be more aware of the strengths and limitations that come with the implementation of 'new' instructional models. A summary of Berlaks' Dilemmas is shown in the table below, illustrating which position a teacher must adopt when they work within one orientation.

Dilemma	Transmissive	Transactive	Transformative
Student Control vs. Teacher Control	Teacher	Both	Student
Personal Knowledge vs. Public Knowledge	Public	Public	Personal
Knowledge as Content vs. Knowledge as Process	Content	Both	Both
Whole Child vs. Student	Student	Student	Whole Child
Intrinsic Motivation vs. Extrinsic Motivation	Extrinsic	Both	Intrinsic
Students having Unique Characteristics vs. Students having Shared Characteristics	Shared	Shared	Unique
Learning as a Social Process vs. Learning as a Individual Process	Individual	Both	Social
Student as a Person vs. Student as a Client	Client	Client	Person
Holistic Leaning vs. Molecular Learning	Molecular	Both	Holistic

Figure 5. Addressing Berlaks' Dilemmas

The divisions between each orientation can be crossed, given the teacher's mastery of a breadth of instructional techniques and the availability of resources in the learning environment to support activities suited to other orientations. TEI, in particular, creates an environment wherein teachers can switch between the transactive, transmissive, and transformative orientations, adapting to students' individual needs.

Correlation of TESSI with the Curricular Orientations and Berlaks' Dilemmas

The classroom model applies instructional strategies that reflect both the transmissive and the transactive orientation. In the TESSI classroom, text-based resources are used to present concepts and to sequence tasks for the students; the teacher still uses lecture as a tool for content delivery, although it tends to be used for small groups of three to five students once the students have developed their own anticipatory set. These activities are representative of the transmissive orientation. TESSI students use technology as an essential tool to explore, model, and analyze concepts; the more complex computer simulations, multi-media analysis activities, and learner-directed experiments are used to develop problem-solving and critical thinking skills. The teacher's role involves more facilitation in response to the variety of transactive activities taking place simultaneously around the classroom. TESSI students apply the scientific method and problem-solving algorithms to explore the fundamentals of science, which, by definition, corresponds to the transactive orientation.

Berlaks' Dilemmas

The TESSI classroom model has the flexibility to accommodate multiple aspects of the issues raised by Berlak & Berlak (1981). The challenge faced by the TESSI teacher is to select which aspects of Berlaks' dilemmas they will choose to address. The teacher is continually applying a wide range of interpersonal, administrative, modeling, and mentoring skills spontaneously throughout each class. It is important for TESSI teachers to have the opportunity to select which aspects of each orientation they will adopt, in order to reduce professional discord and to establish a more consistent approach with their students. In this context, TESSI teachers have the opportunity to better realize their own professional potential.

1. *Whole Child versus Child as a Student:* The TESSI model focuses on meeting the needs of the student; the aesthetic, emotional, and moral development are not defined as aspects of this instructional model. Many of the features of group dynamics in teacher-centered activities are difficult to retain in such a student-centered classroom, as students are generally working on different topics and activities at the same time. Social skills are developed when students work in collaborative groups, but ethical and moral development would be restricted to those behaviors modeled by the teacher: these skills are not a specific goal of this classroom model.

2. *Teacher versus Student Control:* There is a combination of both teacher and student control of the learning environment. Teachers control most of the administrative features in the classroom, whereas students can determine their goals, the types of activities, and within guidelines set by the teacher, the pace of their work. Students can elect to work individually or in small collaborative groups, receiving direct guidance from the teacher when necessary. Students also have control over the level of mastery they attain through the completion of corrective assignments and re-testing on unique

objectives. TESSI students learn to manage their own time and resources in order to reach their personal goals.

3. *Personal Knowledge versus Public Knowledge:* Although the nature of science dictates the learning of public knowledge, in this style of classroom, students are regularly developing their own understanding of the underlying concepts and then comparing them with the 'correct' solution. In most computer simulations, the students can control a number of variables and then run the simulation to see if their perceptions are correct or if they need revision. Students are encouraged to recognize their preconceptions and revise them to encompass their new level of understanding. This approach is a key component of effective science instruction as defined by Osborne and Freyberg (1985).

4. *Knowledge as Content versus Knowledge as Process:* Knowledge of the course material is a combination of both content knowledge (the language of science and mathematics) and process knowledge (problem-solving and the scientific method). Indirectly acquired knowledge, including collaborative learning and computer-based skills, are process-based.

5. *Extrinsic versus Intrinsic Motivation:* The TESSI classroom model provides opportunities for both extrinsic and instrinsic forms of motivation. Teachers supply the extrinsic motivation through grades, mentoring, tutoring, and direct, individual interactions with students. The multiple roles assumed by the teacher as they circulate throughout the classroom makes it imperative that they apply a variety of motivational strategies. Students seem less secure with their acquired knowledge in this setting compared to the teacher-centered classroom environment where they are regularly told what is 'right' or 'wrong' by the resident expert. Alternatively, TESSI students are

encouraged to rely on intrinsic motivation to manage their time and resources to complete course requirements. When students explore a simulation, they enter a prediction; if the prediction is correct, their learning is reinforced intrinsically by the correlation with the 'accepted public knowledge' calculated by the computer. It would be virtually impossible to provide this level of motivation on an individual basis in a transmissive classroom environment. The students' motivation is more directly reinforced when they reach their goals on interactive tests and unit exams. The mastery reports and the collection of their work in portfolios provides the opportunity for the student, their parents, and the teacher to reflect on the student's successes, again providing both extrinsic and intrinsic motivation for the students.

6. *Learning is Holistic versus Learning is Molecular:* The study guides used in the TESSI program present the course content in a molecular fashion. The basic concepts are presented in textual form, accompanied by brief video or simulated representations of the concepts. Students then apply problem-solving algorithms to situations that incorporate the new concept.

7. *Each Child is Unique versus Children Having Shared Characteristics:* The TESSI classroom model addresses the student as a unique individual, with their own combination of intelligences and associated learning styles. Students can select the activities that best suit their own learning characteristics. The technology-based classroom model is well suited to meeting the needs of six of the multiple intelligence classifications: the Linguistic, where the study guides present the material in textual format, and individualized instruction is primarily oral through interactions with their peers and with the teacher; the Logical/ Mathematical, where the problem-solving nature of science and the mathematical language of science requires an application of this form

of intelligence; the Spatial, where students can explore concepts using multi-media analysis activities or computer simulations where the concepts are represented visually; the Kinesthetic, where several activities require physical movement of groups of students to model concepts; the Interpersonal, where students often form small groups to reflect, tutor, and problem-solve together; and the Intrapersonal, where students have the opportunity to work individually for personal exploration of the concepts and internal reflection at their own rate.

8. *Learning is Social versus Learning is Individual:* Learning is mainly a social activity, but there is opportunity for individualizing the learning process. The students can work individually, collaboratively in small groups, or they can partake in whole class discussions. Teacher-centered presentations are available on an individual basis and for small groups, but rarely for the entire class.

9. *Child as a Person versus Child as a Client:* The child is viewed primarily as a client, but the TESSI classroom model also helps to develop skills that are useful well beyond the scope of the course. A unique interpretation of this dilemma may best be phrased as 'the student is a client of lifelong learning'.

The Historical Development of the TESSI Model

The TESSI project was the embodiment of Janice Woodrow's vision that began in 1989 with the TEPI project (Technology Enhanced Physics Instruction). The project's primary goals were to address the challenges of successfully implementing technology, such as computers and multimedia resources, into the classroom. The team members (Woodrow, Spann, and Farenholtz) had developed a working relationship through teacher training and as executive members of the local Physics Teachers Association. The project began in 1990 as an open-ended exploration of the effective application of technology in the Physics classroom. Through each stage of technology implementation, the team members observed the effects on students' learning, motivation, and success, in addition to subsequent changes in the classroom environment and teaching strategies. The results of the TEPI project laid the foundation for a more complete integration of technology and the evolution of the TEI model.

The TEPI project began with the installation of the teacher stations, which included computers and multimedia presentation hardware. Before the technology could be incorporated directly into the classroom, the teachers had to be trained in the use of the technology and software. This training process became a cooperative effort between two participating physics teachers (Spann and Farenholtz). In the article "The Role of Computer Technology in Restructuring Schools" (Collins, 1993), the author suggests that limited teacher experience with computers would fuel the resistance to implementing technological change. Contrary to Collins' statement, the TEPI project demonstrated that motivated teachers without extensive prior computer experience will learn to use the technology provided they are given support in terms of release time and professional development.

The initial expectation of the TEPI project was to incorporate computer simulations into traditional Physics instruction. It quickly became apparent that, although lectures were enhanced by the animated graphical representations in a simulation, lectures did not take advantage of the many potentials the technology offered. In his article, Collins lists several advantages to the learner using the technology first hand, such as increased time on task, self-paced learning, and the integration of visual aspects with the verbal and cognitive processes in learning. These developments were observed in the TEPI project once the student computer stations were placed in the classroom. However, achieving the outcomes suggested by Collins required more than simply installing computer technology; it became evident that the learning environment needed to be restructured into learning centers, which in turn required the development of a study guide that would direct the students, more or less independently, through a progression of activities. Once these changes were implemented in the TEPI classrooms, the project team began to see many of the anticipated positive educational outcomes. There was an immediate increase in students' engagement time, and spontaneous peer tutoring and support became evident. Students began to problem-solve in collaborative groups. These groups were self selecting according to their rate of progress through the material. Students became increasingly self-motivated; there was regular and immediate feedback, both from their peers and from the simulation interface. Students with higher abilities began to work at accelerated rates, and became tutors for students who were struggling with earlier concepts. The classroom environment, from the students' perspective, had radically improved over the traditional transmissive setting.

The changes in student activity necessitated modifications in the teachers' approach to instruction and classroom management. Lecture time was significantly reduced; the teacher began to focus on small group instruction, acting more as a coach or facilitator. Weaker students were given opportunities for more frequent support and direction from the teacher.

Group lecture was used for summative review or to clarify particularly difficult concepts. During these sessions, students tended to internalize the concepts more readily, as the anticipatory set had already been developed through their own explorations of the topic. Students were motivated to pursue the problem through their personal experience and direct visualization of the concept as shown by the simulations or in the multimedia presentations. The technology also provided the teacher with multiple strategies for modeling a concept; students could explore a concept through a simulation, multimedia presentation, hands-on demonstration and experiment, teacher-led discussion, or through traditional textbook research and problem-solving. Evaluation of students' progress was mastery-based, using the LXR•TEST™ generator. Tests could be taken interactively on the computers, and the software provided students with immediate feedback on their responses as they worked through each test. The tests, therefore, became both an evaluation and a learning tool.

The effectiveness of the students' interactions with the technology is, however, dependent on the type and quality of that interaction. Gavriel & Salomon (1992) discuss the importance of designing the interface and activities in order to ensure that students access higher cognitive processes. The authors suggest that computers will help students to construct new knowledge bases rather than accessing prior knowledge, provided that the control of variables and feedback promotes higher level thinking skills. The TEPI project team recognized that computers would be used as instructional tools for tasks such as the introduction, exploration, modeling, and evaluation of concepts; the TEPI team then decided to access students' higher level thinking through the use of simulations and collaborative problem-solving activities. Considerable efforts were made to structure the simulation interfaces and activity guides to encourage students to explore scenarios at their own rate, thus allowing for different intellectual abilities or learning styles.

The positive changes evident in the TEPI classrooms did not arise without the associated challenges of funding restrictions and increased workload for the developers. The TEPI project accessed the majority of its funding through external sources in the form of grants acquired by Janice Woodrow. The increase to the teacher's workload was substantial; all resources for student activities needed to be developed and published for use in the classroom, as they were not commercially available. In traditional classrooms this would not pose a significant problem; in a technology-based classroom, however, resources must be developed to accommodate a variety of learning styles. The teacher also had to contend with hardware and networking problems. An additional time constraint arose from learning to use the technology; both students and teachers worked through the learning curve associated with each software package and classroom routine. The TEPI project team attempted to address these concerns by allocating funding towards release time and towards higher levels of technology that would reduce the teacher's workload. Although the teaching loads were not reduced for both teachers, the team did have access to two release days per month to develop resources and discuss alternative teaching strategies.

The TEPI project team found that implementing technological change also required a physical restructuring of the learning environment. This restructuring was particularly difficult as there were no working models to follow, and the architectural restrictions were unique to each physical plant. The team developed an original design for a combined multimedia presentation/teacher workstation, and coordinated changes to the lighting and layout of the classrooms to accommodate the additional hardware. Other physical considerations, such as the increase in room temperature, continued to become apparent after the technology was in place.

The TEPI project has been ultimately successful, and has expanded into the TESSI project as a result of the following attributes:

1. *The composition of the project team.* TEPI was directed by Janice Woodrow, a professor experienced with current educational technology, working in conjunction with two Physics teachers, Gordon Spann and Aubry Farenholtz, who had previous computer and professional development experience. The dynamics of the team has proven particularly successful for two reasons. Firstly, the two teachers had prior experience working on technology-related projects, and established an effective working relationship that promoted the sharing of resources and new instructional approaches. Secondly, an experienced researcher directed and guided the team's efforts, kept them apprised of recent advances in technology and educational models, and objectively evaluated the project's outcomes. This combination helped the team to meet the challenges of implementing technological change in the classroom by sharing tasks and matching responsibilities to each team member's strengths.

2. *Project Support.* The project received full support from administrations at both high schools and the university; this was essential for the team to access additional release time, reduce teaching loads, and take advantage of related professional development opportunities.

3. *Access to Professional Development.* Project members had access to professional development opportunities at local and international conferences, as well as through coursework at local universities.

4. *Frequent Observation, Evaluation, and Debriefing.* The project director observed and videotaped classroom sessions at each site on a biweekly basis. The TEPI team met frequently to review the effectiveness of the instructional strategies and resources used in the classroom.

The TEPI project found that a student-centered, Technology Enhanced classroom could better meet students' individual needs compared to a traditional, transmissive classroom setting. Students had the opportunity to work towards the mastery of objectives at their own rate, operate at higher cognitive levels, and work as a team through regular collaborative learning activities; students assumed a direct responsibility for their own learning. Based on the success of the TEPI project, the team decided to explore the effectiveness of the TEPI educational model in junior Science courses, in addition to senior Biology and Chemistry; at this point, the project was renamed as TESSI (Technology Enhanced Secondary Science Instruction), and additional Science teachers and researchers were added to the team.

Appendix 3: *The Design Features of Activity Guides Developed for TEI Classrooms*

A critical component of the TEI model is the availability of the instructional resources that will form the basis for students' experiential learning activities. The resources developed for the TESSI project provide an exemplary model for the structure and content of student activity guides. The resources were developed in conjunction with the evolution of the TESSI instructional model, and therefore reflect the pedagogical approach used in TEI. The structure of the resources corresponds with Fullan's recommendation with respect to the use of innovative materials as part of implementing a new program: "The effective use of materials depends on their articulation with beliefs and teaching approaches." (Fullan, 1982, pg. 33)

The student-centered activities in a TEI classroom are designed to address one of four operational outcomes:

1. *Introduction of Concepts:* these activities can provide an overview of the upcoming concepts in a unit of study, stimulate the developmental questions related to the upcoming topics, and often provide a source of intellectual curiosity and motivation in students.
2. *Concept Development/Exploration:* these activities are designed to develop an understanding of more specific concepts and problem solving skills. Students are often exploring "What if?" scenarios, which are open-ended explorations where students control a variety of variables and observe their impact with a particular outcomes. These activities are designed to develop students' problem-solving skills in a non-mathematical environment.
3. *Data Acquisition & Analysis:* these activities are designed to provide students with measurable aspects of a concept for detailed analysis. An objective of an analysis activity would be that students would collect and analyze data in order to either verify or

disprove a given theory or conceptual relationship. Students would be expected to use technology to assist with data collection, such as with MBL tools, and with data analysis, such as with graphical analysis software. The technology affords more time to be spent on conceptual analysis and development than on traditional measurement skills.[24]

4. *Evaluation*: these activities are used in TESSI classrooms to measure students' problem-solving skills with respect to course outcomes. Students are evaluated using Technology Enhanced lab examinations, computer-based interactive tests, and simulations to test their understanding of a single concept or theory. The evaluation activities are outcomes-based, and students often have an opportunity to complete corrective work and then re-test.

In the process of training other teachers to create TEI instructional resources, the developers (Spann and Farenholtz) established an organizational sequence to help ensure that the resources were well suited to a student-centered environment. This sequence is detailed below:

1. Identify the curricular outcomes the activity is to address.
2. Identify, sort, and classify all concepts or skills used in the simulation.
3. Identify the prerequisite knowledge or skills required to successfully complete the activity.
4. Determine the type of activity: introductory, exploratory, analytical, or evaluative. Link the structure and content of the student directions to the purpose of the activity. For example, introductory activities will contain leading, open-ended questions; exploratory activities will contain "What If..?" questions; analytical activities will contain directed

[24] Traditional measurement skills are still an important aspect of the TESSI science classroom. However, once students have demonstrated that they can measure physical characteristics using more traditional tools, they are encouraged to use modern technology to expedite the measurement process in order to focus more on the concepts and their interrelationships.

questions and instructions; and evaluative activities will contain questions which reference one outcome or skill that students have already explored.

5. Develop a teacher's resource which provides a clear context for the use of the activity, along with explicit technical and pedagogical suggestions.
6. Exchange the material between TEI trainers or teachers for review and editing.
7. Use students' feedback after they complete the activity to evaluate the resources. Key areas would include clarity of instructions, and assumptions with respect to students' levels of technological literacy.

Establishing a TEI Classroom

For several decades teachers have searched for ways to supplement their transmissive approach in an attempt to help students develop skills that were not being fostered in teacher-centered classrooms. Examples of these skills include the ability to collaborate, organize, self-evaluate, manage time and resources, and to learn independently. The alternative approaches developed by transmissive teachers have included such strategies as cooperative learning activities, group-based projects, or philosophical frameworks that encourage reflective thinking from alternative perspectives[25]. Although these instructional strategies can be used effectively on a long-term basis, these strategies are usually short-lived and only used occasionally by transmissive teachers. Similarly, existing TEI classrooms could also become a short-lived or narrowly applied innovation; the benefits of TEI could also be confined to just one classroom unless educational leaders integrate TEI into the professional culture of the school.

Those administrators choosing to support the implementation of TEI must first address the curricular orientation of their teachers. The diversity of the orientations of the staff can be a reflection of the strength of a school, and teachers should not be forced to change their preferred orientation for the sake of using a new tool. Professional stress, particularly during times of change, can be linked to teachers operating in an orientation which does not match their own philosophy. Technology can, however, be successfully integrated into classrooms of each orientation, although the transactive approach creates the most opportunities for developing life-

[25] Examples of these types of activities are: **a.** cooperative learning – Jigsaws or peer coaching, **b.** group projects – role play, group research or group presentations, and **c.** philosophical frameworks – Seven Hats, Concept Mapping.

long learning skills. Those people coordinating the implementation of TEI should plan to integrate the technology first with teachers whose natural inclination is towards the transactive orientation. The central issue is one of control: when the teacher dictates the timing and sequence of all interactions in the classroom, the student will assume a more passive role. When students are given the opportunity to manage their own path towards mastery of an aspect of the curriculum, and they can work towards goals that intrinsically have meaning for them, they will be more actively involved in the learning process. The implication for the teacher is that they should use instructional strategies that encourage students to assume more responsibility for their learning and help them to reflect on their own learning processes. When students understand the educational rationale for the structure in a transactive classroom, their investment in the process is indicated by increased time on-task (Woodrow, 1998).

Full integration of technology in schools is prevented by the limited financial resources available for capital investment. However, this constraint is being reduced by the distribution of funds dedicated specifically to the purchase of technology. In British Columbia, for example, the Ministry of Education has allocated $80 million over the last four years towards the installation of technology in schools[26]. In the majority of cases, those resources have been devoted to upgrading computer science or business education labs, or establishing local area networks for Internet access, as prescribed in district technology plans. In the majority of schools, the installation of technology has had little pedagogical impact on teachers or students; these technology plans do not make the full integration of technology within classrooms a priority. The individual computers that are installed in classrooms are used by a small portion of the students for word-processing, communication, and research. The teacher may also use the computer for test generation or electronic reporting, but it otherwise does not affect the

[26] British Columbia Ministry of Education news release, 1999.

instructional processes in the classroom. Funds that are made available through technology grants need to be redistributed to those teachers who are interested in establishing TEI classrooms. It may be helpful for administrators to consider that in the case of science labs, the overall cost of TEI may be comparable to the purchase of the full complement of standard equipment; in TEI settings, students would be working on a variety of activities simultaneously, reducing the numbers of hands-on workstations required from a standard fifteen to two or three.

It should be noted that the financial requirements of TEI classrooms are best distributed over several years as the teachers develop their own levels of technological literacy. In the ideal case, a small group of teachers within the same district would implement TEI simultaneously, as they would be able to benefit from each others' experience (Predretti, Mayer-Smith, & Woodrow, In Press). In the first year, teachers will learn to configure and maintain the operating system as well as the software applicable to their subject. Teachers will be able to use test generators such as LXR•TEST™ for student assessment, or use the computer for small group presentations and activities. Funds to purchase the software, test banks, and multimedia resources would need to be allocated by administrators. In the second year, the student computers would be installed at a 3:1 ratio; the teacher would learn to manage the local area network and use the technology in the context of a transmissive setting. In the third year, the teacher would shift to a transactive pedagogical approach, thus formally establishing the TEI classroom. Revisions to the arrangement of furniture may be required in order to spread the technology and other workstations throughout the classroom. Instructional resources tailored to the student-centered, technology-based classroom would need to be purchased or developed.

Equally important to the purchase and installation of the technology is the quality, frequency, and duration of technical and pedagogical support.

"Research strongly suggests that teachers must acquire new skills needed to operate in technology-rich environments...Teachers need support in "learning the technology" but the main thrust of the help should be in integrating technology with effective pedagogy" (Glennan & Melmed, 1996, 1997).

The rate of change and sophistication of infrastructure for technology is increasing at an exponential rate. Historical models of 'professional development' cannot meet the scope of pedagogical and technical challenges associated with TEI classrooms. Two hour symposiums or one day workshops are not well suited to implementing lasting changes in instructional techniques or developing a working knowledge of sophisticated computer-related technologies. Teachers need to develop skills in managing local area networks. As technical problems will immediately impact the daily operations in a TEI classroom, teachers need access to responsive and local expertise. In order for the teacher to be able to solve similar technical problems in the future, it is important that the teacher have the opportunity to work collaboratively with the local experts as the problems are being rectified. As the teachers shift their instructional approach from the transmissive to the transactive, they will also need *in situ* pedagogical support[27]. Colleagues with an understanding of the operational aspects of the TEI classroom should be available for observation, team teaching, and debriefing in order to provide constructive feedback for the teachers.

[27] One example of a professional development model in practice is the case of the expansion of the TESSI (Technology Enhanced Secondary Science Instruction) project to schools in Mexico. Each teacher had access to trainers who could respond immediately electronically, or within a few days in person. The trainers had technical and pedagogical experience in TEI, and were available for support throughout the year. Training sessions were held periodically throughout the year, each focussing on one aspect of TEI: technical issues, pedagogical strategies, project evaluation, and resource development. An essential component of each of these sessions was for teachers to share their challenges and successes with TEI, and to collaboratively develop strategies to solve some of the problems.

Once the TEI classrooms are in operation, they will have an immediate impact on students. In their study 'Technology, Text and Talk', Mayer, Pedretti and Woodrow (1998) collected data from approximately two thirds of the students in a TESSI program, and examined students' perspectives on the technology and pedagogy in the classroom.

> *"... the questionnaire data revealed that TESSI students recognized that their classroom was "different" and "special" largely due to the presence of technologies and changing classroom practices. They characterized the physical differences of their classroom in terms of the presence of multiple technologies and the educational opportunities these afforded. Students were also keenly aware that the roles of the teacher and learners, the classroom organization, and the pedagogical interactions in these technology rich classrooms were markedly different from those in their other courses."*

Other teachers in the school, however, will not have an opportunity to see TEI in operation. The degree to which the teaching staff support and implement aspects of TEI is contingent on the leadership of the administration and the degree to which innovation and educational change is a part of the school culture.

Each of the terms below are defined in the context of the operation of a TEI classroom.

CAI (Computer Assisted Instruction, aka. Technology Assisted Instruction): In CAI settings the teacher uses technology to enhance their presentations, either through computer-based data collection and analysis or through multimedia presentations.

CDI (Computer Directed Instruction, aka. Technology Directed Instruction): In CDI settings students are prompted, directed, and evaluated by the computer. The CDI model is based on rote learning strategies and rarely addresses transferable knowledge or skills that can be applied outside of the CDI context. CDI de-emphasizes the role of the teacher.

CMI (Computer Mediated Instruction, aka. Technology Mediated Instruction): In CMI settings the computer evaluates and diagnoses students' needs, guides them through the next step in the learning, and records their progress for teacher reference. As with CDI, CMI de-emphasizes the role of the teacher.

Experiential Learning: The development of an understanding of concepts and their interrelationships through frequent, student-centered activities, that require individual interactions with technology, associated equipment, peers, and text.

Formative Assessment: An evaluation of a student's understanding and/or skills that is used primarily to direct the student to the next stage of the learning process. Formative assessments are rarely used in the calculations of final grades, and are usually activity-based.

Goal Setting: Students, in consultation with their teacher, set a performance standard as measured using summative assessment strategies. Students have the opportunity to revise their goals as they explore different aspects of the curricula; students base their goals on their personal strengths and weaknesses with respect to the curriculum and previous performance on related topics.

Instruction: The providing of a learning experience for students, monitoring students' progress, and revising instructional strategies to better meet the needs of the learner. Instructional strategies reflect a curricular orientation (see *transmissive*, *transactive*, and *transformative.*)

Learning Style: A description of students' inherent physical and mental capabilities that impact their ability to develop an understanding of a concept and interrelationships between concepts. Learning styles that are readily addressed in a TEI environment include: visual, aural, exploratory, and kinesthetic.

Literacy: The ability to use language, in both oral and in written forms, to communicate effectively.

Multimedia: The combination of text, graphics, audio, and video in a rich, interactive technology-based environment that can be observed and manipulated to explore a concept.

Pedagogical Framework: The curricular orientation of the teacher – an educator's personal belief structure about the purposes and methodologies in what service schools should provide and how students learn.

Real Time: Students can see the results of an analysis or the representation of a relationship between concepts, simultaneously with the real-world action or physical event.

Reproducible: Projects results, such as with the implementation of a TEI, can be obtained in a variety of settings, assuming that the operational criteria for the program (see Chapter 4) have been addressed.

Scaleable: The ability to expand the number of locations of a project to include the majority of schools in that region. Scalability implies that the costs in terms of financial commitment, training, and personnel are feasible for the majority of schools, given their decision to implement the program.

Student-Centered: Activity in the classroom focuses on student exploration and concept development through direct interaction with an instructional resource. The teacher's role shifts from a lecturer to a guide for the student, providing 'just-in-time' instruction as dictated by the student's progress.

Software: Programs that add functionality to a computer. The software in a TEI setting is used to simulate, analyze, measure, research, manage, publish, and present concepts.

Summative Assessment: An evaluation of a student's understanding and/or their skills at the end of the learning process for one section of the curriculum. Summative assessments are used in the calculations of final grades, usually in the form of a written exam, lab exam, or project.

Technological Literacy: A person's ability to use computer-related technologies as a tool to research, organize, analyze, and publish information. These skills include familiarity with computer operating systems, the Internet, and common business applications such as spreadsheets and word processors.

Technology: The means by which humans support or extend their physical and mental capabilities. With respect to secondary education, technology may be defined as a tool that assists with instruction and learning. More specifically, technology with respect to the teacher is a tool used to enhance a presentation, improve the accuracy or efficacy of a measurement, illustrate a concept, develop instructional resources, or assist with evaluation. Technology with respect to the student is a computer or computer-related tool used to assist with students' learning processes in a task-oriented classroom environment. The tool is used to model concepts or to simulate and manipulate their interrelationships. It is also used for measurement, analysis, product development, hypothesis generation, and self-evaluation. The technology increases student engagement – requiring interaction, but providing immediate feedback.

Test Bank: A computer-based resource that contains large numbers of test questions which are classified by curricular outcome. Question types often include multiple choice, matching, and open-ended.

Test Generator: Computer software that uses a test bank to generate interactive and paper-based tests for each curricular outcome. Advanced test generators, such as LXR•TEST™ also score tests and provide detailed reporting, such as individual mastery reports, in addition to test and class statistics.

Transactive Orientation: A pedagogical framework wherein the function of education is to create a dialogue between students and the curriculum, in which the student reconstructs knowledge through the dialogue process. The central element of transactive orientation is an emphasis on instructional strategies that facilitate problem-solving, the application of the scientific method, and individualized interaction with the environment.

Transformative Orientation: A pedagogical framework wherein the function of education is to focus on personal and social change. It encompasses three approaches: teaching students skills that promote personal and social transformation, viewing social change as a movement towards harmony with the environment rather than an effort to exert control over it, and the attribution of a spiritual dimension to the environment.

Transmissive Orientation: A pedagogical framework wherein the function of education is to transmit facts, skills, and values to students. This orientation stresses the mastery of traditional school subjects through traditional methodologies, particularly through lecture and text-based activities.