Secondary Math and Science Teachers' Perceptions of Software Relevance and Associated Technology Training Needs

by

Catherine Theresa Collier
B.A., Nazareth College of Rochester (1970)
M.L.S., Syracuse University (1978)
M.S.C.I.S., Syracuse University (1979)

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Signature of Author: ____________________ Date: 4/1/96

Signature of Dissertation Director: ____________________

Signature of Other Dissertation
Committee Members: ____________________ ____________________

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UMI
300 North Zeeb Road
Ann Arbor, MI 48103

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Dissertation Supervisor: John F. LeBaron, Ed. D.
Professor and Faculty Chair, College of Education

The dissertation study focuses on the relevance of software to the math-science curriculum, according to secondary math and science teachers, and identifies topics for initial training aimed at preparing computer-novice teachers to use computers in instruction. Literature on technology training indicates two prevalent approaches. While the two approaches to technology training are not necessarily at odds with one another, neither by itself provides a strong foundation for technology training for secondary math and science teachers. Math-science-specific technology training operates without a framework for development over time of a coherent set of technology competencies. General-competency technology training does not provide definition around the needs of math-science teachers for state-of-the art technology for math-science instruction, particularly in light of today's math-science curriculum software.

The research questions addressed by this study are the following:

1. What types of software do secondary math-science teachers indicate as most important for math-science instruction?
2. What types of software do secondary math-science teachers perceive as most important as a subject of training to prepare them for instructional use of computers?
3. What differences exist between teachers whose use of computers in instruction is aligned with recommendations by standards bodies relative to instructional technology, and other respondents, in regard to Research Questions 1 and 2?

A survey was conducted with a population of high school math and science teachers asking them to rate the relevance of various types of software to math-science curriculum and the importance of various training topics, which have been drawn from the literature on technology training. Their responses were analyzed to construct a framework for secondary math-science teachers of software that is useful for instructional purposes. Teachers indicated that Data Manipulation Tools and Math-Science Curriculum Software are highly relevant to math-science curriculum. Respondents also assigned priorities to software for inclusion in technology training for computer novices who could be expected to begin using computers in instruction. Teachers gave highest priority to training with Data Manipulation Tools, especially spreadsheet and graphing software, and also gave high priority to training with one or more Math-Science Curriculum software packages and with word processing.

Differences in response were noted between those using computers for activities aligned with standards and all other respondents. Instructional users generally assigned higher importance to software relative to the curriculum, but both groups perceived similar priorities in regard to initial training.

From these findings, a framework for initial technology training is constructed which is shown to update and expand existing models for technology training-- the general-competency model and the math-science-specific training model.

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Chapter 1

The Problem

The integration of technology as a tool for teaching and learning in our schools has been a subject of controversy and interest for more than half a century. Larry Cuban (1986) in his classic Teachers and Machines: The Classroom Use of Technology Since 1920 recounts the ongoing struggle between proponents of educational technology and teachers who resist technology use. Resistance to the use of technology, including computers, in instruction is attributed to many factors (Cuban, 1986; Office of Technology Assessment [OTA], 1995), including lack of access to reliable hardware, lack of appropriate software, insufficient training, insufficient time in the schoolday, lack of technical support, and lack of technology leadership. With the advent of powerful desktop computers (Finkel, 1990) and advances in math and science curriculum software (Dede, 1987, 1990; Kinnaman, 1990; Merrimack Education Center [MEC], 1995) and recommendations from major standards organizations, such as the National Council of Teachers of Mathematics (NCTM) and the American Association for the Advancement of Science (AAAS), for the use of technology in math and science instruction, there is a strong case for integrating computers into math and science teaching and learning.

As with any innovation in education, technology integration requires staff development (David, 1990; Fullan, 1991; Joyce & Showers, 1980). The model of staff development considered most appropriate for integration of technology in instruction is commonly referred to as technology training.

Technology training is here defined as skills development achieved through demonstration of instructional techniques using computers, hands-on practice with computer software and hardware, and guided development of instructional materials and activities that incorporate computers. Based on the literature, it is recommended that technology training be accompanied by modeling of instructional practice with technology, ongoing technical support, and coaching or feedback in the effectiveness of new instructional practices that integrate computer technology (Franklin & Strudler, 1990; Joyce & Showers, 1995; Kinnaman, 1993; OTA, 1995). The study focuses on the relevance of software to secondary math-science curriculum and the content of associated technology training for secondary math and science teachers, and it seeks to identify the elements of training that are required for a math-science teacher to begin using computers in instruction.

Divergent Approaches to Technology Training for Math and Science Education

Literature on technology training indicates two prevalent approaches. One approach, which will be termed the "math-science-specific model of technology training," favors intensive training in the use of state-of-the-art instructional technology or in math-science curriculum software. Another approach, which will be termed the "general-competency model of technology training," specifies a general level of competency desirable for all teachers in support of using technology in instruction and in support of professional responsibilities.

Math-science-specific technology training.

A prominent approach to technology training, specifically directed at math and science teachers, is characterized by intensive training in curriculum-specific software (Carleer, 1989; Ellis, 1990; Franklin & Strudler, 1988, 1989, 1990; Jurkat, et al, 1991; Roseman & Brearton, 1989; Williams-Robertson, 1992). As with much of the training funded by Eisenhower grants and National Science Foundation grants, this training for math and science teachers introduces teachers to state-of-the-art software and related technology (microcomputer-based laboratories and laser holography, for example) and focuses on application of these technologies in the classroom. The training is usually hands-on, and it may be accompanied by placement of equipment and software in the participant's school. Often, the training is offered in a series of workshops with ongoing technical support and communication between sessions.

This math-science-specific technology training is designed to acquaint a well-defined population of math and science teachers with current technology and to pass this experience along to the students in their schools. The development of teacher technology competency is restricted to one or a few technologies in the context of the granting agency's mission. It is not related to a more general set of teacher technology competencies. Nor it is necessarily related to a school district's vision for technology. In most cases, it is also not related to established curriculum. Exceptions are the ENLIST Micros project (Ellis, 1990) and the Computers to Enhance Science Education project (Roseman & Brearton, 1989) which worked collaboratively with many schools to integrate technology with the curriculum.

The initiative for math-science-specific technology training often comes from a granting agency or a university wishing to further the use of state-of-the-art technology in math-science instruction. The moving force behind general-competency technology training is often a regional resource center or teacher education institution wishing to meet the needs of all the schools in its region and to support local, regional, and state efforts at technology planning and curriculum planning.

General-competency technology training.

Several models exist for general-competency technology training. For example, the State of California (CA) proposed thirteen faculty competencies, grouped into Basic Awareness (such as operating a computer and selecting software), Curriculum Awareness (such as evaluating software and managing files on a common operating platform), and Technological Awareness (such as writing programs and preparing instructional packages with authoring languages) (CA, 1985). The International Society for Technology in Education (ISTE) set forth a different set of thirteen Foundation Standards for all educators in regard to technology, ranging from the ability to evaluate software, to an understanding of the ethical issues arising from computers in society (ISTE, 1992) . The Center for Educational Leadership through Technology (CELT) details almost two hundred Staff Technology Competencies (CELT, 1994). Merrimack Education Center (MEC) sets forth one dozen Professional Technology Competencies (MEC, 1995), grouped into Basic and Advanced competencies, aligned with one dozen Student Technology Competencies.

These general-competency approaches to technology training typically stress teacher competency with the traditional components of "computer literacy." Computer Literacy is commonly defined as productive use of tools software-- word processing, database, and spreadsheet, and other components of popular Works packages, such as Microsoft Works and Claris Works.

An examination of professional development catalogs and inservice workshops for Northeastern Massachusetts, such as those provided by Fitchburg State College, Salem State College, University of Massachusetts Lowell, Merrimack Education Center, the Chapter 1 Computer Cooperative Center (C4), and the North Shore Education Collaborative reveals that many introductory classes and courses in technology for teachers are founded on the model of computer literacy at the heart of the general-competency approach to teacher technology competency. That is, teachers take instruction in Works packages and develop professional materials using these packages. More recently, these organizations have begun instruction in use of networking, including Internet. Instruction in networking and in tools software typically includes skills practice and a discussion of how the technology can be used in an instructional setting or in support of an educator's professional role. Additional courses are offered in the specifics of advanced software, such as PageMaker (for desktop publishing) and HyperCard (for development of instructional packages).

Advances in math-science software and application of tools for math-science instruction.

In the past several years, developments in math-science software have converged with NCTM and AAAS standards recommendations for greater use of technology in math-science instruction. Today's software for math-science instruction can enable a child to visualize and investigate mathematical and scientific concepts. Through QuickTime video on a computer screen, a student watches a plant grow and verifies the location and function of growth points.

Graphical representation combined with powerful computer simulation helps a student explore the process of photosynthesis, varying such factors as the amount of light, the rate of absorption, and the activity of filters. Modeling tools allow the student to study the interrelationships between trigonometric functions/equations and changes in the objects that they are measuring.

Software such as Sunburst's "What's Your Strategy: The Factory" requires students to analyze the process of creating a particular design and then recreate the process step by step. Software such as LOGAL's "Biology Explorer: Cardiology" program allows students to explore the interrelationships of heart function, clogged arteries and increased physical activity. Using probes, they can take measurements of their own and their peers' heart rates and analyze them according to factors such as diet, exercise patterns, and smoking history.

Appendix A shows various types of software available to schools today that might be included in technology training for math-science teachers and subsequently used in instruction in line with NCTM and AAAS standards. Classifications take into account descriptions of highly-rated software products discussed in software catalogs, popular magazines about educational technology, and articles and discussion by authors such as Dede, Tinker, and Kinnaman. The table includes general software tools and math-science curriculum software, and it indicates curriculum applications and professional applications of the particular type of software.

Combined framework for math-science technology training.

While the two approaches to technology training-- the math-science-specific model and the general-competency model-- are not necessarily at odds with one another, neither by itself provides a strong foundation for technology training for secondary math and science teachers. Math-science-specific technology training operates without a framework for development over time of a coherent set of technology competencies. General-competency technology training does not provide definition around the needs of math-science teachers for state-of-the art technology for math-science instruction, particularly in light of today's math-science curriculum software.

One of the most highly regarded models for technology training is David Moursund's Computer-Integrated Instruction Inservice (CI^3) model (Franklin & Strudler, 1988, 1989, 1990). The CI^3 model combines investigation of math-science-specific software with instruction in spreadsheet and database related to science and mathematics. Moursund's training package is still distributed by ISTE, and the ideas put forth relative to spreadsheet and database are still found in articles in popular journals such as Learning and Leading With Technology and Technology and Learning.

Robert Tinker, Chief Scientist with the Technology Education Research Centers (TERC) and contributor to national standards for math and science, argues that technology for use in math and science instruction should include both curriculum-specific technology and software tools. Tinker has been a driving force in software development for math-science instruction (Tinker, 1984) and has spearheaded innovative uses of technology in math-science instruction, including the GlobalLab project, the National Geographic Society Kids Network, and various projects which employ computers in mathematics education. His National-Science-Foundation-sponsored projects, such as the Alice environment for educational telecomputing, are highly regarded.

Tinker has promoted the use of microcomputer-based laboratories in schools and has been a driving force in the development and use of modeling and simulation software in math-science instruction. Nevertheless, he states that

> One of the most promising approaches to educational computing is to make extensive use of a few general-purpose tools such as graphing, modeling, and data acquisition utilities. By using these general tools in math and science instruction, students gain an appreciation for the way computers are used in the larger world. A number of problems relating to software acquisition and local dissemination are simplified. In this case, the problem is not disseminating the software but disseminating ideas on how general-purpose software tools can be used in teaching. (Tinker, 1984, p. 101)

Tinker has captured several key issues in the struggle to define the content of technology training for math and science teachers. His observations are true in 1995, as they were in 1984 when the development of math-science curriculum software was in its infancy. On the one hand, educational software that engages students in scientific investigation and mathematical modeling provides an exciting, authentic learning opportunity for students, since these tools can be used by a wide range of teachers and staff. On the other hand, general-purpose tools can be applied to a wide range of real-world problems involving math and science, and the study and use of these tools is also important for students. Additionally, use of general tools in math and science instruction simplifies access to software and training. On the other hand, today's math-science curriculum software tends to be easier for teachers to learn and apply in the classroom than general tools software.

The dissertation investigates a framework for software and related technology training that combines software tools, particularly those tools like spreadsheet and graphing that are widely used with real-world math and science problems, and math-science-specific instructional software. The framework is reflected in the table in Appendix A. The study asked secondary math and science teachers to indicate the relative importance of types of software to math-science curriculum and instruction and to professional responsibilities. The study also defines a starting point for training for secondary math-science teachers who are computer novices to prepare them for instructional use of computers.

Statement of the Problem

The case is made that technology training that incorporates demonstration, hands-on use, instructional application, and feedback is the favored approach for staff development to promote the integration of computer technology in math and science instruction. Further, a framework for classifying software and related technology training for math and science teachers is investigated, combining tools software, particularly data manipulation tools, and math-science-specific software, such as those packages developed for inquiry and problem-solving activities, in line with NCTM and AAAS standards.

The problem addressed by the dissertation arises from two related situations. First, teachers have a limited amount of time available for mastering technology and incorporating it into classroom instruction. It is unrealistic to expect teachers to participate in comprehensive training in tools software and math-science-specific software before implementing some technology in the classroom. Second, school districts have limited budgets for inservice training (OTA, 1995). It may be unrealistic to expect school districts to subsidize technology training that is not related to technology use in instruction. The literature on technology training does not agree on what training should precede classroom use. Experience with the ENLIST Micros (Ellis, 1990) project suggests that training with a few commercial software packages specifically designed for math-science instruction is sufficient, while Lillie, Hannum, and Stuck (1989) would have us believe that teachers must be fluent with the full range of tools software before they can begin using computers in instruction.

The problem is that we do not have research-based measures of the relative importance of various types of software for instructional and professional use by math-science teachers. Nor do we understand what technology training to provide computer novices as preparation for instructional use of computers. If we concentrate on general tools software training, there may be elements that math-science teachers regard as irrelevant for their needs. If we focus on data-manipulation tools training, we may be overlooking easy-to-learn math-science software that is closely aligned with curriculum.

Research Questions

The study asked secondary math and science teachers to consider the broad range of technology training that might be made available to them, from the universe of general-competency technology training and math-science-specific technology training. Teachers were asked to discriminate among software that is highly relevant to secondary math-science instruction, software that can enhance secondary math-science instruction; software which is useful in support of instruction (for example, to prepare materials and track student progress); and software that is unimportant for instructional use. Teachers were also asked to rate the importance of various types of software as topics of training to prepare them for instructional use of computers. Differences in response were analyzed between teachers already using computers in instruction and those who do not currently use computers in instruction.

The following questions were the focus of this research study:

1. What types of software do secondary math-science teachers indicate as most important for math-science instruction?

2. What types of software do secondary math-science teachers perceive as most important as a subject of training to prepare computer novices for instructional use of computers?

A related issue addressed by the study was motivated by the experiences common to today's teachers. Many who do not use technology are unaware of the advances in math-science software. Many teachers who are computer novices are only familiar with the general-competency technology training model. It is important to understand any differences in their perception of software and technology training, compared to that of computer-using teachers, so that their expectations for training can be addressed and managed. A third question addressed by the study was the following:

3. What differences exist between teachers whose use of computers in instruction is aligned with recommendations by standards bodies relative to instructional technology, and other respondents, in regard to Research Questions 1 and 2?

Significance of the Study

Having answers to these questions will provide a basis for planning technology training for secondary math-science teachers aimed at preparing teachers, particularly computer novices, to use computers in math-science instruction. Understanding which training is useful for instructional purposes will help school districts decide how to prioritize their limited training budgets.

Currently, there is no agreed-upon framework for categorizing, discussing, and prioritizing math-science instructional software. The study yields such a framework by considering a broad range of software available for instructional purposes, measuring teachers' perceptions of the relative importance of various software, and validating a construct for categories of software.

The resulting framework for math-science software is also useful for persons concerned with funding and providing technology training for math-science teachers. Possible application areas are policies for fundamental training for teachers, a framework for delivery of training, and a basis for identifying levels or areas of competency with math-science instructional technology.

Chapter 2

Review of the Literature

Technology training for math and science teachers has been a subject of interest for more than a decade. The literature indicates rapid and exciting advances in math-science curriculum software over the last decade. The literature also indicates that two schools of thought exist concerning what technology training should be provided for math-science teachers: one approach focused on math-science curriculum software; one focused on general competencies for all educators. An overview of advances in math-science curriculum software provides the starting point for the literature review for this dissertation study.

In the last decade, developers of math-science curriculum software have paid attention to national standards for math and science and reflected the requirements of standards associations in their software product design. In mathematics, where the National Council of Teachers of Mathematics (NCTM) standards emphasize problem solving, communication, reasoning, and mathematical connections, Donovan & Sneider (1994) note that "Technology is a natural complement to many of these skills areas... the use of calculators and computers shift the focus away from pencil-and-paper symbolic manipulation toward conceptual understanding, symbol sense, and mathematical modeling." (p. 42).

Science standards from the American Association for the Advancement of Science (AAAS) are set forth in the 1989 Science for All Americans, which laid out essential science concepts for high school graduates, and the 1993 Benchmarks for Science Literacy which gave grade-level recommendations for science education. Inquiry learning is emphasized in these science standards. Technology is seen "as a tool of inquiry to gather, analyze, and interpret data; as a means to improve investigations and communications; and as a subject of study in making connections between science and technology, and between the natural and the designed world." (Donovan & Sneider, p. 15).

Math-science curriculum software today emphasizes inquiry-centered, process-oriented learning, the result of many years of product development and field testing. Kinnaman (1990) surveyed the software developments in place at the turn of the decade. He looked at the "network science" model being developed by TERC; Papert's successor to "LOGO," "MicroWorlds"; Judah Schwartz's inquiry software for mathematics and science, "Geometry Supposer" modeling and visualization software; the Institute for Research on Learning's use of "dynagrams" for modeling and simulation and student use of multimedia to create reports; BBN's LOGAL modeling and simulation software; and Education Development Center's "Journeys" software for inquiry learning in a problem-centered curriculum. Many of these products, now fully available on standard platforms for schools, were developed in light of NCTM and AAAS standards emphasizing technology in math and science instruction.

The table in Appendix A indicates highly-rated math and science software aligned with goals for student achievement with technology. Sources for the table are ASCD's Only the Best, Learning and Leading with Technology, Technology and Learning, Electronic Learning, and contributions from participants in Merrimack Education Center's pilot "PALMS Educational Technology Specialist" training conducted during the Spring and Fall of 1995.

The use of computers for instruction plays an important role in the restructured school (David, 1990), and teachers play a critical role in technology innovation (Joyce & Showers, 1980; Fullan, 1991). Use of multimedia and other technology increases student motivation for learning by providing multi-sensory learning experiences and a high level of interaction (Thomas & Knezek, 1991). Cooperative learning is emphasized, and creative projects stimulate thinking and teamwork. The impact on the curriculum is significant. In the words of Thomas & Knezek, "No longer must the curriculum avoid processes that require students to carry out tedious operations, such as elaborate calculations, precise graphics, or complex data analysis." (Thomas & Knezek, 1991, p. 271)

Instructional technology creates a greater need for a collegial approach, and the result is often integration of programs and inter-disciplinary teaching through teamwork. According to Thomas & Knezek, teachers are the ones who should evaluate new and emerging technologies for instruction and should be key decision makers in the use of software in classrooms. This dissertation study acknowledges the crucial role of the teacher in assessing software and applying it in instruction. While many teachers are not currently using software in instruction, those who do use it have, through their experience, developed a sense of the importance or relevance of particular types of software for instruction and about the learning process involved for teachers to integrate software in instruction.

The situation in Massachusetts is such that integration of technology throughout the math-science curriculum will require introducing many teachers to instructional software and developing in them the confidence and competence to use it effectively in the classroom. The "Training Model" of staff development (Sparks & Loucks-Horsley, 1989) may be the most efficient means for large numbers of teachers to view demonstrations with exemplary software, to develop materials and instructional activities that integrate software, and to receive feedback as they practice. The combination of demonstration, feedback, and coaching inherent in the training model are necessary for skill development (Joyce & Showers, 1980).

In general, the staff development literature offers the following the characteristics of a good training program for technology skill development and application in instruction:

- Training is on-going (Kinnaman, 1993)
- Training is hands-on with expectations for application and feedback (Davis, 1993; OTA, 1995)
- Training is accompanied by modeling and demonstration (Joyce & Showers, 1995; OTA, 1995)
- Training is backed by knowledgeable support and coaching (Beasley & Sutton, 1993; Joyce & Showers, 1995)
- Training is done collaboratively, preferably on-site, with other teachers at the same grade level or subject (Kinnaman, 1993)
- Training focuses on classroom use, with attention to issues of pedagogy (Joyce & Showers, 1995; OTA, 1995)
- Training is geared to specific needs, which change as the technology changes, and which should be driven by the curriculum (Franklin & Strudler, 1990; Loucks-Horsley & Stiegelbauer, 1991; Joyce & Showers, 1995)

The content of training activities is a key consideration. Sparks & Loucks-Horsley (1989) advocate having participants get involved in the needs assessment and selection of content. This dissertation study takes the approach that, while teachers are not being asked to take full responsibility for their training, those who are users of instructional software can act as advisors on training content. Those who are not currently users of technology are also asked to participate so that their expectations for technology training can be understood and addressed.

Knowing where teachers are in their usage of technology will help in planning technology training for a range of teachers (Sprinthall & Thies-Sprinthall, 1983). For example, schools in Massachusetts have generally not had computers available for instruction (CELT, 1994), and the most critical need in Massachusetts is to determine the starting point for novice computer users who will be expected to integrate computers in instruction.

The literature indicates a divergence of thought concerning the content of technology training for teachers. For the past six or seven years, many technology training programs have emphasized instruction in the use of traditional software tools (word processing, database, and spreadsheet). Scrogan (1989) was typical of those who interpreted the 1988 Office of Technology Assessment report as calling for a focus on software tools. In Scrogan's words, a "tool" focus translates to "Help teachers view and use the computer first as a tool for personal productivity. A teacher who has been personally empowered by the computer will eventually want to empower students in the classroom." (p. 84) However, research has shown that one does not necessarily follow the other (OTA, 1995). Scrogan's interpretation did not indicate how long "eventually" might be or what additional training might be needed to move teachers from personal productivity to classroom use.

The next two sections of this literature review discuss a variety of approaches to technology training, divided into two main categories: math-science-specific technology training that has tended to focus narrowly on math-science curriculum software and the general-competency model of technology training that has tended to focus on productivity tools. Each of these approaches offers important insight into the technology training needs of math-science teachers.

Math-Science-Specific Technology Training

Technology training with today's math-science curriculum software may offer the most expedient means for high school math and science teachers to begin using computers in instruction, even those who are novices with computers. Much of today's software is easy to learn and yet powerful enough to offer progressively sophisticated teaching and learning experiences for a wide range of students and learning styles. Using math-science curriculum software as the starting point for technology training is not a new approach. Math-science-specific technology training, the term used by this dissertation study for this approach, has been in common practice for at least a decade.

In his "Preparing Science Teachers for the Information Age," Ellis (1990) cites dozens of approaches for training science teachers to use computers in instruction. Noting that there is no consensus on what teachers need to know and be able to do with computers in science teaching, he poses the question, "Is computer literacy the same for a science teacher as it is for other teachers?" (p. 57). Ellis investigated a variety of introductory courses at universities and concluded that general training in software tools, such as word processing, database, and spreadsheet, did not result in science teachers using computers for instruction. He also surveyed eight approaches to technology training for science teachers which resulted in use of computers in instruction after one year of training. Included was his own "ENLIST Micros" project, which resulted in instructional use of computers by participants during the first year and in subsequent years. Ellis's successful approach and that of several other studies he surveyed are worth discussing in some detail as a foundation for this dissertation study.

Ellis's "ENLIST Micros" project focused on application of microcomputers in science teaching and development of teaching materials incorporating computers and other instructional tools. Teachers in this program were expected to achieve competence with instructional uses of computers, including simulation, drill-and-practice, tutorial, microcomputer-based laboratories, and problem solving.

Another successful training model, the "EQUALS" program at Berkeley's Lawrence Hall of Science, provided a series of workshops for inservice teachers with assignments and support between sessions. The topics addressed by the training were thinking skills, problem solving, software evaluation, and LOGO programming.

Moursund's successful "Computer-Integrated Instruction Inservice" (CI^3) offered eight two-hour sessions focusing on the use of computer tools-- specifically database and spreadsheet-- and development of lessons and activities in science education. Between sessions, participants were encouraged to apply their lessons with students and report their experiences. Problem-solving was an important focus of the workshops.

The following table provides a summary of Ellis's eight models for successful preparation of science teachers to use computers in science instruction. The eight are followed by three other models that are described in succeeding paragraphs of this section:

Table 1

Examples of Math-Science-Specific Training

Investigator	Project	Focus
Ellis, BSCS	ENLIST Micros	Integrating educational technology into extant science programs; computer uses include simulation, microcomputer-based laboratories, and problem solving software
McCarthy, Bank Street College	Mathematics, Science and Technology Teacher Education	Implementation of "The Voyage of the Mimi" instructional program (includes video, computer software, and probes)
Moursund, University of Oregon	Computer-Integrated Instructional Inservice (CI^3)	Integrating general computer tools into curriculum; exploration of commercial software
Seligmann, Ithaca College	Enhancement of Secondary Science Laboratory Instruction	Using computer for analysis of experimental data and for acquisition and manipulation

Table 1, con'd.

Investigator	Project	Focus
Sullivan, University of Wisconsin	Application of Electronics to Teaching high School Physics and Computer Science	Electronics, developing strategies and materials for the classroom
Tweeten, University of New Mexico	Computers in the Science Classroom	Logo and problem solving and computer applications in science education
Watt, Education Development Center	Teachers as Collaborative Researchers: Professional Development Through Assessing Logo Learning	Logo and problem solving and conducting a research project
Roseman, Johns Hopkins	Computers to Enhance Science Education	Integrating computer technology into extant science programs; topics include tools software, programming, probeware, and leadership skills.

Table 1, con'd.

Investigator	Project	Focus
Carleer, Dutch National Policy	School-building Technology Training	Selection of courseware; hands-on; development of instructional unit; implementation; reflection/ revision.
Williams-Robertson, Austin School District	Science and Mathematics Consortium, Technology Initiative	Software demonstrations; hands-on practice in lab setting.
Jurkat, Stevens Institute of Technology	Five New Jersey schools	Inquiry-based software, instructional practices, analysis of effective use of computer in classroom.

Ellis's "ENLIST Micros" model served as a model for other training programs for math and science teachers, and it was replicated by other researchers. Borchers, Shroyer, & Enochs (1992) applied the model in the context of rural school science programs in an effort to increase the use of computers in science instruction in rural schools. During the first-year of the Borchers, Shroyer, & Enochs study, technology training was given with the aim of integrating computer use with classroom science instruction. It focused on application of microcomputers in science education, cooperative learning, and constructivist learning theory. Time was allocated for hands-on evaluation of software, and demonstrations of microcomputer-based laboratories. Teachers were expected to create action plans for their specific situations, including how they would apply their learning in the classroom. Follow-up seminars at the end of the first year included speakers and demonstrations of telecommunications, "Voyage of the Mimi," and database and spreadsheet applications in science. After the first year, it was found that teachers' use of computers in science teaching significantly increased, and teachers increased the ways in which they used computers in instruction.

Just as Ellis's model has been successfully replicated, so has Moursund's Computer-Integrated Instruction Inservice (CI^3) model. The CI^3 Notebook for Secondary Science (Franklin & Strudler, 1990) shows a focus on the following science applications, over the course of eight training sessions:

- Searching and Sorting Databases to Generate and Test Hypotheses
- Creating a Database for Testing Hypotheses
- Introduction to Hypothesis Testing Using a Spreadsheet
- Creating a Spreadsheet
- Integrating Spreadsheet, Database, and Word Processing
- Commercial Software
- Discussion of participant projects

Participants were expected to apply their learning in the classroom with a choice of activities between sessions. Each was expected to develop a project for classroom use by the end of the eight-session instructional period. The approach is still used with science teachers, and it is regarded as an excellent example of computer integration in the science curriculum and of teacher technology training.

The same is true of the Moursund's CI^3 Notebook for Secondary Mathematics (Franklin & Strudler, 1988), whose sessions include:

- Graphing Equations
- Spreadsheets
- Problem Solving
- Databases
- Geometry and Visualization
- Inverted Curriculum
- Participant project reports

The Notebook contains a summary of staff development research and practice and articles on the NCTM standards and impact of computing on mathematics education. The program of instruction pushes teachers to look at cross-curricular graphing opportunities. The commercial math software recommended in the 1989 edition includes programs still recommended and widely used today-- for example, "Green Globs" and "The Factory," both of which emphasize high order thinking skills.

The training models for math-science teachers discussed by Ellis have been successful in the sense that they led to instructional use of computers. Several (Ellis, Moursund, Roseman) consciously incorporated Joyce & Showers' five components of training:

- theory
- demonstration
- practice
- feedback
- coaching

All of them looked to previous training experiences that showed the efficacy of hands-on practice as the core instructional method. They emphasized concrete, practical application of computer courseware in the classroom. Between sessions, teachers were generally expected to practice their skills in the classroom, with support from knowledgeable colleagues in their buildings.

Also founded on Joyce & Showers' model, Carleer (1989) reports on a project for school-building-level training for math and science teachers, using five steps:

1) selection of courseware
2) hands-on with the courseware
3) development of an instructional unit which integrates the courseware
4) implementation with feedback from peers
5) reflection and revision

Carleer's five-step training cycle took place over 3-5 months with development of lesson plans and implementation taking place between formal instruction sessions. Early evidence indicated increased confidence among the newest users.

A slightly broader approach that also incorporated training in word processing is reported in Roseman & Brearton (1989). This multi-year collaboration between Johns Hopkins University and the Baltimore Public Schools was designed to prepare teachers to use computers effectively in science instruction. Working with 100 teachers with varying levels of computer knowledge, none of whom had used computers in instruction before the training, the Johns Hopkins program took the approach that the computer must become a tool in the hands of the classroom science teacher. The "tool focus" of this model is distinctly different from Scrogan's. Topics were: assembly and set up of computers; word processing; database; spreadsheet; integration of applications; configuration and use of probes and probeware; programming; software evaluation. Teachers were required to produce two lesson plans for their classrooms, one using database or spreadsheet, one using probeware. A survey given to teachers after their training indicated that 75% were now using computers in instruction.

A more intensive training experience in Texas focused on math-science curriculum software for teachers who had some previous computer experience. Williams-Robertson (1992) reports on the Austin, TX, Science and Mathematics Consortium grant-funded project to upgrade the skills of math and science teachers throughout the city during a summer 1991 Technology Initiative workshop. The workshop was structured as an eight-day learning experience, with morning sessions focused on software and demonstrations in the use of software in the classroom, and the afternoon devoted to hands-on lab time for practice and exploration. As a result, teachers reported an increase in the amount of computer use in the classroom and in the range of computer activities they use. In addition, 50% reported an increase in the usage of hands-on, cooperative learning techniques generally recommended with science education software.

Instructional use of computers in mathematics has been approached with a similar focus on curriculum software, hands-on training, and guided application in the classroom. Jurkat, et al (1991) discuss a two-year program to improve math instruction through the use of computers. The Stevens Institute, through the Center for Improved Engineering and Science Education, teamed with five New Jersey school districts to train teachers to change instructional practices with their existing classes. The training focused on software that would allow teachers to provide experience not normally possible without computers, used in an instructional context that favored insight and understanding over "correct answers," and which engaged the teacher in analysis of the effectiveness of the computer-based learning activities.

At the start of the training, a few teachers had had some exposure to computers, but none had used computers in instruction. By the end of the first-year workshop, all were comfortable with computers, were confident with computer-based materials, had identified opportunities for use in their classrooms, and were preparing to use computer based activities during the upcoming school year. During the second-year workshop, teachers focused on high-priority curriculum areas for computer integration, developed lesson plans, and planned the evaluation of their computer integration. The success of the project is attributed to the collaborative relationships developed among the teachers, the expertise provided by Stevens Institute of Technology, and the ongoing nature of the support provided.

From the studies above, it is apparent that math-science-specific technology training has resulted in early application of computers in instruction for novices and increased use of technology in math and science classrooms for experienced users. Such training has focused on software that is well matched to curriculum, and participants have been exclusively math and science teachers. In those cases where tools, such as those in the integrated Works packages (for example, Claris Works and Microsoft Works), were the software of choice, they have been approached from a curriculum focus. In the CI^3 training, for example, database software was chosen for students to test hypotheses, and spreadsheets were studied in relation to modeling and visualizing mathematical concepts. The literature indicates that, in successful technology training for math-science teachers, teachers:

- see demonstrations of software

- investigate software in the context of their curriculum and their students' learning needs
- prepare lessons and activities using technology
- implement computer-based activities in the classroom
- receive coaching and feedback

The weakness with these approaches to technology training is that they do not link the math-science teacher's use of technology to an overall framework for professional development and technology training. The general-competency model discussed in the following section does provide such a framework, although it does not offer as much detail as the math-science-specific model above for planning technology training for math-science teachers to apply instructional software in their classrooms. Elements from both approaches may be needed to provide a comprehensive framework for technology training for math-science teachers.

Teacher Technology Competencies: the General-Competency Model

Another body of literature addresses the general question of teacher technology competency-- that is, what do most teachers, not just math and science teachers, need to know about technology and be able to do with technology to use it in instruction and in support of their professional role? The answer to that question provides a general framework for technology training. Such a framework gives teachers and administrators a way to plan and track the progress of skills development and application in the classroom and in one's professional role. Such a framework provides a set of competencies that can be developed over time and supported by a district-wide staff development program. A general-competency framework of this nature is missing in the math-science-specific technology training discussed in the previous section.

Much of the literature for a "general-competency model" of technology training is concerned with scoping the ideal, complete set of technology competencies for teachers. Some, such as Mass Ed Online (CELT, 1994) and Merrimack Education Center (MEC, 1994) suggest a pathway to full competency over time. However, these studies generally do not indicate how training of the magnitude necessary to achieve full competency could be provided to most teachers within the constraints of professional time and limited training budgets.

Courses, classes, and workshops offered by colleges of education and regional resource providers tend to support the general-competency model of technology training. Introductory courses focus on software tools (word processing, database, and spreadsheet) and are usually open to teachers at all levels and in all subject areas. More advanced courses focus on a particular software package, such as PageMaker for desktop publishing or Hypercard for multimedia presentations, or on a particular technology, such as Internet. While application to the curriculum is included as a topic in such courses, it is rarely the central focus of the course. As the most recent OTA report (OTA, 1995) indicates, tools training has not resulted in use of computers in instruction. Teachers have not transferred their knowledge of integrated Works packages into instructional application. This approach to technology training grew out of an era in which competency with the software tools in a typical Works package constituted the definition of "computer literacy," at a time when curriculum software was mostly of the drill-and-practice variety. Times have changed, however. Math-science curriculum software is vastly improved. Other tools, such as hypermedia production tools and electronic reference tools, are widely available.

Nevertheless, the general-competency model offers an important basis for technology training for math-science teachers and teachers of other disciplines. This section discusses a variety of approaches to defining technology competency for teachers.

One comprehensive definition of "fundamental knowledge and competencies" is that developed recently by the International Society for Technology in Education (ISTE) and used in NCATE accreditation. ISTE surveyed professionals in education and instructional technology concerning the level of competence needed for effective use of information technology in and out of the classroom. Following the survey, professional educators developed a set of Foundation Standards for all teachers. The thirteen competencies that comprise the Foundation Standards for all educators in regard to technology (p. 12-13) are found in Appendix B. In regard to training in the use of software, ISTE recommends competence with curriculum-related software, productivity tools (word processing, database, spreadsheet, and print/graphic utilities), multimedia and hypermedia, and telecommunications. Teachers are expected to demonstrate knowledge of computers in support of problem solving, data collection, information management, communications, presentations, and decision making.

ISTE states that "the ultimate purpose of the Standards is to empower students by empowering teachers with the power of knowledge about those technology tools which are so rapidly changing our world." (p. 13)
While these standards are well-founded, it is difficult to imagine how most teachers could be provided with training experiences to achieve this level of competency, given the constraints on teachers' time and the limitations of

training budgets. Those who plan technology training do not have clear direction concerning where to begin and how much training to provide before expecting a teacher to make some application to classroom instruction.

Occasionally, a model for general competency is extended with specific curriculum areas in mind. One example is the North Carolina State Department of Education (1992), which set forth levels of competency for teachers with respect to computers in instruction. All teachers were expected to develop computer literacy, as defined by the state, to develop an understanding of computer ethics, to understand the capabilities and limitation of computers, and to evaluate courseware for specific instructional objectives. Literacy included knowledge of the components of a computer, current uses and potential uses of computers, social issues of computing (privacy, copyright, and so on); ability to use courseware with appropriate teaching strategies for ongoing use in instruction; use of tools (word processing, database, test generation) and a variety of programs, including games, drill-and-practice, simulations, and tutorials. Math and Science teachers were also expected to know how to use special input and output devices, such as probes and scanners and how to use authoring to modify instructional packages. This is one example of specialized knowledge that would enrich instructional use of computers for math-science teachers, particularly science teachers.

Some general-competency models propose a time frame for adoption of computers in instruction which is substantially different from the approach found in the math-science-specific technology training examples discussed in the previous section. In particular, Mass Ed Online (CELT, 1994) calls for a five-year plan of adoption for teacher technology competencies:

- the Entry level, wherein teachers rethink teaching styles, develop a technology vocabulary, and explore technology tools for learning
- two years to move through the Adoption stage, in which teachers move past fear and actively experiment with applications that mesh with their current teaching styles
- a third year to complete the Adaptation stage, in which teachers use computer tools for greater personal productivity and use tools in classroom activities
- a fourth year to achieve the Appropriation stage, in which teachers master certain technologies and integrate technology seamlessly in instruction. At this stage, teachers are capable of coaching others.
- a fifth year to achieve Invention, in which teachers work with others to "invent" new applications of technology integrated with curriculum.

Using this phased approach, it would appear that teachers do not begin using technology applications in the classroom until their third year of staff development for technology. Yet the literature on math-science-specific training indicates that use of technology in instruction can be initiated in a one-year time frame or less by focusing on curriculum software and encouraging teachers to develop and try computer-based lessons in the earliest phases of training.

Over time, the Mass Ed Online plan calls for teachers to achieve expertise with input/output devices, word processing, database, spreadsheet, graphic utilities, networks, programming, desktop publishing and telecommunications/distance learning. No order is suggested for studying and mastering these technologies.

The Massachusetts Software Council (MSC) has taken a much more specific approach to technology training, using two sources for defining training: administrators and teachers themselves. MSC published The Switched-On Classroom in 1994, with one chapter devoted to staff development for technology. "Staff development," they note, "must not only teach specific skills but also develop teaching strategies and explore the impact that technology will have on teaching methods... Staff technology training should be based on the actual curriculum for which teachers are responsible." (p. 8-9) The Council identifies ten areas of training and staff development (see Appendix B), including these specific software areas: use of CD-ROM packages, computer graphics, networking, e-mail, databases, multimedia, and applications for specific subject areas or grade levels. This suggests a common core of competency for all teachers (CD-ROM packages, graphics, networking, multimedia, and traditional tools) augmented by subject-specific applications.

This approach to technology training, combining a common core of technology competency and subject-specific applications, is repeated by other authors and organizations. Finkel (1990), for example, recommends that department heads receive a thorough grounding in technology and provide leadership for their departments in the use of technology in instruction. Lockard, Abrams, & Many (1990) suggest that teachers should master software and instructional practices that will enrich and extend the curriculum, with the focus on changes in curriculum made possible by powerful software-supported learning environments.

A similar approach to technology competency for teachers derives the set of core competencies for teachers from a definition of student technology competencies. Merrimack Education Center, for example, offers a set of graduation outcomes or "student technology competencies" for a district to customize and integrate with their vision for technology-rich learning environments. Along with this set of student technology competencies are "professional technology competencies" (see Appendix B) which delineate what teachers need to be able to do with technology in support of student learning. The general student competencies are grouped into four areas: Information Access; Data Analysis and Synthesis; Communication; and Inquiry. Core competencies for teachers include familiarity with interactive instructional packages, software tools, telecommunications, electronic reference tools, multimedia/hypermedia tools, desktop publishing, and Internet.

Several of the models above (MSC, MEC, and Finkel, for example) are in agreement on the core competencies for teachers. It is worth noting how rapidly the definition of competencies has changed in the last ten years. In 1985, for example, the State of California, one of the leaders in technology in the schools and in related staff development for technology, put forth an approach to training based on a set of faculty competencies in three fundamental levels (see Appendix B) with an emphasis on the use of Authoring and Programming to develop instructional packages. In ten years, educational software has moved well beyond the era in which, as Kinnaman says, "few pedagogically sound software packages left many schools with the unrealistic expectations that teachers should produce their own courseware." (Kinnaman, 1993, p. 257)

The general-competency models discussed above offer a framework for technology training that is missing in the math-science-specific technology training examples in the previous section. Such a framework would be valuable for those planning comprehensive, ongoing technology training for teachers, including secondary math-science teachers. With the wealth of pedagogically sound math-science curriculum software packages available today (Kinnaman, 1990), it could be that curriculum software is the most expedient starting point for technology training for math-science teachers. As Tinker suggests, however, math-science teachers, along with those from other disciplines, might also benefit by mastering the software tools represented by core competencies for all teachers-- word processing, database, spreadsheet, electronic reference tools, and multimedia tools.

The research literature offers few definitions of "introductory" training for educators. Ellis's study (1990) notes several variations on the "generic introductory course in educational computing" as of 1988. Bitter's introductory course at Arizona State University, as an example, required students to develop six competencies: an understanding of computers and their applications; ability to use a word processor, database, and spreadsheet; understanding of teacher utilities; understanding of the characteristics of educationally sound software; ability to design lesson plans using software programs; and ability to access electronic bulletin boards. Blubaugh at University of Northern Colorado offered an introductory course requiring students to learn telecommunications, word processing, database, and spreadsheet. His students were expected to apply these tools in managing the classroom, and in problem-solving activities for the classroom, to review and evaluate software, and to write programs for solving science problems.

In the same year as Ellis's study, Brownell (1990) surveyed 1000 computer educators in regard to recommended content of an introductory computer course for educators. Working from a mailing list of a computer education journals, Brownell asked persons who offer introductory courses or workshops for teachers to respond along a five-point Likert scale (Strongly Agree to Strongly Disagree) in regard to which topics should be included in an introductory course, and to recommend one piece of software in various content areas. Greater than 90% of the 180 respondents indicated that word processing, database, and spreadsheet should be included, along with methods of integrating computers into content areas. More than 75% of respondents would also include use of computers in problem-solving, use of teacher utilities, information about how computers are being used in teaching, software evaluation, and computer-assisted instruction.

Respondents were also asked to rank order sixteen topics from most important to least important for inclusion in such a course. The top half were, in order:

- Computers and problem solving
- Word processing
- Methods of integrating computers into content areas
- The computer education curriculum
- Software evaluation
- Computer-assisted instruction
- Databases
- Spreadsheets

There was no uniform response recommending software, although programs which address problem solving skills (such as "The Factory"), collaborative learning (Tom Snyder's "Decisions, Decisions" series), and inquiry learning ("Geometric Supposer") were all recommended.

Unfortunately, neither Brownell's study nor the general-competency models are linked to specific training experiences that demonstrate subsequent usage of instructional technology in the classroom, as were the math-science-specific training studies. In Ellis's words, general introductory courses "rarely offer the opportunity for science teachers to integrate what they are learning about the technology into what they are learning about science and science teaching." (p. 59)

Three major studies-- those of Martha Hadley & Karen Sheingold and that of Henry Jay Becker-- give some insight into a possible relationship between tools training and usage patterns of computers in the classroom.

Companion articles by Martha Hadley & Karen Sheingold (Sheingold & Hadley, 1990; Hadley & Sheingold, 1993) present five patterns of computer use by "accomplished teachers." Subjects for the study were the result of referrals from administrators who recommended their most "accomplished teachers" (those who used computers in instruction in a way that was regarded as exemplary in comparison with other teachers in the same school).

Data from the 1990 study on "Accomplished Teachers" was factor analyzed to reveal five distinctive patterns of usage among the more than 600 teachers in the study. For each pattern of usage, some information is presented concerning training the participants have received. However, training history and training needs are not the focus of the study.

The study found that 25% of "accomplished teachers" fit a pattern which was labeled "Enthusiastic Beginners". The Enthusiastic Beginners tend to be elementary teachers who "have trained enough, both on their own and with the help of workshops, to learn basic principles that they have integrated into their teaching" (Hadley & Sheingold, p. 286). This group uses computers for what Sheingold & Hadley call "instructional functions"-- tutorials, drill and practice, and software that accompanies textbooks. This group is unlikely to use multimedia or any of the tools-- word processing, database, spreadsheet, graphics, communication. Computers in their classroom are not supporting collaborative projects or student-initiated products.

A second group, "Supported Integrators," comprise 22% of the sample. These teachers have extensive experience with computers and operate in schools where technical support is above average. They have received training in a variety of settings, including inservice in their district, though the content of the training they have received is not specified. Their students use computers to support collaborative projects and to explore areas of interest, in line with curricular objectives.

A third group are labeled "High School Naturals." 18% of the sample, they are mostly male teachers in secondary math, programming, or technical education. Their use of computers is primarily for quantitative, analytic, and information-gathering functions, rather than for drill and practice of instructional reinforcement. They are self-trained.

A fourth group (19%) are termed "Unsupported Achievers." Their realm is generally not math and science. They use technology primarily to improve student scores on standardized tests. Their training is from local colleges, not from inservice.

The last group (16%) are "Struggling Aspirers." Like the Enthusiastic Beginners, they are mainly elementary school teachers and use computers mainly for instructional functions. They are likely to have been trained on-site or by the district, but they are relatively less confident with technology than the other groups. They regard technology as an extension of teacher-centered learning, rather than as a tool for student-initiated work.

Becker (1994) has given us some information about training related to computer usage in his study "How Our Best Computer-Using Teachers Differ from Other Teachers: Implications for Realizing the Potential of Computers in

Schools." (Becker, 1994) Becker's study is based on 1989 data from the Center for Social Organization of Schools at Johns Hopkins University study of approximately 1400 teachers and administrators from the United States, which in turn was part of the I.E.A. "Comp-Ed" international computer-usage survey (Pelgrum & Plomp, 1991). This survey asked teachers and administrators to report on their use of computers in instruction.

Becker analyzed responses in relation to criteria he developed for "exemplary" computer use. Becker's criteria addressed such dimensions as frequency of use and use in support of high order thinking. For example, 21 items indicated possible exemplary use by Math teachers, including the following (Becker, 1994, p. 18):

- If 25% or more of the activity for "making graphs or charts of data" was done using computers
- If, of the three most important goals for using computers in math teaching, one was NOT "reward for completing other work"
- If the teacher reported using software to demonstrate a math concept or how to solve a math problem "most weeks"

Math teachers who scored 11 out of the possible 21 were considered "exemplary." This corresponded to 11 of the 107 math teachers in the sample. Users judged to be exemplary were then compared with the remainder in terms of variables such as availability of computers in the teacher's school, availability of technology support, and training opportunities in the district. Becker's research indicates that exemplary computer-using teachers constitute only 5% of the computer-using teachers in the United States or 3% of all teachers in the United States. Among all the computer-using teachers, the use of software tools "played only a minor role in the national survey except for word processing in high school English. ...Only 1% of computer-using math teachers said that their students used spreadsheets on more than 5 occasions during the school year." (p. 2)

In regard to technology training, the exemplary users in Becker's study "had greater access to formal district staff development activities than did other computer-using teachers. Two staff development activities were especially significant: instruction in using computer applications such as word processing, spreadsheet, and gradebook managers; and formal training in using computers with the specific subject matter that they taught." (p. 8)

Becker probed into five skills areas that he felt should be learned through training:

- integration of software into lessons for the subject area
- organizing classroom activities to include computer use
- using programming or authoring languages
- using word processing
- using other tools

Becker's "exemplary" teachers on average reported learning 1.6 of 5 of the skills through formal training, with other computer-using teachers learning 1.0 of the 5 through formal training. Exemplary teachers reported learning another 1.5 on their own, while others learned an additional 1.2 on their own. Becker does not give us a breakdown of which skills were addressed in or learned through formal training.

These major computer-usage studies provide interesting insight into how computers are being used in schools but offer little information about the technology training that preceded or accompanied computer usage.

More recently, the 1995 Office of Technology Assessment (OTA) report Teachers and Technology: Making the Connection has provided an overview of efforts to integrate technology in the classroom and associated staff development. The report echoes the need for technology training and the characteristics of good technology training which are listed at the beginning of this literature review.

OTA's report devotes one chapter (Chapter 4: "Helping Teachers Learn About and Use Technology Resources") to professional development for technology. OTA states that in 1995,

> Most teachers have not had suitable training to prepare them to use technology in their teaching... To use technology effectively, teachers need more that just training about how to work the machines and technical support. To achieve sustained use of technology, teachers need hands-on learning, time to experiment, easy access to equipment, and ready access to support personnel who can help them understand how to use technology well in their teaching practice and curriculum. (chap. 4, p. 1)

As for the content of training, OTA notes that "Although sites have made significant progress in helping teachers learn to use generic technology tools such as word processing, database, and desktop publishing, many still struggle with how to integrate technology into the curriculum." (chap. 4, p. 2)

OTA notes that teachers have conflicting demands on their time for learning and incorporating new techniques and standards. OTA's "high-tech" teachers (those who use technology in instruction) tend to hold a student-centered approach to learning, using inquiry methods, collaborative projects, and hands-on approaches to learning, with technology supporting this philosophy.

OTA draws from the National Education Association's "Status of the American Public School Teachers" 1992 survey in noting that "a majority of teachers said that they felt they needed training in order to adequately use a personal computer (56 percent), standard computer software (61 percent), multimedia software (62 percent), instructional videodisks (67 percent), and on-line databases (72 percent)." (chap. 4, p. 5) Further, "For other teachers, the greater need is understanding what the technologies can do. Many teachers had not had the opportunity to observe and learn about the wide range of educational uses to which technology can be put-- particularly various ways it can be incorporated into different curricular areas." (chap. 4, p. 6)

The implication for this dissertation study is that, in a survey of math and science teachers regarding instructional software, many teachers might be expected to report that they are looking for training with software tools and with instructional software. Probably only some teachers-- those who use computers and who may be aware of newer software for math and science-- might be expected to ask for training with interactive modeling and simulation software.

OTA emphasizes that most teachers have had very little training in technology. The training that is provided tends to focus on operating a computer and the mechanics of standard software. Little time is spent on the pedagogical aspects of computers or content-related software.

In a later chapter (Chapter 6: "Technology and Teacher Development: The Federal Role") OTA describes a number of federal initiatives to promote technology integration in curriculum. Many of the programs have been established or piloted since 1988, many of them in math and science. Much of the money from these programs finds its way into local and regional technology training efforts. However, as OTA notes federal support for technology-related teacher training has been "variable from year to year, piecemeal in nature, and lacking in clear strategy or consistent policy."

(chap. 6, p. 2) Definition for the training has been left up to the school district and those consultants who provide training. OTA notes a "need to train with higher intensity and longer duration, to translate exposure to cutting-edge technologies into viable classroom learning experiences, to provide extensive follow-up after the end of formal training, and to improve evaluation and dissemination of projects with federal funds." (chap. 6, p. 2)

This discussion reinforces the observation in the previous section that most math-science-specific technology training, while it results in classroom use of computers, is not linked to a framework of professional technology competence. At the same time, as the OTA report states, "Providing comprehensive training at a level that could make a significant difference is likely to be beyond the range of available funding." (chap. 6, p. 37) Because technology applications are proceeding rapidly in math and science, fueled by technology-related standards in these areas, the new resources in math and science educational software, such as microcomputer-based laboratories, simulations, and modeling, offer rich opportunities for integration of technology in instruction, and could be thought to provide the best starting point for math-science teachers to begin learning computers for instructional and professional use, possibly a better starting point than the study of traditional software tools out of the context of curriculum.

Summary

The section on general-competency training and the previous section on math-science-specific technology training have discussed more than a dozen approaches to technology training. The tables on the following pages

Table 2

Content Addressed by Math-Science-Specific Technology Training

Category/Study	TERC	ENLIST	CI3	Johns Hopkins	Jurkat	Eisenhower/ NSF
Data Manipulation Tools Software	√	√	√	√	--	--
Database	√	--	√	--	--	--
Spreadsheet	√	--	√	--	--	--
Graphics	√	--	--	--	--	--
Publishing/ Presentation Tools Software	√	√	√	√	--	--
Word Processing	√	--	√	--	--	--
Communications	√	--	--	--	--	--
Hypermedia Production	--	--	--	--	--	--
Programming	--	--	--	√	--	--
Computer Lang.	--	--	--	--	--	--
Hypermedia Scripts	--	--	--	--	--	--
Authoring	--	--	--	--	--	--

Table 2, con'd.

Category/Study	TERC	ENLIST	CI3	Johns Hopkins	Jurkat	Eisenhower/ NSF
Math-Science Curriculum Software	√	√	√	√	√	√
Mathematical problem-solving	√	√	--	--	--	√
General problem-solving	--	--	--	--	--	√
Inquiry/ Modeling	√	--	--	--	√	√
Microcomputer-based laboratories	√	√	--	√	--	√
Simulation	√	√	--	--	--	√
Network science	√	--	--	--	--	√
Electronic Reference	--	--	--	--	--	--
Multimedia	--	--	--	--	--	--
Internet	--	--	--	--	--	--

Table 3

Content Addressed by General-Competency Technology Training

Category/Study	OTA 95	CA	NC	ISTE	Switched On	Mass Ed Online	MEC
Data Manipulation Tools Software	√	√	√	√	√	√	√
Database	--	--	--	√	√	√	√
Spreadsheet	--	--	--	√	√	√	√
Graphics	--	--	--	√	√	√	√
Publishing/ Presentation Tools Software	√	√	√	√	√	√	√
Word Processing	--	--	--	√	√	√	√
Communications	--	--	--	√	√	√	√
Hypermedia Production	--	--	--	√	--	√	√
Programming	--	√	--	--	--	--	√
Computer Lang.	--	--	--	--	--	--	√
Hypermedia Script	--	--	--	--	--	--	√
Authoring	--	√	--	--	--	--	√

Table 3, con'd.

Category/Study	OTA 95	CA	NC	ISTE	Switched On	Mass Ed Online	MEC
Math-Science Curriculum Software	√	√	√	√	√	√	√
Mathematical problem-solving	--	--	--	√	--	--	√
General problem-solving	--	--	--	--	--	--	√
Inquiry/ Modeling	--	--	--	√	--	--	√
Microcomputer-based laboratories	--	--	--	--	--	--	√
Simulation	--	--	--	--	--	--	√
Network science	--	--	--	--	--	--	√
Electronic Reference	--	--	--	√	--	√	√
Multimedia	--	--	--	√	--	√	√
Internet	--	--	--	√	--	√	√

summarize the differences and similarities in content of technology training between the math-science-specific training approach (Table 2) and the general-competency approach (Table 3).

The tables point out that there is no fundamental agreement in the literature on an overall framework for technology training for teachers in general and for math-science teachers in particular. Some math-science-specific training (especially the Eisenhower and NSF-funded training) focuses exclusively on math-science curriculum software, while others (especially CI^3) favor particular tools, and still others (notably TERC) achieve a balance between the two. The general-competency model favors software tools and mentions curriculum software as an important consideration, without providing detail. Exceptions are ISTE and MEC, who call for problem-solving and inquiry software as key components.

In reviewing the literature on math-science-specific technology training, general-competency models for technology training, and recent advances in math-science software, there is no general agreement on an overall framework for technology training for math-science teachers; nor is there consensus on where to begin training for expedient application in instruction.

It is time to update the ideas about the content of technology training for math and science teachers. The literature suggests that teachers should be involved in the process. In particular, computer-using math and science teachers are in a position to recommend software that is usable in the classroom and highly relevant to today's math and science curriculum. The dissertation study is designed to gather information from math and science teachers relative to their usage of instructional software, their view of the relevance of various types of software-- both curriculum software and general tools-- to the curriculum, and a preferred starting point for technology training.

Chapter 3
Design and Methodology

Statement of the Problem

Integration of technology in instruction throughout the K-12 curriculum and, particularly, in Math and Science instruction, is a goal of many influential organizations, including NCTM, AAAS, and Massachusetts Curriculum Frameworks. However, the task of integrating technology in math-science instruction entails investment in staff development by school districts that have limited budgets for staff development in technology and by teachers who have little time to engage in technology training and to develop technology-based instructional practices.

In particular, a definition of introductory training is needed by teacher education institutions and professional-development service providers to plan technology training for inservice teachers. Such a definition is also needed by districts to know what level of training to provide for their teachers before expecting some degree of technology integration in the classroom.

The study was designed to measure secondary math-science teachers' perceptions of the relevance of various types of software to math-science curriculum and associated training needs. The research questions addressed by this study were the following:

1. What types of software do secondary math-science teachers indicate as most important for math-science instruction?

2. What types of software do secondary math-science teachers perceive as most important as a subject of training to prepare them for instructional use of computers?

3. What differences exist between teachers whose use of computers in instruction is aligned with recommendations by standards bodies relative to instructional technology, and other respondents, in regard to Research Questions 1 and 2?

The dissertation asked math and science teachers to consider the broad range of technology training that might be made available to them, including topics from the general-competency model of technology training and the math-science-specific model of technology training. First, teachers were asked to rate the importance of various types of software-- including math-science curriculum software, software tools, and other instructional software-- to the math-science curriculum. Next, teachers were asked to assign a priority to each type of software for inclusion in an introductory training program for computer novices who could be expected to apply instructional technology in the math or science classroom as a result of the training.

Population and Sample

The dissertation focused on high school math and science teachers, a population that is interesting and important for several reasons:

- NCTM and AAAS standards, respectively, call for greater use of technology in math and science instruction (NCTM, 1991; AAAS, 1993)

- in Massachusetts, the NSF-funded Partnerships Advancing Learning of Math and Science (PALMS) project is actively seeking to change math and science instructional practices, including greater use of technology in instruction (Massachusetts Department of Education [MDOE], 1994b)
- Massachusetts Curriculum Frameworks for math and science call for use of technology in instruction (MDOE, 1995a, 1994b)
- Massachusetts Common Core of Learning incorporates technology competency in core learning (MDOE, 1994a)
- additional Massachusetts initiatives, such as the $(REMS)^2$ project at Merrimack Education Center (Goodrich, 1994), the Haystack project at MIT (Northeast Radio Observatory Corporation, 1994), the Massachusetts Corporation for Educational Telecommunications (Drexler, 1995), and the Technology Education Research Centers (Tinker & Abbe, 1990; Tinker, 1994) seek to infuse technology in math and science instruction

Teachers were chosen as the population for this study, rather than technology directors or computer coordinators, because teachers are the ones expected to use computers in instruction. Teachers' perceptions of technology use and technology training need to be understood and addressed if training programs designed for them are to be successful (Sparks & Loucks-Horsley, 1989).

The specific population for this study were the high school (grades 9-12) math and science teachers from the Northeast PALMS Region in Massachusetts. At the time of the study, the Northeast Region of PALMS consisted of 15 schools, 10 served by Merrimack Education Center, and an additional 5 served by the North Shore Education Collaborative in affiliation with Salem State College. The districts were the following: Amesbury, Andover, Beverley, Chelmsford, Danvers, Dracut, Greater Lawrence, Lowell, Groton-Dunstable, Peabody, Shirley, Tewksbury, Tyngsborough, Wilmington, Winthrop.

The sample for this study was the complete population-- that is, all high school math and science teachers in the 15-school region. This population was 288 teachers, approximately half math and half science. The sample size of 288 considered manageable for a survey-based study. Current knowledge of teacher technology competency among the PALMS schools was incomplete, but informal interaction with teachers involved in staff development indicated that teachers varied widely in their technology preparation. If service providers were to design technology training that served the whole population, the study would need to minimize sampling error and try to capture responses at the extremes.

Instrumentation

The dissertation used a survey instrument (a self-administered questionnaire) to query high school math and science teachers in the PALMS schools of the Massachusetts North Shore and Merrimack Valley regions in regard to their perception of the relative importance of software of technology training. Teachers were asked to assess each type of software relative to its importance in instructional use. Categories of importance ranged from Very Important to Unimportant on a scale from 4 to 1. Teachers were also asked about their own expertise with computers and their usage of computers in instruction.

The data was analyzed to construct a framework reflecting math-science teachers' perceptions of the relative importance of types of software for instructional use and a related framework of software topics for inclusion in introductory training.

Computer-using respondents were identified as to whether or not their use of computers addressed NCTM and AAAS standards and Massachusetts Curriculum Frameworks recommendations for instructional technology. The differences in users' responses, compared to non-users' responses, were examined in regard to Research Questions 1 and 2.

Variables.

The dependent variables in the study were the perceived importance of types of software for instructional use and their priority in introductory training. Independent variables were the teacher's self-reported expertise with computers, their instructional practices with technology, and background matters such as subjects taught and years of experience with computers.

Interrelation of research questions and survey items.

Table 4 summarizes the interrelation between Research Questions and Survey Questions.

Research Question 1 investigated teachers' perception of the importance/relevance of various types of software to math-science instruction. Survey question 1, items A-O, asked respondents to indicate degree of importance along a 4-point Likert scale from Very Important to Unimportant.

Response categories for relative importance were the following:

Very Important - The software is highly relevant to math/science curriculum and instruction

Important - The software is not directly related to math/science curriculum, but could be used to enhance math/science instruction

Somewhat Important - The software may be used to support instruction but would not be used with students in the classroom/lab

Unimportant - The software is not likely to be used by a high school math/science teacher

Research Question 2 investigated teachers' perception of the priority of various types of software as topics for introductory training. Survey question 2, items A-M, asked respondents to indicate priority along a 3-point Likert scale from High Priority to Low Priority.

Response categories for priority were the following:

High Priority - The software is essential for the computer novice in preparing for instructional use of computers.

Medium Priority - The software might be used by the computer novice for classroom/lab instructional use.

Low Priority - The software probably should not be included in introductory training

Research Question 3 investigated the difference in response to Research Questions 1 and 2 for respondents who are using computers in instruction in alignment with NCTM and AAAS standards and Massachusetts Curriculum Frameworks recommendations for technology, and all other respondents.

Respondents using computers in line with standards were identified by response to Survey question 5.

The instructional practices in Survey question 5 range from drill and practice to several that are aligned with standards:

- Calculation
- Record measurements
- Manipulate data with a spreadsheet or database
- Simulate a system or phenomenon
- Collaborative problem-solving
- Inquiry ("What if...?" thinking)
- Mathematical modeling
- Exchange data with students in other schools

Table 4

Interrelation of Research Questions and Survey Items

Research Question	Survey Question
1. Importance of software to curriculum and professional use	1. A-O
2. Priority for inclusion in Introductory training	2. A-M
3. Difference between standards-conscious users and others	5. A-N

Survey questions 3 and 4 provided additional information concerning teachers' self-reported expertise with computers and the usage of computers by math-science teachers. This information will be useful for those planning technology training for these teachers. Background information (Survey question 4) consisted of the following:

- Years of experience with computers
- Years of experience with computers in instruction
- Years of experience teaching
- Subjects taught
- Grade levels taught

The survey instrument is in Appendix C.

Interrelation of survey items and software/topics for technology training.

Table 5 represents the interrelation of survey items and types of software. The categories of software in Table 5 are drawn from the literature, particularly Mass Ed Online's taxonomy for educational software, most recently documented in Mass Ed Online: Technology Planning Kit (CELT, 1996). Mass Ed Online uses the following categories of software:

- Computer-Aided Instruction
- Creativity Technologies
- Data Manipulation
- Design Technologies
- Telecommunications
- Presentation Technologies
- Publishing and Productivity Technologies
- Research Technologies
- Learning Management Technologies

The taxonomy has been modified for purposes of this study. Two categories (Computer-Aided Instruction and Learning Management Technologies) were not of interest to this study. Presentation, Creativity, and Productivity Tools were merged for simplicity into Publishing Tools. Design Technologies (Lego/LOGO, Computer-Aided Design, and so on) were expanded into Math-Science Curriculum Software. A category was added for Programming/Authoring tools. Telecommunications was represented in several categories-- Electronic Mail with Publishing Tools, Network Science in Math-Science Curriculum Software, and Internet Research in Electronic Research Tools. The purpose of this survey question was to put forth a framework for software related to the math-science curriculum, which would be tested and validated by secondary math-science teachers, particularly those using instructional technology in ways recommended by standards and by the Curriculum Frameworks.

Such a framework would be useful in planning technology/curriculum integration, software acquisition, and related training. The reader will note that, even with the simplifications in Table 5, teachers who responded to the survey did not distinguish Electronic Research Tools as a separate category. In their perception, these tools align with Publishing Tools. Appendix A presents examples of how the software in Table 5 might be used and examples of software products in each category.

Survey questions 1, 2, and 3 consist of items that represent different types of software. Data Manipulation Tools include database, spreadsheet, and tools for generating charts and graphs. Math-Science Curriculum Software includes drill and practice software, simulation, modeling, collaborative/network science, inquiry/decision-making software, and microcomputer-based laboratories. Publishing Tools include word processing, electronic mail, drawing/painting tools, and hypermedia production tools. Programming/Authoring software includes computer languages, hypermedia authoring, and scripting languages. Electronic Research Tools includes CD-ROM reference materials and Internet search tools.

Table 5

Interrelation of Survey Items and Software Types

Software/ Topic of Training	Survey Question #1 Importance to Instruction	Survey Question #2 Priority for Training	Survey Question #3 Self-reported Expertise
Data Manipulation Tools	B,C,E	B,D,J	B,C,E
Math-Science Curriculum Software	G,H,J,N,O	A,C,F,M	G,H,J,N,O,P
Publishing Tools	A,D,F,I	K,L	A, D , F,I
Programming/Authoring	K,L	H,I,N	K,L
Electronic Research Tools	M	E,G	M

Intercorrelation of items and grouping of respondents.

A matrix was created showing the intercorrelation of items from Survey Question 1. These intercorrelated items were used to create and validate indices for five types of software (Data Manipulation Tools; Math-Science Curriculum Software; Publishing Tools; Programming/Authoring; and Electronic Research) to provide data reduction. Since the possibility existed for overlap of categories of software, the intercorrelations were used to determine the validity of the proposed construct. (As noted above, results indicated that teachers perceived only four categories or indices, with Publishing Tools and Electronic Research Tools closely correlated in their view.)

Respondents were grouped to analyze the differences between standards-aligned computer users and other respondents. "Standards-aligned" computer-users were those whose instructional practices indicate application of standards for technology.

Data Analysis

Descriptive statistics were applied to the data to determine range, mean, median, mode, standard deviation, and variance. Measures of central tendency were used to indicate averages for various indices for each group of respondents, in regard to the importance of the types of software for math-science teachers and the priority for inclusion in introductory training.

Since the prerequisites were met, analysis of variance was used to measure the difference in response between standards-aligned users and others in regard to importance of each type of software for instructional use and for inclusion in introductory training.

Survey Administration

The survey was administered at department meetings between mid-October and the first week of December during the 1995-1996 school year. The survey was placed on the agenda for two all-day PALMS Leadership Team Meeting October 17 and 18. At these meetings, the researcher explained the purpose of the survey and identified one contact person from each school district. Contacts were given a packet of surveys and instructions and asked to administer the survey at the high school science and math departmental meetings during the specified time period.

A cover letter to teachers identified the survey as sponsored by PALMS and Merrimack Education Center and asked them to respond to the survey during a fifteen minute period. Contacts then collected the completed surveys and returned them to MEC by mail immediately following administration, using prepaid return envelopes provided by the researcher. A memo was sent November 7 reminding contacts to administer the survey, and a reminder was included as an agenda item on the December 4 PALMS Leadership Team meeting.

No personal information was given by respondents. When the surveys were returned, a unique sequential number was assigned to each survey, a composite number (school plus sequence number) which served as a key to the data record.

The goal was response from all math-science teachers in all fifteen high schools. Because the survey was administered to departments within schools, the criteria for "acceptable" and "unacceptable" rate of response were the following: response from at least half the teachers in the math and science departments from 75% of the schools (11 of 15) would be an acceptable rate of response. Response from fewer than half the schools would be an unacceptable rate of response. In fact 11 schools responded, with questionnaires returned from 172 teachers in these schools, representing 84% of the high school math-science teachers in these schools (n=205) and 60% of the total population (n=288).

Validity and Reliability

The survey items had face validity since they were drawn from research and popular literature on educational technology and refined through informal discussion with practitioners and through field test of the instrument (see below).

Content validity of the items pertaining to instructional practices has been achieved by selecting a wide range of items from the literature, notably Becker, and from NCTM and AAAS standards, from reports on best practice with technology, and input from math-science teachers.

The proposed five categories or indices of software (Data Manipulation Tools, Math-Science Curriculum Software, Publishing Tools, Programming/Authoring, and Electronic Research Tools) were construct-validated through an intercorrelation matrix and additive indices. The additive indices were also intercorrelated. As will be seen in Chapter 4, four indices were obtained, rather than five, with Electronic Research Tools being subsumed by Publishing Tools.

To enhance reliability, the instrument was based on a "Teacher Technology Survey" used by Merrimack Education Center with about one dozen schools. Since teachers were expected to be unfamiliar with some items on the survey, instructions told them to leave blank any items that they did not know.

To provide consistent measures, the questions had a predetermined list of acceptable responses. Response categories and instructions were revised based on two field tests (see below). Survey questions 1, 2, and 3 each used a Likert Scale, and the scales were consistent: high-to-low, left-to-right.

<u>Field test.</u>

The survey instrument was field tested in June with the 13 math and science teachers from Malden Catholic High School. These teachers had a wide range of experience (or inexperience) with instructional technology.

Teachers were asked to note items that were unclear or that they could not answer. The survey was revised based on the responses.

The revised instrument was then field tested with MEC sponsorship during a Summer Science Institute at University of Massachusetts Lowell on July 19, 1995, with a group of 23 math-science teachers from the 14 high schools of the (REMS)^2 project (Goodrich, 1994). This field test was administered in "real time" to judge the amount of time required for teachers to respond (minimum 6 minutes, maximum 10 minutes) and to identify unclear items or instructions. The survey was again revised (see Appendix C).

Confidentiality and social desirability.

The Background question (4 A-C) allowed the respondent to select ranges, thus protecting confidentiality.

The issue of "social desirability" was a concern with a survey of this nature. That is, if the survey were not confidential, respondents might want to report greater knowledge of computers or greater use of computers.

Similarly, respondents were likely to be aware of NCTM and AAAS standards that encourage use of technology, and they would be likely to respond "Yes" unanimously to a question such as "Do you support NCTM/ AAAS standards and Curriculum Frameworks calling for the use of technology in instruction?" For that reason, respondents were asked to choose among various uses of instructional technology in Survey question 5, without identifying some uses as "in keeping with standards."

Subjective questions.

Steps have been taken to guard against subjective response. Compound questions have been avoided throughout.

Survey questions 5 concerning instructional practices was only completed by teachers who used computers in instruction. The question was formatted for Yes/No response and did not make or call for subjective judgment about such divergent uses of computers as "educational games," "drill and practice," or "collaborative problem solving." Respondents were required to consider each item and indicate use or non-use explicitly.

Further Research

Directions for further study were indicated by the results of the survey. Further research should examine the effect of diverse factors on use of instructional technology, such as availability of hardware, software, and technical support, nature of the training available to teachers, and administrative support for instructional innovation. Given the limitations of the survey, which was administered only to math-science teachers at the high school level, further research would need to widen the population to other grade levels and other disciplines and to encompass higher education. Nor did the survey take into account the perceptions and recommendations of technology coordinators or persons with district-wide responsibility for curriculum and staff development. Also, the survey did not explore the relationship between use of instructional technology and student achievement.

Summary

A survey was conducted with a population of high school math and science teachers asking them to rate the relevance of software to math-science curriculum and to rate the importance of a set of training topics, which were drawn from the literature on technology training. Their responses were analyzed to construct a framework for software that is useful for instructional purposes in the secondary math-science curriculum. Respondents were asked to assign priorities to topics for inclusion in technology training for computer novices who could be expected to begin using computers in instruction.

Differences in response were noted between those respondents already using computers for activities aligned with standards and those not using computers in this way.

The framework developed for training was then compared to existing general-competency models for technology training, particularly those set forth by ISTE, Mass Ed Online, and Merrimack Education Center. The framework was also compared with existing models for math-science-specific training, which typically focus on introductory training without a context for overall development of expertise.

Chapter 4
Study Findings

This chapter presents the findings of the educational software survey, describes the techniques used for data analysis and data reduction, and discusses the results in relation to the research questions. The chapter begins with a restatement of the study questions, followed by a description of the respondents to the survey, their perceptions concerning the relevance of software to math-science curriculum, and their perceptions of training priorities leading to use of computers in instruction. Finally, the differences in response are summarized between those using computers in math-science instruction and those not using computers in math-science instruction.

Research Questions

Integration of technology in Math and Science instruction is a goal of NCTM, AAAS, and the Massachusetts Curriculum Frameworks, yet the task of integrating technology in math-science instruction entails investment in staff development by school districts that have limited budgets for staff development in technology and by teachers who have little time to engage in technology training and to develop technology-based instructional practices.

The research study was designed to measure high school math and science teachers' perceptions of the relevance of various types of software to math-science curriculum and to assess the associated training needs for high school math and science teachers.

The research questions addressed by the study were the following:

1. What types of software do secondary math-science teachers indicate as most important for math-science instruction?

2. What types of software do secondary math-science teachers perceive as most important as a subject of training to prepare them for instructional use of computers?

3. What differences exist between teachers whose use of computers in instruction is aligned with recommendations by standards bodies relative to instructional technology, and other respondents, in regard to Research Questions 1 and 2?

To answer these questions, the researcher prepared an Educational Software Survey (Appendix C) for math and science teachers in 15 high schools in the northeast PALMS region of Massachusetts. Surveys were completed and returned during the Fall of 1995. The results are presented in this chapter. Implications of the findings, limitations of the study, and suggestions for further research are discussed in the next chapter.

Indices Categorizing Software for Math-Science Curriculum and Instruction

The researcher developed and tested five categories of software with possible relevance to the math-science curriculum. The taxonomy adapted for the survey is that used by Mass Ed Online (CELT, 1996), which categorizes software by usage. The nine Mass Ed Online categories (computer-aided instruction, creativity technologies, data manipulation, design technologies, telecommunications, presentation technologies, publishing and productivity technologies, research technologies, and learning management technologies) were simplified into five categories of software to provide a construct for measuring and discussing the relevance of various types of software to math-science curriculum. Items for each category were included in Survey Questions 1-3 to test teachers' perceptions of software relevance to curriculum, the perceived importance of software topics in technology training, and teachers' self-reported expertise with each type of software. It was expected that teachers' responses concerning software items would correlate along the lines of the five indices or categories, which would validate the five categories or indices as a useful framework for discussing relevance of software to math-science curriculum and topics for technology training. The proposed five indices, in the expected order of relevance to the math-science curriculum, were the following:

1) Math-Science Curriculum Software, which includes modeling and simulation software, problem-solving software, microcomputer-based laboratories, and network science
2) Data Manipulation Tools, which includes spreadsheet, graphic/charting software, and database
3) Publishing Tools, which includes word processing, multimedia tools, electronic mail, and drawing/illustration software
4) Programming/Authoring, including programming languages and scripting languages
5) Electronic Research Tools, which includes interactive multimedia encyclopedias and Internet reference sources

An intercorrelation matrix of items was prepared for teachers' responses to Survey Question 1, and additive indices were developed to provide data reduction (see Appendix D). Data analysis indicated that the teachers who responded to the survey perceive four rather than five groups of software items, which correspond to four of the proposed five indices, with Electronic Research Tools correlated with Publishing Tools rather than standing apart as a distinct index. The <u>four software indices, which resulted from data analysis and reduction</u>, are used throughout the remainder of the chapter as a basis for discussion of the findings. The 4 indices are presented here in the order of perceived relevance to math-science curriculum. They consist of the following:

1) <u>Data Manipulation Tools</u>, which includes spreadsheet, graphic/charting software, and database
2) <u>Math-Science Curriculum Software</u>, which includes modeling and simulation software, problem-solving software, microcomputer-b[illegible] laboratories, and network science
3) <u>Publishing Tools</u>, which includes word processing, multimedia tools, electronic research tools, electronic mail, and drawing/illustration software
4) <u>Programming/Authoring</u>, including programming languages and scripting languages

The four indices provide a useful framework for discussing software for use in math-science curriculum and instruction and for discussing technology training for teachers. Individual items within each index are sometimes highlighted in the discussion that follows, when considering priorities or starting points for instructional use and associated training.

Characteristics of the Sample

The survey instrument in Appendix C was distributed to representatives of the 15 Northeast PALMS schools during Leadership Team meetings October 17 and October 18. The contacts agreed to administer the questionnaires to math and science high school teachers in their districts during regular Math and Science Department meetings during the next six weeks.

Of the 15 schools, 11 (73%) returned their questionnaires within the agreed timeframe. In all but one case, schools returned questionnaires from both the math and science department meetings. The single exception reported being unable to use department meeting time to administer the survey and, instead, asked individual teachers to complete the questionnaire and return it through interdepartmental mail; this school returned questionnaires from approximately 80% of the math department and 30% of the science department. The total number of respondents (n=172) from the 11 schools represented 84% of the math and science teachers in these schools (n=205) and 60% of the total population in the 15 schools (n=288).

Table 6 shows the number of high school, math and science teachers for each school, followed by the number of respondents, the percentage of teachers responding from that school, and the percentage of respondents who report using computers in instruction in ways recommended by standards bodies such as NCTM and AAAS.

Table 6

Number and Percentage of Respondents

School (by size)	# Teachers	# Responding	# Using in Instruction
1	8	8	8
2	11	11	9
3	12	12	4
4	14	14	7
5	15	14	9
6	16	14	6
7	17	15	9
8	23	17	10
9	24	23	11
10	27	25	12
11	38	19	12
Total	205	172 (84%)	97 (56%)

Appendix C presents the findings for each survey item. Responses to Survey Questions 3-5 are summarized in this section to provide a composite profile of the respondents. These questions concern background (years teaching, years using computers, subjects and grades taught), self-reported expertise with computers, and, for those using computers in instruction, their computer-using instructional practices.

Characteristics of non-respondents.

Fifteen schools were asked to participate in the study, while only 11 actually responded to the survey. From conversations and interactions with non-participating districts, the following were the reasons for non-participation:

- in one case, departmental meetings were not held during the survey period, and the contact person was immersed in budgeting activities during the same time
- one school has a history of antipathy with the sponsoring organization
- two contacts who committed were unable to administer the survey for unknown reasons

The first two of the four non-participating schools are known to make use of math-science curriculum software. One of these two districts makes use of graphing software and interactive physics software in a nationally-publicized interdisciplinary unit (Mosto & Nordengren, 1995). The second school is aggressively building its capacity to use microcomputer-based laboratory software and probes with its science program.

The other two non-participating schools use technology to some degree. Conversations and interactions with individuals at these schools suggest that the level of expertise among the high school math-science teachers is similar to other schools who participated in the survey. One of the schools is actively working to integrate technology with math-science instruction, while the other follows a computer-literacy approach to technology (that is, students learn to use traditional software tools as a separate curriculum strand).

<u>Teaching experience of the sample respondents.</u>

Teachers who report teaching math comprise 63% (n=109) of the sample; those teaching science comprise 51% (n=87). Note that in all but one school, one or more teachers reported teaching both math and science. Thirty teachers also reported teaching computers/programming. The question was included to identify and eliminate any respondent who only taught computers without also teaching math or science. All of those who reported teaching computers/programming were also math teachers. No further analysis was done concerning the computer/programming teachers.

With few exceptions, teachers responding to the survey instrument reported that they teach or have taught at multiple grade levels, with approximately 85% reporting experience at each grade level 9-12.

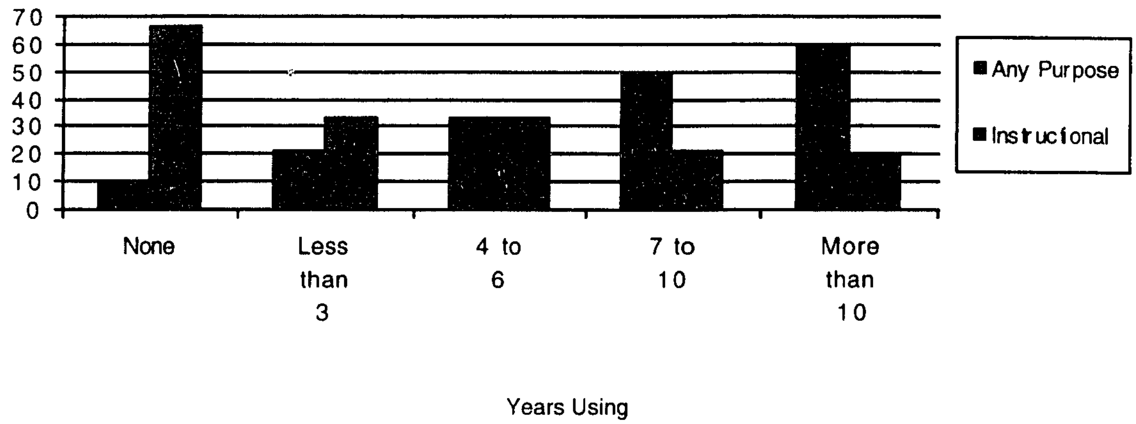
Those who have been teaching more than 10 years represent 78% of the sample. Another 7% report teaching 7-10 years, 5% report teaching 4-6 years; and 10% report teaching 1-3 years.

Computer usage of the sample respondents.

More than 1/3 of the sample report that they have been using computers for more than 10 years, but only 11% have been using computers in instruction for more than 10 years. Those with no computer experience comprise only 6% of the respondents, but an additional 32% have never used computers in instruction. Figure 1 indicates non-instructional vs. instructional use of computers by respondents. It is important to note that, while 59 respondents have been using computers for more than 10 years, only 19 of those have been using computers in instruction for that amount of time and an additional 21 have been using computers for more than 7 years.

Figure 1

General vs. Instructional Use of Computers by Respondents



A surprisingly high percentage (56%, n=97) of teachers responding to the survey report that they are already using computers in instruction in a manner consistent with recommendations by standards bodies, such as NCTM and AAAS. Those practices included

- calculation (33%)
- using spreadsheets/graphics to manipulate/visualize data (31%)
- simulation of scientific phenomena (21%)
- inquiry (20%)
- microcomputer-based laboratory experimentation (16%)
- mathematical and scientific problem solving (15%)
- mathematical modeling (15%)
- network science (9%)

However, the two most common computer-based instructional practices reported by respondents are

- drill and practice (45%)

- educational games (39%)

Those using computers in instruction average two different uses, with three being the most common number of computer-based practices. The distribution of those using computers in instruction, by subject taught, is represented in Table 7.

Table 7

Math and Science Teachers Use of Computers in Instruction

Subject Taught	Using Computers in Instruction	Not Using in Instruction	Total by Subject
Mathematics	59	50	109
Science	55	32	87
Total	97	75	172

Computer expertise of the sample respondents.

Teachers' self-reported expertise with computer software is generally higher for those using computers in instruction compared with those not using computers in instruction, although the difference should not be interpreted as causative. Teachers were asked to report their level of expertise with various types of software using a four-point scale, as follows:

4 - Expert use it with confidence and make use of most features

3 - Intermediate know just enough to use it productively

2 - Novice have used it some but need practice/support to use productively

1 - None never used the technology

Major findings in regard to computer expertise were the following:

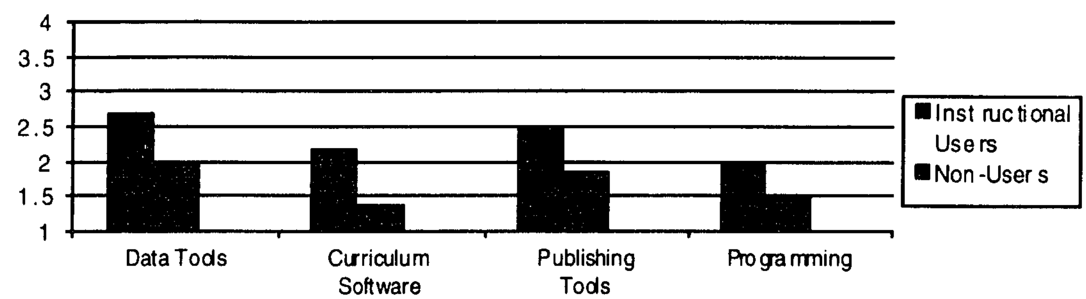
- Those who use computers in instruction report intermediate-to-expert level competence with word processing (mean=3.4) and with no other type of software. Non-users do not report higher than intermediate level expertise with any software.
- Those who use computers in instruction report intermediate level competence with spreadsheet, (mean=2.79), graphics (mean=2.72), drill and practice software (mean=2.77), database (mean=2.72), and electronic reference tools (mean=2.52). Non-users report this level only with word processing (mean=2.7).
- Users report novice-to-intermediate competence with electronic mail (mean=2.43), problem-solving software (mean=2.36), programming (mean=2.36), simulation software (mean=2.27), drawing (mean=2.24), modeling (mean=2.21), and microcomputer-based laboratories (mean=2.04). Non-users report this level of expertise with only spreadsheet (mean=2.14) and database (mean=2.04).
- Users report novice-level expertise with multimedia tools (mean=1.99), network science (mean=1.78), and authoring software (mean=1.77). Non-users report this level or less for all other types of software.

Across the four software indices, instructional users and non-users are compared in Figure 2. Instructional computer users report the highest level of expertise with Data Manipulation Tools (mean=2.70), followed by Publishing Tools (mean=2.48), Math-Science Curriculum Software (mean=2.17), and Programming/Authoring (mean=1.98). Non-instructional users report the least experience with Math-Science Curriculum Software, with means as follows: Data Manipulation Tools (mean=1.98), followed by Publishing Tools (mean=1.83), Programming/Authoring (mean=1.46), and Math-Science Curriculum Software (mean=1.38).

Figure 2

Expertise Across Software Indices

Instructional Users vs. Non-Users



Overall, teachers responding to the survey reported greater familiarity with computers than expected. From informal discussion with teachers, it was anticipated that 50-75% of the population would report computer literacy, mainly experience with traditional tools (word processing, database, spreadsheet, drawing, and electronic mail) and that only 10-20% of the population would report using instructional technology in line with standards. In fact, the number of math-science teachers who report using computers in instruction is greater than 50% of respondents. Even teachers not using computers in instruction report that they use computers for other purposes, with the exception of 10 respondents (6% of respondents), who report that they do not use computers for any purpose.

Relevance of Software to Math-Science Curriculum and Instruction

This section presents the findings for Survey Question 1, designed to measure teachers' perception of the relevance of various types of software to math-science curriculum and instruction. The results show differences in familiarity with software between instructional users and non-users. The results show that the two indices for Data Manipulation Tools and Math-Science Curriculum Software are perceived by instructional users and non-users alike to have the highest relevance to math-science curriculum. The results also indicate that teachers who use computers in instruction differ significantly from their peers in their perceptions concerning relevance of software to curriculum, placing higher importance on most types of software in regard to use in the curriculum. Appendix E gives the mean and standard deviation for users' and non-users' responses to items and indices for Survey Question 1 (relevance of software to curriculum) and Survey Question 2 (importance in initial training).

Familiarity with software.

The research anticipated that a large number of respondents would be unfamiliar with some types of software, and field tests of the survey instrument bore out this concern. Accordingly, respondents were instructed to leave blank any items that they were unfamiliar with. Overall, as expected, those teachers using computers in instruction had much greater familiarity with all types of software than did non-users. Teachers were least familiar with Multimedia Tools (22 users and 36 non-users left this item blank) and Authoring software (24 users and 34 non-users left this item blank). About one-third of non-users were unfamiliar with simulation software (n=23) and microcomputer-based laboratories (n=26). On average, 10% of users (n=10) left an item blank, while 21% of non-users (n=16) left an item blank.

For purposes of analysis of Survey Question 1, the mean response for each group of users was substituted for blank responses.

Software indices and relevance of software to math-science curriculum.

Survey Question 1 asked math-science teachers to rate the relevance to curriculum of various types of software, using four response categories, as follows:

4 - Very Important	The software is highly relevant to math/science curriculum and instruction
3 - Important	The software is not directly related to math/science curriculum, but could be used to enhance math/science instruction
2 - Somewhat Important	The software may be used to support instruction but would not be used with students in the classroom/lab
1 - Unimportant	The software is not likely to be used by a high school math/science teacher

The question consisted of 15 items with several from each of the four software indices, as follows:

Data Manipulation Tools:

B- Database

C- Spreadsheet

E- Graphing/Charting

Math-Science Curriculum Software:

G- Microcomputer-based Laboratories

H- Modeling

J- Problem-solving

N- Simulation

O- Network Science

Publishing Tools:

A- Word Processing

D- Electronic Mail

F- Drawing

I- Multimedia Tools

M- Electronic Reference

Programming/Authoring:

K- Scripting/Authoring

L- Computer Programming

An intercorrelation matrix of items was prepared for teachers' responses to Survey Question 1, and additive indices were developed to provide data reduction (see Appendix D). Data analysis indicated that the teachers who responded to the survey perceive 4 groups of software items, which correspond to the 4 software indices above. In order of perceived relevance to math-science curriculum, they are: Data Manipulation Tools, Math-Science Curriculum Software, Publishing Tools, and Programming/Authoring.

Individual items within each index are sometimes highlighted in the discussion that follows, when considering priorities or starting points for instructional use and associated training.

Relevance to curriculum.

Teachers who report that they already use computers in instruction rated the Data Manipulation Tools index and the Math-Science Curriculum Software index Important-to-Very-Important (that is, greater than 3 out of 4) in regard to relevance to math-science curriculum. One individual item from the Publishing Tools index, word processing also received a rating greater than 3. Table 8 indicates the relative importance placed on each index, with Word Processing singled out for its importance.

Table 8

Software with Greatest Relevance to Math-Science Curriculum

Index	**Mean (St.Dev)**
Data Manipulation Tools	3.37 (.57)
Math-Science Curriculum Software	3.29 (.55)
Word Processing (from Publishing Tools Index)	3.11 (.81)
Publishing Tools (including Word Processing)	2.74 (.61)
Programming/Authoring	2.31 (.77)

Although it was expected that Math-Science Curriculum Software would be rated highest, it is not surprising to find that Data Manipulation Tools and Math-Science Curriculum Software are perceived to be of highest importance or greatest relevance in math-science instruction. However, it is interesting to find word processing so high in the list of relevance to curriculum. Evidently, teachers feel that word processing is valuable directly in teaching math and science, not just as a tool for teachers to prepare instructional materials. This may reflect teachers' emphasis on the importance of communicating scientific findings and teaching the language of mathematics.

Differences in perceived relevance for instructional users and non-users.

Teachers who are not using computers in instruction ranked the indices in the same order but with consistently lower scores for importance/ relevance to curriculum. They rated Data Manipulation Tools highest (mean=3.19), followed by Math-Science Curriculum Software (mean=3.10), Publishing Tools (mean=2.45), and Programming/Authoring (mean=2.10).

The researcher performed ANOVA for the four indices to analyze difference in response between instructional users and non-users. ANOVA indicated that users and non-users differed significantly in their perception of the relevance of Data Manipulation Tools, Math-Science Curriculum Software, and Publishing Tools.

Relevance of data manipulation tools.

All teachers responding to the survey, regardless of whether they use computers in instruction, gave the highest rating to Data Manipulation Tools in regard to relevance to the curriculum. However, ANOVA indicates that teachers currently using computers in instruction rate Data Manipulation Tools significantly higher in relevance to math-science curriculum than do non-users, as indicated in Table 9.

Table 9

Analysis of Variance - Data Manipulation Tools Index

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Users	97	982	10.12	2.92
Non-users	75	719	9.58	3.32

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	12.36	1	12.36	3.99	.047
Within Groups	526.02	170	3.09		
Total	538.38	171			

Relevance of math-science curriculum software.

Teachers currently using computers in instruction rate Math-Science Curriculum Software as significantly higher in relevance to math-science curriculum than do non-users, as indicated by Table 10.

Table 10

Analysis of Variance - Math-Science Curriculum Software Index

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Users	97	1594	16.43	7.57
Non-users	75	1161	15.48	8.83

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	38.24	1	38.24	4.71	.031
Within Groups	1380.08	170	8.12		
Total	1418.32	171			

Given that instructional-computer-users report less than intermediate expertise with Math-Science Curriculum software and do not report using

Math-Science Curriculum Software to any great extent in their current teaching practice, the difference may be attributed less to experience than to simple awareness of newer curriculum software and its potential effectiveness in teaching math and science. The next section (Priorities for Software Training for Math-Science Curriculum and Instruction) notes that their perception of the relevance of Math-Science Curriculum Software is paralleled by their strong recommendation that Math-Science Curriculum Software receive priority in training to prepare computer novices to use computers in instruction.

Relevance of publishing tools.

Teachers currently using computers in instruction also rate the Publishing Tools index as significantly higher in relevance to math-science curriculum than do non-users, as indicated by Table 11.

Table 11

Analysis of Variance - Publishing Tools Index

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Users	97	1330	13.7	9.33
Non-users	75	917	12.2	6.28

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	92.21	1	92.21	11.52	.0008
Within Groups	1360.61	170	8.00		
Total	1452.83	171			

Computer-using teachers, in contrast to their non-computer-using peers, apparently perceive that Publishing Tools have greater relevance in teaching students to communicate their scientific ideas and findings and to express the language of mathematics and their understanding of mathematical concepts.

Results in regard to network science and programming.

Two surprises in the overall assessment of relevance of software to curriculum were the low scores given to two individual items: Network Science from the Math-Science Curriculum Software index and Programming Languages from the Programming/Authoring index. Even teachers currently using computers in instruction rank Network Science lower than word processing as an instructional technology. This assessment is in spite of exemplary network science programs in the region, such as Simmons College "Environet," TERC-sponsored "GlobalLab," and MEC-sponsored "(REMS)^2."

Teachers placed an even lower value on network science's underlying technology, electronic mail (mean=2.42, the second lowest scoring item of the 15 items in Survey Question 1). In practice, only 9% of teachers (n=15) report that they have their students exchange data with students in other schools, the lowest usage of the 14 items measured in Survey Question 5. It will be interesting to see if this figure increases and if the value placed on networking rises as more schools become users of high-bandwidth, graphical-user-interface access to Internet, such as that only recently made possible by MECnet, MEOL, and other networking initiatives in the region.

Another surprisingly low score was that given to Programming Languages. Teachers currently using computers in instruction rated Programming halfway between "Somewhat Important" and "Important," (mean= 2.51, standard deviation=.87). Non-users assign it a mean of 2.45 (.99). Programming techniques are traditionally associated with problem-solving and logic activities, as well as being a keystone in the discipline of computer science. Overall, Programming/Authoring tools were rated lowest in relevance to curriculum by both groups of teachers. In terms of the current high school curriculum, computer science is normally an optional/elective subject, and programming is sometimes addressed only as an Advanced Placement subject. This category may increase in perceived relevance as schools make greater use of software such as modeling and simulation, which employ sophisticated spreadsheet-based algorithms in their operation, and which can be customized and extended through programming and authoring features. It is apparent that few teachers are currently using these newer curriculum packages (simulation 21% and modeling 15%), and it is likely that most use them only at an entry level at the present time.

Summary of software relevance to curriculum.

In summary, teachers perceive a high degree of relevance to math-science curriculum, in order, for:

1) Data Manipulation Tools, particularly spreadsheet and graphing/charting software
2) Math-Science Curriculum Software
3) Word Processing, from the Publishing Tools index

There are significant differences in perception of relevance of software to curriculum between teachers who are currently using computers in instruction and those not using computers in instruction, as indicated in Table 12. Users perceive significantly higher relevance than do non-users in regard to Data Manipulation Tools, Math-Science Curriculum Software, and Publishing Tools.

The reasons for measuring differences in perceived relevance between instructional users and non-users were to determine if users had greater awareness of newer Math-Science Curriculum Software and to understand how non-users' preconceptions would need to be addressed. It appears that instructional users, even though they do not have much experience with Math-Science Curriculum Software, are more familiar with this class of software and perceive that it is highly relevant to math-science curriculum. Non-users, on the other hand, place generally less importance on all types of software, although they see that Data Manipulation Tools and Math-Science Curriculum Software have greatest relevance to math-science curriculum.

Table 12

Comparison of Instructional Users vs. Non-Users Concerning Relevance of Software to Math-Science Curriculum

Software Index	Instructional Users	Non-Users	Mean Difference	F
Data Manipulation Tools	3.37	3.19	.18*	3.99
Math-Science Curriculum Software	3.29	3.10	.19*	4.71
Publishing Tools	2.74	2.45	.29**	11.52
Programming/ Authoring	2.31	2.1	.21	3.48

* significant at the p <.05 level

** significant at the p <.01 level

Given teachers' relative inexperience with Math-Science Curriculum Software, further research might test for increases in perceived relevance for

Math-Science Curriculum Software, particularly network science, and, possibly, for Programming/Authoring Tools.

Responses by teachers already using computers in instruction indicate that, within the Data Manipulation Tools, highest importance is assigned to Graphing/Charting (mean=3.71) and Spreadsheet (mean=3.40), with less importance given to Database (mean=3.02). It appears that the single most valuable investment for high school math-science curriculum at this time is a spreadsheet package with graphing/charting capability.

Priorities for Initial Software Training for Math-Science Curriculum and Instruction

Teachers were asked in Survey Question 2 to indicate their priorities for initial training-- that is, training for computer novices to prepare them to use computers in instruction. It was expected that a different set of priorities would emerge for those already using computers in instruction, perhaps aligned with their current level of expertise, and those not using computers in instruction, perhaps aligned with traditional software tools (word processing, database, spreadsheet, drawing, and communications). However, there were no statistically significant differences in response between instructional computer-users and non-users. Respondents in both groups indicated they were in agreement on a set of priorities which was different from either set of expectations. Their priorities for technology training, as measured by the survey, are aligned with instructional computer-users' perceptions of what software is most relevant to math-science curriculum.

Table 13 indicates the relative priorities for the four indices of software for each group of respondents. Mean scores are based on a scale of 1 to 3, as follows:

3 - High Priority — The software is essential for the computer novice in preparing for instructional use of computers

2 - Medium Priority — The software might be used by the computer novice for classroom/lab instructional use

1 - Low Priority — The software probably should not be included in introductory training

Table 13

Comparison of Instructional Users vs. Non-Users Concerning Priorities for Training

Software Index	Instructional Users	Non-Users	Mean Difference[a]	F
Data Manipulation Tools	2.55	2.46	.09	.46
Math-Science Curriculum Software	2.43	2.46	.03	1.85
Publishing Tools	2.23	2.16	.07	.95
Programming/ Authoring	1.76	1.72	.04	.36

[a] None of these were significant at the $p < .05$ level

ANOVA was performed for each index. No significant difference was found between users and non-users for any of the 4 indices.

What is interesting about the perceived priorities of the software indices for Survey Question 2 is that they match the order of relevance to curriculum indicated by computer-using teachers in response to Survey Question 1, in which Data Manipulation Tools and Math-Science Curriculum Software were perceived to have highest relevance to curriculum and Programming/Authoring were perceived to have the least relevance.

The order of priority does not match the order of users' expertise with computer software (Figure 2). Users' reported expertise with Math-Science Curriculum Software (mean=2.17) is less than both Data Manipulation Tools (mean=2.70) and Publishing Tools (mean=2.48). Neither group of respondents places highest priority on training with traditional tools (word processing, database, spreadsheet, drawing, and communication), where instructional users mean=2.51 and non-users mean=2.43. The reason for examining the difference in response for instructional users *versus* non-users was to see what expectations non-users had regarding training needs. It was expected that non-users would call for training with traditional tools as the preferred starting point. The findings indicate that their perception of training needs is consistent with perceived importance of software to the math-science curriculum. In short, their expectations, like those of their instructional-computer-using peers, are well matched to priorities for instructional use of computers in math-science curriculum.

Highest priority: data manipulation tools.

Teachers currently using computers in instruction assign higher priority to training with Data Manipulation Tools (mean=2.55) than with Math-Science Curriculum Software (mean=2.31). Teachers not currently using computers in instruction assign equal priority (mean=2.46) to training with Data Manipulation Tools and Math-Science Curriculum Software. The two groups are not significantly different, in a statistical sense, in their responses on either index.

Examination of individual software topics shows an interesting difference between instructional users and non-users. Those currently using computers in instruction rank spreadsheet as a training topic much higher than do non-users (3rd out of 15 items, compared to 7th out of 15). In fact, non-users rank spreadsheet below database in priority. Again, users place strong emphasis on the use of spreadsheet in teaching math and science. As with Survey Question 1, where users indicated the relevance of software to math-science curriculum, it appears that spreadsheet software with charting/graphing capability is the single best investment in software and training for math and science instructional use at the secondary level.

Competing priority: math-science curriculum software.

Math-Science Curriculum Software is perceived as second in importance for training to prepare novices for instructional use of computers. Further examination of the data for this index yielded interesting results.

Additional analysis was done to determine whether math teachers using computers in instruction had a different set of priorities from science teachers using computers in instruction, in regard to training with Math-Science Curriculum Software. The study was not specifically designed to elicit such differences; all teachers were asked to respond for both math and science. However, a ranking of individual items within the Math-Science Curriculum Software index indicates that the top priorities are different by discipline. Table 14 indicates math teachers' emphasis on modeling software and science teachers' emphasis on microcomputer-based laboratories.

Table 14

Priorities for Math vs. Science Teachers

Regarding Training with Math-Science Curriculum Software

Math	Mean (StDev)	Science	Mean(StDev)
Modeling	2.64 (.51)	**Problem Solving**	2.63 (.48)
Problem Solving	2.63 (.55)	**Simulation**	2.43 (.55)
Simulation	2.31 (.63)	**Microcomputer-based Lab**	2.40 (.69)

The data indicates that computer-using math and science teachers perceive Math-Science Curriculum Software as having high priority for training, although they do not agree on which Math-Science Curriculum Software topics are most important. The data suggests that, while Math-Science Curriculum Software is highly relevant to the curriculum, the Math-Science Curriculum Software of choice for particular subjects differs. Hence, training needs differ within the index of Math-Science Curriculum Software, depending on the discipline being taught. This is a reasonable assumption. After all, it does not make sense for an Algebra I teacher to make use of a microcomputer-based lab, or for a Biology teacher to make use of algebra modeling software, although each type of software is highly relevant in context and likely to constitute a training priority for teachers in a particular discipline.

The apparent disagreement between math and science teachers concerning specific priorities for training with Math-Science Curriculum Software is understandable. As teachers become more familiar with Math-Science Curriculum Software, the importance of Math-Science Curriculum

Software as an index may rise and there may be more discernment among respondents concerning which software should receive priority. Future research in this area should be designed to elicit differences by discipline.

Priority of word processing and other publishing tools.

Publishing Tools as a whole are ranked third in priority among the four indices. However, Word Processing is rated in the top five individual topics by all respondents. This priority could be attributed wholly to the usefulness in preparing instructional materials and professional documents. However, the emphasis is also mirrored in computer-using teachers' perceptions of the relevance of word processing to curriculum, noted in Survey Question 1.

Lowest priority: programming/authoring.

As was the case with teachers' perceptions of relevance to curriculum, Programming/Authoring tools are rated lowest in priority for initial training to prepare computer novices to use computers in instruction. This result is not surprising. It is interesting, though, that some training models put forth ten or more years ago, such as the State of California (CA, 1995) indicated that Programming/Authoring was an essential topic to prepare teachers for instructional use of computers.

Software topics for initial training.

From the responses by teachers participating in the survey, it appears that an initial training program that features

- spreadsheet and graphics from the Data Manipulation Tools index
- one discipline-specific Math-Science Curriculum Software package

- word processing from the Publishing Tools index

is the preferred approach to preparing computer novices to use computers in instruction.

<u>Summary of Differences in Response Between Users and Non-users</u>

The study was designed to measure teachers' perceptions of relevance of various types of software to math-science curriculum (Research Question 1), teachers' priorities for initial training (Research Question 2), and the differences in response between teachers currently using computers in instruction and those not using computers in instruction (Research Question 3). The differences noted between instructional-computer-users and non-users have been discussed in each of the major sections above in regard to Research Questions 1 and 2. This section summarizes those differences.

The number of instructional computer users in the sample was much higher than expected (56%, n=97) and was evenly distributed among math and science teachers (Table 7) and across grade levels. The proportion of users at individual schools ranged from a low of 33% to a high of 100%. Users reported significantly greater level of expertise than non-users with all types of software, including traditional software tools. Many teachers who report that they have been using computers generally for many years also report that they do not currently use computers in instruction. Further research might investigate if this is due to limited instructional computing resources in the respondents' schools, to computer training that has focused on productivity rather than on instructional use of computers, or some other cause.

In regard to software relevance, users perceive significantly higher relevance than do non-users in regard to Data Manipulation Tools, Math-Science Curriculum Software, and Publishing Tools. Respondents indicate three tiers of relevance, with Data Manipulation Tools and Math-Science Curriculum Software having the highest relevance to math-science curriculum; Publishing Tools having moderate relevance to math-science curriculum; and Programming/Authoring tools having the least relevance to math-science curriculum. This ranking also applies to respondents' priorities for technology training.

There is no significant difference between users and non-users in regard to preferences for initial training. Respondents perceive that Data Manipulation Tools are highest priority, followed by Math-Science Curriculum Software and Publishing Tools. Math and science teachers who use computers in instruction report different priorities among individual examples of Math-Science Curriculum Software by discipline. This is understandable, since Math-Science Curriculum Software is discipline specific at the secondary level.

Finally, since users and non-users alike report intermediate or higher level of expertise with word processing software (from the Publishing Tools index), while non-users report only novice level of competence or no experience with other types of software, there would seem to be a greater need among non-users for training in spreadsheet and graphing/charting software (from the Data Manipulation Tools index) among the population studied. Both users and non-users report novice level of competence with Math-Science Curriculum Software. Training with Math-Science Curriculum Software should be designed for users and non-users alike, for this population, although it should be aimed at specific disciplines.

Chapter 5
Implications for Further Research and Practice

This chapter discusses the importance of the findings of the educational software survey in the context of the study, along with the wider implications. Limitations of the study are noted. Based on the findings and the limitations of the study, directions for further research are suggested.

Significance of the Findings In Relation to the Research Questions

The research study was designed to measure teachers' perceptions of the relevance of various software to math-science curriculum at the high school level and to define the associated training needs for those teachers who are computer novices to begin using computers in instruction. It also explored the differences in response between those teachers already using computers in ways recommended by standards bodies and those teachers not currently using computers in instruction in order to characterize and address the expectations of non-users in regard to software relevance and associated training needs. The population chosen for the study were the math-science high school teachers in the Northeast PALMS region of Massachusetts, districts who have agreed to act as demonstration sites for effective practices in math and science teaching and learning.

Framework for software relevant to math-science curriculum.

From the findings of the research study, a framework emerges for classifying software that is relevant to math-science curriculum. The framework suggested by the survey results, which measured math-science teachers' perceptions of software relevance to math-science curriculum, is a modification of the software categories put forth in the literature, particularly Mass Ed Online's classification of software according to usage. Simplifications to the Mass Ed Online categories were made, and 4 categories were found to be meaningful to math-science teachers for use in math-science curriculum and instruction. One category regarding Math-Science Curriculum Software was expanded as a result of the study.

The framework that emerges from the research study for math-science curriculum is summarized in Table 15.

Table 15

Relevance of Software for Math-Science Curriculum with Examples

Relevance	Type of Software	Examples of Software
Highly Relevant	**Data Manipulation Tools**	
	Spreadsheet	Excel
	Graphing/Charting	Excel
	Database	Clarisworks Database
	Math-Science Curriculum Software	
	Modeling	Algebra Analyzer
	Simulation	Physics Explorer
	Problem Solving	Decisions, Decisions
	Network Science	Environet
	Microcomputer-based Lab	Vernier Universal Laboratory Interface
Relevant	**Publishing Tools**	
	Word Processing	Word Perfect
	Electronic Mail	First Class Mail
	Multimedia Tools	Hyperstudio
	Desktop Publishing	Pagemaker
	Multimedia Encyclopedia	Encarta
	Internet Reference	Netscape
Somewhat Relevant	**Programming/Authoring**	
	Scripting Languages	HyperTalk
	Authoring Tools	Toolbox
	Programming Languages	Pascal; C++

The framework for software relevant to math-science curriculum gives further definition to the category of Math-Science Curriculum Software by encompassing the remarkable development of Math-Science Curriculum Software in the last dozen years. At the time of the NSF-supported SAMSON study (Tinker, 1984), commercial software development for math and science was limited, and most math-science software curriculum was of the "drill and practice" variety. Today's software offerings for math-science curriculum include powerful modeling, such as Logal's Inventor series; micro-computer-based laboratories, such as Vernier's Universal Laboratory Interface; problem-solving software, such as "Decisions, Decisions: The Environment"; simulation software, such as Logal's Explorer series; and network projects, such as GlobalLab and Environet for data exchange and inquiry.

Yet software relevant to math-science curriculum goes beyond that developed specifically for math-science skill development and concept development. According to teachers who participated in the PALMS Educational Software Survey, Data Manipulation Tools, such as spreadsheet, graphing/charting software, and database are highly relevant to the math and science curriculum. In fact, participants in the research study rated Data Manipulation Tools slightly higher than Math-Science Curriculum Software, in terms of relevance to math-science instruction.

Teachers participating in the research study also noted that other commercially available tools are relevant to the math-science curriculum. Publishing Tools, such as word processing, electronic references, and multimedia tools, were rated Important to math-science curriculum and instruction.

Finally, teachers perceived that the category Programming/Authoring Tools is lowest in importance to high school math-science curriculum.

Teachers not currently using computers in instruction place less importance overall on software, although they perceive Data Manipulation Tools as most relevant and Programming/Authoring as least relevant, as do their instructional-computer-using peers. This finding indicates a manageable difference between the two groups, and it is reasonable to assume that non-users' perception of the relevance of software to curriculum will increase as they learn more about software in the context of instructional use.

The framework in Table 15 meshes with the Mass Ed Online classification of software, from which it was drawn. The study validates that categories such as Data Manipulation Tools and Publishing Tools are meaningful to math-science teachers; adds a category for Programming/Authoring; and, most important, gives richness and definition to the category Math-Science Curriculum Software.

Extensions to math-science-specific and general competency models for technology training.

The study also adds to current understanding concerning technology training for math-science teachers. The research study does not contradict existing models for technology training, but the findings do extend the Math-Science-Specific and General Competency models for technology training in a way that shows both models in a broader context.

The Math-Science-Specific Model discussed at length in Chapter 2 advocates training exclusively for math and science teachers focused on specific curriculum objectives and using software that is highly relevant to the curriculum. This model has been shown to be a powerful element in professional development for instructional use of computers. Its weakness is that it does not look at professional development in the broader context of technology integration across the K-12 curriculum or in conjunction with training for teachers from other disciplines.

The research study updates and extends this model. In terms of Math-Science Curriculum Software, several new types of software have become widely available since the studies done five years ago. For example, Logal's modeling and simulation software for math and science have come on the market in the last two years. Increased access to Internet has made network science more accessible to students in the last five years.

The Math-Science-Specific Training model is also extended through the research study to include more software tools and to overlap with tools training for teachers in other disciplines. The Math-Science-Specific Training model has noted the importance of data manipulation tools for math-science instruction, and it has noted the usefulness of word processing for teacher productivity and preparation of instructional materials.

The research study indicates that word processing and other Publishing Tools are also important to student learning. These tools can be used in instruction as vehicles for students to communicate their ideas and to demonstrate knowledge. In addition, new electronic research/reference tools, such as multimedia encyclopedias, reference works including "A.D.A.M." and "BodyWorks," and the visually-rich resources available through the World Wide Web, including Harvard Medical School's "The Whole Brain Atlas" (http://www.med.harvard.edu/AANLIB/home.html) and "Interactive Physics Experiments" (http://www.mip.berkeley.edu/physics/physics.html), bring reference materials into the classroom.

Programming/Authoring tools are rated lowest in priority for initial training to prepare computer novices to use computers in instruction. This result is not surprising. It is interesting, though, that some training models put forth ten or more years ago, such as the State of California (CA, 1995) indicated that Programming/Authoring was an essential topic to prepare teachers for instructional use of computers.

This finding underscores the rapid changes in instructional software and the impact on associated training needs. In a decade, for example, significant advances have been made in Math-Science Curriculum Software. Teachers responding the survey indicate that, even though they do not have much experience with Math-Science Curriculum Software, they perceive that it is highly relevant to math-science curriculum and that it has high priority for technology training for computer novices preparing to use computers in instruction.

At the same time, many of the Math-Science Curriculum Software packages available today have powerful spreadsheets at their core, coupled with scripting capabilities that make it possible for teachers to customize and extend the reach of the software package. For this reason, we may see, in several years time, that Programming/Authoring is once again considered an important topic for math-science teachers preparing to use software in instruction.

These extensions to the Math-Science-Specific training model overlap with the training that could reasonably be made available to teachers in other disciplines, for example, training with Publishing Tools. The General Competency training model stresses the importance of a variety of tools for all teachers, both for productivity and as an instructional technology. Publishing Tools, such as word processing, interactive multimedia reference works, electronic mail, and multimedia tools, are useful to teachers at all grade levels and in all curriculum strands, including math-science, as the study indicates. Where the General Competency model has been weak is in the area of subject-specific approaches to technology integration and associated training needs. The research study fleshes out the portions of the model relative to math-science curriculum at the high school level.

The General Competency Model has also failed to indicate the scope of initial training for classroom teachers or how much training is needed before one can expect teachers to begin using computers in instruction. This dissertation suggests a strategy for initial training, in regard to secondary math and science teachers who are preparing to use computers in instruction.

Training strategies for instructional use of computers.

While training is not the complete answer to curriculum integration of technology (OTA, 1995), it is considered one of the most efficient ways to prepare teachers for instructional use of computers (Sparks & Loucks-Horsley, 1989). Schools have limited budgets for professional development, and teachers have limited time to engage in training. The research study indicates that an expedient approach to technology training for computer-novice math-science teachers consists of the following topics:

- Spreadsheet and Graphing/Charting from the Data Manipulation Tools index
- Selected Math-Science Curriculum Software
- Word Processing from the Publishing Tools index

Drawing from recommendations for effective technology training (Franklin & Strudler, 1990; Joyce & Showers, 1995; OTA, 1995), one possible example of such a training program for math-science teachers is a semesterlong course of study that meets every two weeks, with the following topical outline:

1) Orientation to instructional use of computers. Hands-on with mouse, menu, and windows. Demonstration of software and overview of assignments.

2) Word processing fundamentals, with ongoing assignment of a professional journal focused on growing expertise and ideas/plans for technology integration.

3-4) Spreadsheet fundamentals with exercises geared to subjects taught by the participants, including generation of graphs and charts.

5) Inquiry activities, using data and information from electronic references, leading to a written report that uses word processing, spreadsheet, graphs, and charts. Interim assignment of data gathering, due in spreadsheet form.

6) In-class scientific/mathematical report using data and reference material, word processing, spreadsheet, and charts/graphs. Participants discuss ways to develop these skills in students.

7-8) Focus on math-science curriculum software selected by use in the department. Participants generate and present lesson plans and materials using tools that include those used in weeks 1-6.

Drawing from the framework of software relevant to math-science curriculum (Table 14), follow-on training for math and science teachers might include the following:

- Advanced Training with Data Manipulation Tools, including:
  - Use of spreadsheets to demonstrate mathematical and scientific concepts (Tinker, 1994)

- Systems software, such as "Stella II", for simulation and modeling (Zaraza, 1995)

• Advanced Training with Selected Math-Science Curriculum Software Packages, including:
  - Use of scripting capability to customize and extend the software
  - Interdisciplinary units, such as collaboration between Physics and Trigonometry (Mosto & Nordengren, 1995)

Strategies for training for the population represented by the sample.

Teachers who responded to the survey, users and non-users alike, reported intermediate or higher level of expertise with word processing software. Teachers not currently using software in instruction reported only novice level of competence or no experience with other types of software. There would seem to be a greater need among non-users in the population studied for training in spreadsheet and graphing/charting software.

Both users and non-users report novice level of competence with Math-Science Curriculum Software. Training with Math-Science Curriculum Software could be designed to accommodate users and non-users alike for the population studied. It should be noted, however, that training with math-science curriculum software is contingent upon selection of specific packages for individual schools and subjects.

It is sometimes desirable to extend the scope of training sessions to include more teachers-- perhaps from other disciplines or from other schools. The following efficiencies are possible:

- Training with tools-- Data Manipulation Tools and Publishing Tools-- could be offered to teachers from other disciplines, as well as math-science teachers, with projects focused on curriculum.
- For Math-Science Curriculum Software, if a family of products is selected (such as Logal or Vernier), training can be offered for the Math- Science department(s) as a whole, with projects focused on learning needs of specific subjects or student groups.
- Training with particular Math-Science Curriculum Software packages can be offered for teachers of similar subjects/grade levels from other schools. In this regard, models used by Jurkat (1991) and Williams-Roberston (1992) are especially relevant.

Limitations of the Study

The population for the study cannot be said to represent secondary math-science teachers throughout the state of Massachusetts, the New England region, or the United States as a whole. However, the study was designed to elicit response from teachers who are using computers in line with recommendations from standards bodies, such as NCTM and AAAS, and, as such, the respondents may be representative of computer-using teachers in a wider region. Replication of the study is possible and would indicate if other computer-using math-science teachers have similar perceptions of software relevance and training priorities. Further research might also examine differences in response related to gender, years of teaching experience, and subject specialization.

It was a surprise to find so many math-science teachers (56% of the 172 respondents, n=97) already using computers in instruction for such purposes as problem-solving, modeling, simulation, visualization, and calculation. The study was not designed to measure the extent to which teachers carry out these practices. That is, respondents who indicated they use spreadsheet and visualization tools may only be using these tools with one group of students on rare occasions, or they may be making widespread use of them with all of their students. Further research should measure usage patterns and frequency.

In the same vein, the study did not examine contributing factors in computer use. These factors might include availability and nature of technology training, availability of hardware and software, availability of technical support, and level of administrative support for technology integration. While this information was not germane to the study, given the high percentage of use, further research might examine whether these factors are present in schools where usage is high.

Non-participating high schools.

Fifteen schools were asked to participate in the study, while only 11 actually responded to the survey. From conversations and interactions with non-participating districts, the following were the reasons for non-participation:

- in one case, departmental meetings were not held during the survey period, and the contact person was immersed in budgeting activities during the same time
- one school has a history of antipathy with the sponsoring organization
- two contacts who committed were unable to administer the survey for unknown reasons

The first two of the four non-participating schools are known to make use of math-science curriculum software. One of these two districts makes use of graphing software and interactive physics software in a nationally-publicized interdisciplinary unit (Mosto & Nordengren, 1995). The second school is aggressively building its capacity to use microcomputer-based laboratory software and probes with its science program.

The other two non-participating schools use technology to some degree. Conversations and interactions with individuals at these schools suggest that the level of expertise among the high school math-science teachers is similar to other schools who participated in the survey. One of the schools is actively working to integrate technology with math-science instruction, while the other follows a computer-literacy approach to technology (that is, students learn to use traditional software tools as a separate curriculum strand).

Districts undertaking the recommended strategy.

At least one district responding to the survey is at the beginning stage of implementing a technology training program that closely parallels the training strategy recommended by the study. In regard to their participation in the survey, most teachers indicated at the time of the survey that they were novices with computers, and they were anticipating imminent placement of a computer in each of their classrooms. It would be interesting to see how their responses, particularly in regard to usage, differ after one or two years of training and classroom application.

Graphing calculators.

Another known limitation of the study was its exclusion of graphing calculators as a technology in support of math-science curriculum. The study was designed specifically for computer software, although the researcher recognizes that graphing calculators, televised distance-learning programs, and non-computer instrumentation such as microscopes are all technologies that support math-science learning.

Implications for Further Research

This section explores further research that is indicated by the study. Topics for further study are the following:

- Usage patterns
- Effect of training and other environmental factors on instructional use
- Differences in perception by technology coordinators, curriculum coordinators, and staff developers
- Differences in usage over time
- Software relevance and training needs for other disciplines
- Impact of instructional use of technology on student learning in the context of systemic change

Usage Patterns.

Since the time of the survey, the Northeast PALMS region has grown from 15 to 30 school districts, many of whom are working to integrate technology with math-science curriculum and instruction. Further research with this population could examine the usage patterns of technology in support of math-science learning, in combination with such factors as training, availability of hardware and software, technical support, and administrative support for technology integration. Such a study might be more qualitative in design. Informal discussion with those participating in the current study suggests that department heads are knowledgeable about the extent to which their teachers are integrating technology, the training available to them, and the constraints and pressures operating in their schools which influence the degree of computer integration. This suggests that in-depth discussion with these key individuals and observations over a period of time (such as one or more school years), rather than a one-time survey, will yield valuable information about the process and quality of technology integration.

Effect of training and other environmental factors on instructional use.

The study found that only 6% of respondents do not use computers for any purpose, while 32% use computers for some purpose but not for math-science instruction. It is unclear why these 32% are not using computers in instruction. The reason may simply be lack of available hardware and software. It may also be that their training has not prepared them for instructional use. Perhaps they have learned productivity tools without considering instructional applications or classroom management. Perhaps their training did not address the benefits of teaching practices that incorporate technology. Further study should investigate this concern.

Differences in perception by technology coordinators, curriculum coordinators, and staff developers.

The study chose classroom teachers as its population, rather than technology coordinators, curriculum coordinators, or persons engaged in teacher education or inservice for math, science, or instructional technology. Further research might investigate differences in the perceptions of these groups in the context of overall staff development planning or in the context of math-science education.

Other disciplines.

The research study focused narrowly on high school math and science teachers in a particular geographic location. However, similar studies would be valuable for elementary and middle school instruction of math and science and for other disciplines. For example, word processing has been a mainstay in the teaching of writing and language arts, but newer software is available that affects the writing and research process, including the Publishing Tools studied here. Social Studies instruction also benefits from these tools, along with desktop video (Brown, 1995) and videoconferencing (LeBaron & Warshawsky, 1991). Foreign languages, the arts, health, and technology education are other curriculum areas with a growing list of curriculum software. Studies designed for these areas could validate and expand the Mass Ed Online classification of educational software (CELT, 1996) used as the starting point for this study, possibly providing a framework for software integration across the K-12 curriculum.

Impact on student learning in context of systemic change.

The research study did not address one of the most important aspects of technology integration-- impact on student learning. Given the degree of usage already evident in the schools who participated in the study, and the emphasis placed by PALMS on innovative instructional practices, including educational technology in support of math-science curriculum and instruction, this area should be explored further.

It is also the case in Massachusetts that many high schools, including some that participated in the study, have made or are considering a shift to block scheduling as part of the Mass Ed Reform initiative. For example, discussion with the 13 schools who participate in the Merrimack Education Center High School Restructuring Collaborative indicates that these schools are looking to project-based curriculum with technology integration as important strategies. While it is difficult in these situations to isolate the impact of technology on student learning (Smith, 1988), the high cost of purchasing and supporting technology infrastructure and the implications for technology training and development of new instructional practices make it highly desirable to assess the impact of technology on student learning in math and science and in other curriculum strands.

Studies in this regard might follow the lead of the Center for Technology in Education (CTE, 1991), with the Design Experiments. In these studies, a conscious design for a new learning environment is formulated and developed, along with criteria for assessing the effectiveness, and a mechanism for adjusting the plan in process. The aim of such experiments is a long-term change in the learning environment that has a positive impact on student achievement.

Another approach to measuring impact of instructional technology on student learning in mathematics is provided in Confrey, Piliero, Rizzuti, & Smith (1995), who piloted a program for the Apple Classrooms of Tomorrow. Students were found to demonstrate increased understanding of mathematical concepts as a result of using multirepresentational software in a high school mathematics classroom.

Another possible approach is action research (Lieberman, 1992) with emphasis on high-order thinking, student engagement, and active construction of knowledge.

Summary

The research study asked high school math and science teachers in the 15 school districts of the Northeast PALMS region of Massachusetts to indicate their perception of the relevance of various types of software to math-science curriculum. From the results, a framework classifying software according to its relevance to math-science curriculum is put forth, which encompasses a wide range of software tools (both Data Manipulation Tools and Publishing Tools) and Math-Science Curriculum Software, along with Programming/ Authoring languages. The framework modifies and extends the Mass Ed Online classification of educational software. Teachers were also asked to indicate their level of expertise with software and the priorities they perceive for training designed to prepare computer novices to use computers in instruction. From the survey results, a strategy for technology training has been proposed that extends the existing Math-Science-Specific and General Competency models for technology training. This research study has also noted directions for further research with PALMS schools, with teachers in other disciplines, and with students who are learning in environments that integrate technology in support of math-science curriculum.

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Appendix A

Categories of Math-Science Software with Examples

General Category	Example Instructional Use (MS) Professional Use (PROF)	Example Software Title
Data Manipulation Tools	MS: test hypotheses; mathematical modeling; "what if" thinking; calculation. PROF: grading, budgeting.	Microsoft Works Excel
Database	MS: Gather and analyze data; test hypotheses. PROF: inventory equipment; track instructional objectives.	Microsoft Works
Spreadsheet	MS: mathematical modeling; "what if" thinking; simultaneous calculation. PROF: grading, budgeting.	Microsoft Excel
Charting/ Graphics	MS: visual representation of data and results; illustration of shapes and constructs; PROF: reporting grades	Microsoft Excel

General Category	Example Instructional Use (MS); Professional Use (PROF)	Example Software Title
Math-Science Curriculum Software	MS: drill and practice; data analysis; logic; systems thinking; modeling and simulation, investigation of math and science principles	
Mathematical problem-solving	MS: step-by-step procedure to accomplish a task	LOGO The Factory
General problem-solving	MS: thinking and reasoning skills	Decisions, Decisions: The Environment
Inquiry/ Modeling	MS: investigation of complex relationships and mathematical principles	LOGAL Algebra Analyzer
Microcomputer-based labs	MS: data acquisition and analysis	Vernier Universal Lab Interface
Simulation	MS: systems thinking, investigate scientific concepts	LOGAL Physics Explorer
Network science	MS: collect and analyze data	TERC GlobalLab

General Category	Example Instructional Use (MS); Professional Use (PROF)	Example Software
Publishing Tools		
Word Processing	MS: Writing reports, communicating findings. PROF: preparing tests and materials; communicating with parents	Microsoft Word
Electronic Mail	MS: collaborative data collection and analysis; network research. PROF: support curriculum change, communicate with colleagues	Microphone, First Class Mail
Electronic Research/ Reference	MS: sound, visual, textual, motion, research PROF: educational research	Multimedia Encyclopedia
Internet	MS: access to current, emerging data PROF: access to educational research, lesson plans, current practices	World Wide Web, bulletin boards
Hypermedia Production	MS: Student multimedia reports PROF: presentations	HyperCard, Toolbox

General Category	Example Instructional Use (MS) Professional Use (PROF)	Example Software Title
Programming/ Authoring		
Computer Languages	MS: computer science principles; logic	Pascal, C++, BASIC
Hypermedia Authoring	MS/PROF: development of instructional packages	HyperTalk, Toolbox

Appendix B

Models of Technology Competency

This Appendix contains details of the general-competency models for technology training discussed in Chapter 2 of this dissertation proposal. The models are presented in the order in which they appear in Chapter 2.

ISTE Foundation Standards:

1. Demonstrate ability to operate a computer system in order to successfully utilize software
2. Evaluate and use computers and related technologies to support the instructional process.
3. Apply current instructional principles, research, and appropriate assessment practices to the use of computers and related technologies.
4. Explore, evaluate, and use computer/technology-based materials, including applications, educational software, and associated documentation.
5. Demonstrate knowledge of computers for problem solving, data collection, information management, communications, presentations, and decision making.
6. Design and develop student learning activities that integrate computing and technology for a variety of student grouping strategies and for diverse student populations.

7. Evaluate and select and integrate computer/technology-based instruction in the curriculum of one's subject area(s) and/or grade levels.
8. Demonstrate knowledge of uses of multimedia, hypermedia, and telecommunications to support instruction.
9. Demonstrate skill in using productivity tools for professional and personal use, including word processing, database, spreadsheet, and print/graphic utilities.
10. Demonstrate knowledge of equity, ethical, legal and human issues of computing and technology use as they relate to society and model appropriate behaviors.
11. Identify resources for staying current in applications of computing and related technologies in education.
12. Use computer-based technologies to access information to enhance personal and professional productivity.
13. Apply computers and related technologies to facilitate emerging roles of the learner and the educator.

The Massachusetts Software Council (The Switched-On Classroom) identifies ten areas of training and staff development:

- Introductory training
- Computer ethics instruction
- Technology-specific training in the use of CD-ROM, computer graphics, networking, e-mail, databases, multimedia, and others
- Subject/grade level training, focusing on applications that are appropriate for specific subject areas or grade levels

- Software courses in technology such as Windows, PageMaker, and HyperCard
- Curriculum writing courses
- Distance learning instruction
- Classroom management strategies
- Technology as an assessment tool
- Process training

Merrimack Education Center's teacher technology competencies:

- Basic
  - Use of CD-ROM and other interactive software packages in classroom instruction
  - Use of Software Tools with students to develop Student Technology Competencies
  - Use of Software Tools to enhance professional productivity and prepare presentations
  - Use of telecommunications for linking with students and teachers around the world
  - Use of laserdisk, VCR, and other technology in support of instruction
  - Use of electronic reference tools and strategies to guide students in responsible use of such tools
- Advanced
  - Use of Multimedia Tools and Authoring/Scripting to develop and customize Instructional Packages
  - Use of Desktop Publishing tools/features to prepare high-quality printed communication

- Use of multimedia packages to prepare non-print presentations, oversee student multimedia production
- Editing sound, image, and other non-text media for use in multimedia/hypermedia packages
- Providing televised instruction, overseeing student TV/film production.
- Use Internet reference tools/materials and guide students in responsible use of such tools/materials.

The State of California faculty competencies:

Level I: Basic Awareness

- Can operate computer
  - Knows major parts of computer system
  - Is able to use disk drives and printers
  - Can use keyboard
- Can choose software
  - Knows sources of courseware information
  - Can match software to applications

Level II: Curriculum Awareness

- Can evaluate software
  - Can apply selection and evaluation criteria
  - Can determine relative effectiveness and appropriateness of software
- Understands basic computer operations and capabilities
  - Knows the functions of common operating systems
  - Can perform basic disk and file management operations

Level III: Technological Awareness

- Can use authoring languages or packages
  - Can prepare instructional specifications
  - Can use authoring programs to create simple drill and practice routines
- Can write programs
  - Is able to use high-level programming languages
  - Can translate instructional design specifications into computer code

Appendix C

MERRIMACK EDUCATION CENTER

101 Mill Road, Chelmsford, Massachusetts 01824

508-256-3985
FAX 508-256-6890

John S. Barranco, Ed.D.
Executive Director
Leslie C. Bernal, Ed.D.
Senior Associate Director

Burton E. Goodrich, Ed.D.
Associate Director
Edward J. Roberts, M.Ed.
Director of Professional Development
Jeffrey M. Belgot
Director of Technology Systems

October 17, 1995

Dear Math/Science Teacher:

As a Northeast Regional Provider for the Partnerships Advancing the Learning of Math and Science (PALMS), Merrimack Education Center is pleased to sponsor this scholarly research on instructional technology in support of math/science education.

The Northeast PALMS Region has earned a distinction during the past year for its attention to the crucial role of instructional technology in math/science education. Your school's participation in PALMS demonstrates your commitment to innovative, high-quality math/science education.

It is important for us to understand the view of classroom teachers on the relevance of technology to math/science curriculum and to understand teachers' priorities for training to incorporate technology in classroom instruction.

Your participation in this research will help PALMS Regional Providers, such as Merrimack Education Center, to offer timely and effective training in the use of technology for math/science education. It will also increase our common understanding of the importance of instructional technology for math/science education.

Sincerely,

Burton Goodrich

Dr. Burton Goodrich

Partnerships Advancing Learning of Math and Science (PALMS)

Educational Software Survey

To Teachers:

In your high school, some teachers may be experienced using computers in instruction, while others may have little or no experience with computers. This survey asks you to reflect on the training a math or science teacher needs in order to use computers in instruction, whether in a classroom or a lab setting. Whether you have computer experience or not, your answers will help us determine priorities for technology training for math and science teachers.

Please answer the questions on this survey thoughtfully and honestly. When an item is unfamiliar to you, leave it blank.

You should <u>not</u> indicate your name on the survey. Your answers will be treated confidentially.

When you have completed the survey, please return it to your survey administrator. Thank you for participating in this survey!

Catherine Collier,

Instructor, PALMS Educational Technology Program

1. Some computer software is highly relevant to math/science instruction at the high school level. Some software may not be useful for classroom instruction but is useful in support of a teacher's professional work-- for example, to prepare instructional materials. For each type of software A-O below, use a check mark (√) to indicate the importance of the software using the scale below. If you are not familiar with a particular item, you should leave it blank.

Very Important - The software is highly relevant to math/science curriculum at the high school level and could be used with students in math/science instruction

Important - The software is not directly related to math/science curriculum, but could be used with students in the classroom or lab to enhance math/science instruction at the high school level

Somewhat Important - The software may be used to support instruction (for example, preparation of instructional materials of tracking student progress) but would not be used with students in math/science instruction

Unimportant - The software is not likely to be used by a high school math/science teacher, either directly in instruction or in support of instructional activities

Very Important	Important	Somewhat Important	Unimportant	(blank)	
31%	35%	26%	4%	(4%)	A. Word Processing
28%	37%	22%	3%	(9%)	B. Database
42%	31%	17%	2%	(8%)	C. Spreadsheet
10%	19%	34%	23%	(15%)	D. Electronic Mail
69%	24%	5%	0%	(3%)	E. Graphs and Charts
14%	30%	27%	20%	(9%)	F. Drawing or Painting
42%	19%	15%	3%	(22%)	G. Microcomputer-based laboratory
41%	29%	13%	2%	(15%)	H. Software for Inquiry or Modeling
17%	28%	17%	4%	(34%)	I. Multimedia/Hypermedia Tools
53%	29%	8%	2%	(8%)	J. Software for Problem Solving
3%	15%	27%	22%	(34%)	K. Scripting/Authoring
19%	23%	22%	20%	(16%)	L. Computer Programming
15%	35%	31%	7%	(12%)	M. Electronic Reference Tools (e.g., Grolier's Multimedia Encyclopedia)
27%	38%	12%	4%	(19%)	N. Simulation Software
26%	33%	18%	5%	(17%)	O. Collaborative science projects using telecommunications

2. High school math and science teachers may need different introductory computer training than other teachers. Consider an introductory training program for high school math and science teachers who are computer novices, where such a training would prepare them to use computers in instruction. For each of the following topics, indicate the priority of the topic for introductory training. If you are not familiar with a particular item, you should leave it blank.

High Priority - The software is essential for the computer novice in preparing for instructional use of computers. Study of this software must be included in introductory training.

Medium Priority - The software might be used by the computer novice for classroom/lab instructional use. Study of this software might be included in introductory training.

Low Priority - The software probably should not be included in introductory training (for example, an advanced topic).

High Priority	Medium Priority	Low Priority	(blank)	
66%	28%	2%	(3%)	A. Using problem-solving software
48%	38%	9%	(5%)	B. Creating a spreadsheet
45%	39%	8%	(8%)	C. Using an instructional package to simulate a system or a phenomenon (e.g., Gravity)
41%	40%	15%	(4%)	D. Creating a database
28%	45%	17%	(10%)	E. Using electronic references, such as Grolier's Multimedia Encyclopedia
52%	31%	6%	(11%)	F. Using software to model math principles
31%	41%	21%	(8%)	G. Searching the Internet
6%	22%	42%	(30%)	H. Using a scripting language to customize an instructional package
10%	22%	44%	(24%)	I. Structured programming skills, such as FOR loops and FUNCTION calls
81%	17%	0%	(2%)	J. Producing graphs and charts to show data
46%	33%	11%	(10%)	K. Using a word processor's formatting features
28%	40%	13%	(19%)	L. Using multimedia/hypermedia with students to produce a presentation/report
27%	22%	13%	(38%)	M. Using computer-based sensors ("probeware")
30%	30%	15%	(25%)	N. Using multimedia/hypermedia to develop interactive instruction for student use

3. Please rate your level of expertise with each of the following software by checking the category that best describes your knowledge of the technology. Use the rating scale below. If you are not familiar with a particular item, you should leave it blank.

EXPERT -	use it with confidence and make use of most features
INTERMEDIATE -	know just enough to use it productively
NOVICE -	have used it some but need practice/support to use productively
NONE -	never used the technology

EXPERT	INTER-MEDIATE	NOVICE	NONE	(BLANK)	
35%	42%	19%	3%	(1%)	A. Word Processing
13%	30%	38%	17%	(2%)	B. Database
19%	27%	35%	16%	(2%)	C. Spreadsheet
10%	27%	22%	36%	(5%)	D. Electronic Mail
12%	27%	40%	17%	(4%)	E. Graphs and Charts
6%	23%	36%	31%	(4%)	F. Drawing or Painting
15%	29%	27%	26%	(4%)	G. Drill & Practice Software
3%	20%	27%	42%	(8%)	H. Software for Inquiry or Modeling
3%	14%	27%	47%	(9%)	I. Multimedia/Hypermedia Tools
4%	24%	32%	33%	(7%)	J. Software for Problem Solving
3%	9%	15%	57%	(16%)	K. Scripting/Authoring
12%	18%	35%	30%	(5%)	L. Computer Programming
12%	26%	31%	27%	(4%)	M. Electronic Reference Tools (e.g., Grolier's Multimedia Encyclopedia)
7%	16%	29%	42%	(6%)	N. Simulation Software
2%	8%	24%	58%	(7%)	O. Collaborative science projects using telecommunications
7%	12%	23%	49%	(9%)	P. Microcomputer-based laboratory

4. Background Information

A. How many years have you been using computers for any purpose, including this year?

6%	(0)	28%	(6-10)
12%	(1-2)	34%	(more than 10)
19%	(3-5)		

B. How many years have you been using computers in instruction, including this year?

38%	(0)	12%	(6-10)
19%	(1-2)	11%	(more than 10)
19%	(3-5)		

C. How many years have you been teaching, including this year?

10%	(1-3)	7%	(7-10)
5%	(4-6)	78%	(more than 10)

D. Which of the following subjects have you taught or do you currently teach? (check all that apply)

n=109 (63%) Math
n=30 (17%) Computers/Programming
n=87 (51%) Science

E. Which of the following grade levels have you taught or do you currently teach? (check all that apply)

n=148 (86%) Grade 9	n=147 (85%) Grade 11
n=150 (87%) Grade 10	n=143 (83%) Grade 12

If you have never used computers in instruction, please return your survey to your survey administrator at this time. Thank you for your participation!

If you have used computers in instruction in the past and/or currently use computers in instruction, please answer Question 5 on the next page.

5. Do you now or did you in the past use computers with your students for the following instructional activities?

YES	NO	
n=77 (45%)	n=95 (55%)	A. Drill and practice
n=57 (33%)	n=115 (67%)	B. Calculation
n=27 (16%)	n=145 (84%)	C. Gather data with probes or sensors
n=67 (39%)	n=105 (61%)	D. Educational games
n=53 (31%)	n=119 (69%)	E. Manipulate data with a spreadsheet or database
n=38 (22%)	n=134 (78%)	F. Computer programming
n=65 (38%)	n=107 (62%)	G. Writing or word processing
n=36 (21%)	n=136 (79%)	H. Simulate a system or phenomenon
n=26 (15%)	n=146 (85%)	I. Collaborative problem-solving
n=35 (20%)	n=137 (80%)	J. Inquiry ("What if...?" thinking)
n=25 (15%)	n=147 (85%)	K. Mathematical Modeling
n=15 (9%)	n=157 (91%)	L. Exchange data with students in other schools
n=32 (19%)	n=140 (81%)	M. Produce printed publications
n=18 (10%)	n=154 (90%)	N. Produce non-print presentations (e.g., multimedia or video)

Thank you for completing this survey!

Please return your completed survey to your survey administrator

Appendix D

Intercorrelations and Software Indices

Data Manipulation Tools

	Database	Spreadsheet	Graph/Chart
Database	1		
Spreadsheet	0.56	1	
Graphs/Charts	0.18	0.52	1

Curriculum Software

	Micro-based Lab	Modelling	Problem-solv	Simulation	Net Science
Micro-based Lab	1				
Modelling	0.5	1			
Problem-solving	0.53	0.52	1		
Simulation	0.23	0.4	0.29	1	
Network Science	0.45	0.44	0.43	0.35	1

Software Indices

	Data Tools	Curric SW	Publishing	Programming
Data Tools	1			
Curric SW	0.56	1		
Publishing	0.55	0.49	1	
Programming	0.46	0.32	0.48	1

Publishing Tools

	Word Processing	E-Mail	Drawing	Multimedia	Elec. Reference
Word Processing	1				
E-Mail	0.35	1			
Drawing	0.31	0.43	1		
Multimedia	0.25	0.39	0.32	1	
Elec. Reference	0.38	0.43	0.36	0.33	1

Programming/Authoring

	Prog. Lang	Scripting
Prog. Lang		
Scripting	0.5	

Appendix E

Mean (and Standard Deviation), Instructional Users and Non-Users for Software Indices and Individual Items, Survey Questions 1-3

Software Index	Survey Question 1		Survey Question 2		Survey Question 3	
	Users	Non-users	Users	Non-users	Users	Non-users
Data Manipulation Tools	3.37 (.57)	3.19 (.61)	2.55 (.43)	2.46 (.46)	2.70 (.84)	1.98 (.67)
Spreadsheet	3.40 (.79)	3.00 (.77)	2.55 (.60	2.24 (.65)	2.75 (1.03)	2.12 (.84)
Graphing/Charting	3.71 (.52)	3.60 (.61)	2.85 (.35)	2.79 (.40)	2.67 (.94)	1.81 (.69)
Database	3.02 (.84)	2.99 (.73)	2.24 (.77)	2.33 (.59)	2.68 (.93)	2.00 (.81)
Math-Science Curriculum Software	3.29 (.55)	3.10 (.59)	2.43 (.35)	2.46 (.36)	2.17 (.72)	1.38 (.42)
Modeling	3.40 (.73)	3.11 (.77)	2.46 (.59)	2.58 (.59)	2.11 (.91)	1.31 (.57)
Simulation	3.22 (.71)	2.85 (.74)	2.36 (.60)	2.45 (.65)	2.22 (1.00)	1.32 (.55)
Problem Solving	3.42 (.74)	3.49 (.67)	2.62 (.52)	2.72 (.50)	2.26 (.93)	1.48 (.62)
Network Science	3.07 (.79)	2.82 (.82)			1.74 (.85)	1.13 (.38)
Microcomputer-based Lab	3.33 (.81)	3.20 (.92)	2.27 (.66)	2.11 (.59)	1.97 (1.05)	1.28 (.58)
Publishing Tools	2.74 (.61)	2.45 (.50)	2.23 (.48)	2.16 (.46)	2.48 (.70)	1.83 (.57)
Word Processing	3.11 (.81)	2.79 (.88)	2.41 (.69)	2.35 (.62)	3.40 (.69)	2.68 (.84)
Electronic Mail	2.42 (.97)	1.86 (.71)			2.37 (1.05)	1.69 (.91)
Multimedia Tools	2.97 (.75)	2.69 (.62)	2.20 (.66)	2.16 (.58)	1.92 (.90)	1.28 (.56)
Multimedia Encyclopedia	2.73 (.87)	2.57 (.70)	2.17 (.65)	2.06 (.68)	2.37 (1.01)	1.79 (.86)
Internet Reference			2.14 (.73)	2.06 (.70)		
Programming/Authoring	2.31 (.77)	2.10 (1.25)	1.76 (.49)	1.72 (.39)	1.98 (.82)	1.46 (.48)
Scripting/Authoring	2.11 (.76)	1.76 (.56)	1.51 (.60)	1.46 (.49)	1.65 (.91)	1.15 (.48)
Programming Languages	2.51 (1.02)	2.45 (.99)	1.59 (.69)	1.49 (.53)	2.32 (1.09)	1.77 (.80)

Biographical Sketch of Author

Catherine Collier holds a B.A. in English (1970) from Nazareth College of Rochester. She also holds an Master of Library Science (1978) from the School of Information Studies, Syracuse University, and a Master of Science in Computer and Information Science (1979) from the School of Computer and Information Science, Syracuse University.

Ms. Collier is Technology Specialist for the Merrimack Education Center, Chelmsford, MA. She provides technology planning and professional development consulting for schools in the Merrimack Valley and North Shore areas of Massachusetts. She also teaches graduate education courses through Fitchburg State College and University of Massachusetts Lowell. With Dr. John LeBaron and Dr. Linda Friel, Ms. Collier has authored A Travel Agent in CyberSchool: The Internet, Schools, and the Library-Media Program, forthcoming from Libraries Unlimited (1996).

Ms. Collier has worked extensively in the information industry, including software engineering at OCLC, Xerox Corporation, and Digital Equipment Corporation. Her products include library automation, network services, and database services. She is a charter member of the Digital Equipment Corporation "Engineers Into Education" Program.